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Effects of discharge from carwash on the physico-chemical parameters and zooplanktonic abundance of Odo-Ebo River, Ile-Ife, Nigeria

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Abstract. The study determines the physico-chemical parameters of water from Odo-Ebo River with a view to providing information on the effects of discharge from carwash on the River's water quality. Samples (48) for physico-chemical water quality were collected monthly over a period of an annual cycle (February 2015–January 2016) from four stations, namely: upstream (about 500 m before the carwash), two discharge points (1st and 2nd discharge points), and downstream (about 500 m after the carwash). The discharge points had higher mean values in 9 out of the 13 investigated water quality parameters, especially plant nutrient ions (phosphate, nitrate, and sulphate), with the discharge points significantly differing from the other stations in terms of phosphate concentration and apparent colour. This led to reduction in dissolved oxygen and zooplankton abundance, changes in apparent water colour, and increase in COD at the effluent receiving points. Furthermore, the higher mean values of dissolved oxygen, BOD_5, turbidity, and true colour recorded upstream and downstream were reflections of higher biological productivity and organic detritus at these stations as compared to discharge points. The specific presence of some eutrophic species at the discharge points has only further proven the negative effects the effluent from the carwash had on the river, thus posing a potential threat to its aquatic organisms' diversity. This eutrophication effect was observed downstream as an increase in zooplankton abundance and diversity. Therefore, environmental protection regulations are needed to reduce anthropogenic influence on the rivers in Nigeria.

Keywords water quality, diversity, eutrophic species, carwash, discharge points

1. Introduction

Freshwater habitats occupy a relatively small portion of the Earth's surface as compared to marine and terrestrial habitats, but their importance for man is far greater than their areas [1]. However, freshwater has become a scarce commodity due to overexploitations and pollution [2, 3, 4]. Reservoirs, rivers, streams, and lakes that constitute 55% of freshwater are vulnerable to pollution as a result of various human activities, which are capable of destroying the quality of waters and their inhabiting organisms [5, 6]. Moreover, rivers are used as sites for refuse disposal, human sewage, and waste water from kitchens, abattoirs, and industrial sites [7]. Likewise, water bodies running through areas of significant human impact, such as farms, urban settlements, and industrial locations, are susceptible to pollution [7]. In most developing countries, discharge of effluent from factory, farm, commercial establishments, or households into water bodies, such as rivers, streams, lakes, or lagoons, has become a serious problem due to increase in urban and industrial development [8]).

Surfactants and other ingredients of detergents are common constituents in domestic and municipal effluents, which ultimately reach the natural environment and cause various toxicities to aquatic organisms [9, 10]. Thus, detergent wastes can have poisonous effects on all types of aquatic life if they get accumulated in sufficient quantities [11]. Detergents could also affect receiving aquatic environments by causing foaming and eutrophication, therefore limiting oxygen production [12]. The hazard of detergent pollution also lies in their effect on water ecosystems as a whole for surfactants may adversely affect microalgae at the lowest trophic level, impacting their function as major suppliers of oxygen to water bodies and result in community structure infringement [13].

Therefore, contamination of water bodies by discharge is viewed as a worldwide issue due to its effects on the ecosystem. In Nigeria, it is a significant challenge due to the attitude of the populace and industries towards effluent disposal and management [14]. In view of this, discharges from car wash and other anthropogenic sources might result in serious threat to the lives that inhabit the water body. Hence, the discharge level of detergents of domestic and industrial wastewater should be monitored so as to prevent environmental degradation. Therefore, this study seeks to identify and evaluate the impact of car wash sited along a river bank on the receiving ecosystem.

2. Materials and methods

Study area and sampling sites

Odo-Ebo River is one of the rivers that flow within Ile-Ife, Osun State. The river was divided into upstream, discharge points, and downstream. The river upstream, where less human activities were observed, is located at latitude 07°29.290′'N and longitude 004°32.326'E, with an elevation of 267 m (*Fig. 1*). The first discharge point where effluents flow into the river is located at latitude 07°29.294'N and longitude 004°32.327'E, with an elevation of 266 m, while the second discharge point is located at latitude 07°29.308'N and longitude 004°32.318'E, with an elevation of 266 m. The car wash workshops were located at these discharge points. The river downstream station was sited close to an abattoir at latitude 07°29.313'N and longitude 004°32.306'E, with an elevation of 262 m.

Sample Collection

Samples were collected monthly from the four sampling stations for a period of 12 months for physico-chemical water quality and planktonic analysis. On the field, air temperature and water temperature were determined *in-situ* using mercury-in-glass thermometer. Samples for dissolved oxygen and 5-day biological oxygen demand (BOD_5) were collected in oxygen bottles (125/250 ml reagent bottles). Dissolved oxygen samples were fixed immediately upon collection with Winkler's reagents (manganous sulphate and potassium iodide). BOD_5 samples were collected in black reagent bottles and kept in a dark cupboard at room temperature (about 27± 2°c) for 5 days, after which they were treated for oxygen determination.

Physico-chemical analysis

Water samples (36 samples) collected in 2-litre polyethylene jerry cans were used for the determination of other chemical parameters. The samples were analysed for true colour, apparent colour, and turbidity using the colorimetric method [15]. The chemical analysis of the water samples was in accordance with the standard methods of Golterman et al. (1978) [16], Mackereth et al. (1978) [15], Ademoroti (1996) [17], and APHA et al. (2000) [18], as applicable. The chemical parameters analysed include a major ion (SO_4^{2-}), salinity parameters (alkalinity, conductivity), plant nutrient (nitrate, PO_4^{3-}), and oxygen parameters (DO, BOD_5, and COD).

Samples for zooplankton analysis were collected by straining 30 litres of water through a fine-meshed plankton net (mesh size = 45 μm) to a concentrate volume of 30 ml preserved with 5% formaldehyde and Lugol's solution in a specimen bottle for later examination and identification.

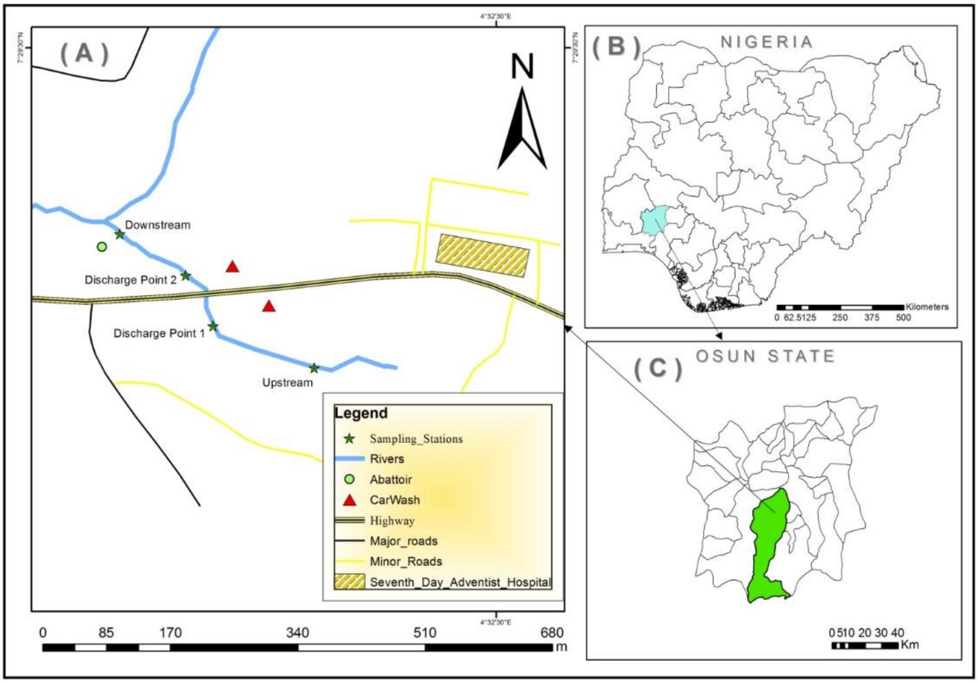

Figure 1. Map showing Nigeria map (A), Osun state map (B), and sampling points' locations at Ile-Ife (C)

These preserved samples containing plankton were examined in the laboratory using Omax binocular light compound microscope and their scaled pictures taken by placing 1 ml in a plankton chamber. Measurements and enumeration of the recorded plankton were also made.

The recorded zooplanktons were identified using standard identification guides, which include the works of Jeje and Fernando (1985) [19], Fernando (2002) [20], and Suthers and Rissik (2009) [21]. The abundance of each plankton species per unit volume of the original water source was estimated based on the records obtained. Abundance of each species was determined using the following equation:

$$A = \frac{ab}{c} \times 1000,$$

where:

A– abundance of species per litre of original water source,

a – abundance of species in the counting chamber,

b – total concentration volume of water used (1 ml), and

c – triginal volume of water (l).

Statistical analysis

The data collected were subjected to various descriptive and inferential analyses, such as the means, standard deviations, analysis of variance, t-test, and correlation, to test the effects of car wash discharge on Odo-Ebo River's water quality and planktonic abundance both temporally and spatially, as applicable, using SPSS 21.

3. Results

The values of temperature (air and water) and salinity were within a very narrow range with their coefficients of variation being less than 10%, while the coefficients of variation recorded for oxygen parameters (DO, BOD5, and COD), major ions (phosphate, sulphate, and nitrate), and other hydro-physical conditions (alkalinity, turbidity, true colour, and apparent colour) were greater than 50%, showing a wide dispersion of values around their mean (*Table 1*). The wide range was more pronounced in sulphate concentrations recorded with CV greater than 1 in all the stations investigated (*Table 1*). This variation was also revealed in the percentage differences of 2% to 32% increase in the sulphate concentration among the sampled stations. The highest percentage increase in sulphate was between upstream and downstream, followed closely by an increment of 30% observed between upstream and Discharge Point 2, while the lowest increment was observed between Discharge Point 2 and downstream, thus reflecting the effects of the effluent on the sulphate concentration of the water body.

In general, in 9 of the 13 investigated water quality parameters, the discharge points were characterized by higher mean values than those of the upstream and downstream sections. For these 9 parameters (water temperature, pH, conductivity, chemical oxygen demand, alkalinity, phosphate, sulphate, nitrate, and apparent colour), the discharge points differed from 10% to 13% on the average in comparison with other stations. The major ions (phosphate, sulphate, and nitrate) were also, on the average, 17% higher in concentration (2% to 30%) at the discharge points than upstream and downstream. On the other hand, only 4 parameters (DO, BOD_5, turbidity, and true colour) had higher means (13% to 30% higher on the average) upstream and downstream.

The effect of the effluent was also observed temporally with 8 of the 13 assessed parameters (conductivity, DO, COD, BOD_5, alkalinity, sulphate, turbidity, and true colour) having higher mean concentration during the rainy season, while phosphate and nitrate recorded higher mean concentrations during the dry season. Notably, among these parameters was sulphate, whose mean concentration during the rainy season was 400% higher than its recorded concentration in the dry season (*Table 1*).

Table 1. Descriptive statistics of the physico-chemical water quality parameters of Odo-Ebo River between February 2015 and January 2016

Parameters	Temporal average				Spatial average								Overall		Effluent discharges, irrigation, and reuse standards [22]	
	Rainy season		Dry season		Upstream		Discharge Point 1		Discharge Point 2		Downstream					
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Min	Max	Mean	
Air Temperature (°C)	26.02	4.46	26.88	3.32	26.88	4.67	26.18	4.32	26.03	4.15	26.42	3.77	24.00	28.80	26.38	
Water Temperature (°C)	26.08	2.75	26.00	3.16	26.09	1.78	26.11	3.44	26.38	2.95	25.60	2.67	24.00	27.20	26.05	< 40
pH	7.06	5.57	7.17	3.36	6.92	5.95	6.99	5.91	7.26	2.05	7.26	2.18	5.80#	7.55	7.11	6.5–8.5
Conductivity (μScm^{-1})	442.61	5.03	439.15	5.70	429.00	3.76	439.00	4.46	450.00	7.01	447.00	4.28	400.00	490.00	441.17	1,000
Dissolved oxygen (mg/l)	5.17	41.42	4.11	60.69	4.93	56.97	4.51	43.37	4.07	55.46	5.40	42.67	0.40#	10.00	4.73	> 4
Biological oxygen demand (mg/l)	2.56	54.00	1.90	77.25	2.67	68.25	1.91	54.55	1.66	54.28	2.92	54.27	0.34	6.70	2.29	< 6
Chemical oxygen demand (mg/l)	39.92	58.96	26.76	58.46	35.65	77.09	35.77	47.08	36.69	45.27	29.63	83.83	6.87	96.30	34.44	30
Alkalinity ($CaCO_3$ mg/l)	99.93	28.45	95.05	22.92	86.92	11.15	106.00	38.75	98.75	25.81	99.92	13.70	62.00	200.00	97.90	50–200
Phosphate (mg/l)	33.28*	9.30	38.73*	19.87	33.95*	12.78	40.12*	23.99	34.54*	10.06	33.60*	5.17	28.00*	52.67*	35.55	3.5
Sulphate (mg/l)	23.25	86.80	5.78	50.58	13.17	100.82	16.14	112.24	17.12	121.27	17.44	113.20	1.50	60.86	15.97	500
Nitrate (mg/l)	5.27	46.32	6.31	62.19	4.97	37.04	6.00	63.03	6.38	64.97	5.44	45.66	2.44	16.86	5.70	40
Turbidity (NTU)	89.01*	51.08	44.48	62.57	78.62*	64.59	76.21*	72.44	61.18*	59.90	65.81*	55.21	3.43#	219.17*	70.45	30-60
True colour (Pt Co)	84.43	22.31	91.40	8.51	87.75	11.61	87.08	24.44	86.17	19.89	88.33	14.92	37.00	107.00	87.33	
Apparent colour (Pt Co)	96.64	8.05	92.25	4.77	89.83	5.24	95.92	7.08	95.25	5.15	98.25	8.43	80.00	120.00*	94.81	< 100

NB: * values higher than the desirable limit; # values lower than the desirable limit; CV – coefficient of variation

Table 2. Temporal and spatial variations in the physico-chemical water quality parameters of Odo-Ebo River, Ile-Ife, Osun State, Nigeria

Parameters	Rainy season Mean ± SD	Dry season Mean ± SD	F- Value	Prob.	Upstream Mean ± SD	Discharge Point 1 Mean ± SD	Discharge Point 2 Mean ± SD	Downstream Mean ± SD	F- value	Prob.
Air Temperature (°C)	26.02 ± 1.16	26.88 ± 0.89	8.316	0.006	26.88 ± 1.26	26.18 ± 1.13	26.03 ± 1.08	26.42 ± 1.00	1.766	0.169
Water Temperature (°C)	26.07± 0.72	26.00 ± 0.82	0.131	0.719	26.09 ± 0.46ab	26.11 ± 0.90ab	26.38 ± 0.78a	25.60 ± 0.68b	2.092	0.117
pH	7.06 ± 0.39	7.17 ± 0.24	1.520	0.225	6.92 ± 0.41a	6.99 ± 0.41a	7.26 ± 0.15b	7.26 ± 0.16b	3.348*	0.028
Conductivity (μScm^{-1})	443 ± 22.27	439 ± 25.05	0.261	0.612	429 ± 16.09a	439 ± 19.57ab	450 ± 31.56b	447 ± 19.14ab	1.840	0.155
Dissolved oxygen (mg/l)	5.17 ± 2.14	4.11 ± 2.49	2.402	0.129	4.93 ± 2.8	4.51 ± 1.95	4.07 ± 2.26	5.40 ± 2.30	0.737	0.536
Biochemical oxygen demand (mg/l)	2.56 ± 1.39	1.90 ± 1.47	2.680	0.109	2.67 ± 1.82ab	1.91 ± 1.04ab	1.66 ± 0.90a	2.92 ± 1.58b	2.537	0.070
Chemical oxygen demand (mg/l)	39.91 ± 23.54	26.75± 15.64	4.212*	0.047	35.65 ± 27.48	35.77 ± 16.84	36.69 ± 16.61	29.63 ± 24.84	0.268	0.848
Alkalinity ($CaCO_3$ mg/l)	99.93 ± 28.43	95.05 ± 21.74	0.394	0.534	86.92 ± 9.69	106.00 ± 41.06	98.75 ± 25.49	99.92 ± 13.69	0.994	0.405
Phosphate (mg/l)	33.28 ± 3.09	38.73 ± 7.70	63.789*	0.000	33.95 ± 4.34a	40.12 ± 9.62b	34.54 ± 3.47a	33.60 ± 1.74a	30.799**	0.000
Sulphate (mg/l)	23.25 ± 20.18	5.77 ± 2.92	13.065**	0.001	13.17 ± 13.27	16.14 ± 18.15	17.12 ± 20.77	17.44 ± 19.75	0.121	0.947
Nitrate (mg/l)	5.26 ± 2.44	6.31 ± 3.92	1.191	0.282	4.97 ± 1.84	6.00 ± 3.78	6.38 ± 4.14	5.44 ± 2.49	0.556	0.647
Turbidity (NTU)	89.01 ± 45.47	44.48 ± 27.83	13.685**	0.001	78.62 ± 50.78	76.21 ± 55.21	61.18 ± 36.64	65.81 ± 36.33	0.430	0.733
True colour (Pt Co)	84.43 ± 18.83	91.40 ± 7.78	2.176	0.148	87.75 ± 10.16	87.08 ± 21.28	86.17 ± 17.14	88.33 ± 13.18	0.012	0.998
Apparent colour (Pt Co)	96.64 ± 7.78	92.25 ± 4.40	6.100*	0. 018	89.83 ± 4.71a	95.92 ± 6.79b	95.25 ± 4.90b	98.25 ± 8.29b	3.886*	0.016

NB: * significant difference; ** highly significant difference. Values in a row followed by different letters are significantly different at p ≤

Despite these temporal and spatial variations in the mean concentration of the studied parameters, only 3 parameters (pH, phosphate, and apparent colour) showed statistically significant differences among the stations ($p < 0.05$) (*Table 2*), while temporally only 5 parameters, namely COD, phosphate, sulphate, turbidity, and apparent colour, showed statistically significant difference between the two seasonal cycles studied (*Table 2*). The result of Duncan's post-hoc test revealed further effects of the effluent, with the discharge points significantly differing from the other stations in terms of phosphate concentration and apparent colour (*Table 2*).

The effect of the effluent was also revealed in the diversity and abundance of organisms recorded both temporally and spatially. Although the discharge points had lower zooplankton abundance as compared to upstream (*Table 3*), these stations were more diverse in terms of number of species than determined by Margalef's index for species richness of 1.59 (14 species) and 1.55 (13 species) for discharge points 1 and 2 respectively as well as the low values of Simpson's index (*Table 3*) indicating the effluent's effect.

Moreover, the highest zooplankton abundance (4,800 Org/m3) and Margalef's index (2.01) was recorded downstream from 18 species, thus implying the flow of the effluent. The species recorded were, however, evenly distributed in all stations based on the evenness index and Hill's diversity indices determined, which showed that on the average 82.5% of the recorded species contributed to the total abundance. Temporally, the species were also evenly distributed with 79.5% of the recorded species contributing to abundance on the average. A higher abundance (9,900 Org/m3) and species richness (3.15) was recorded during the rainy season from 30 species as compared to 12 species (4,900 Org/m3) recorded during the dry season (*Table 3*).

All the 31 species recorded were represented during the rainy season except *Anuraeopsis fissa*, while only 12 species were recorded during the dry season. Of the total species recorded, 9 species were only recorded from discharge points, namely *Anuraeopsis fissa*, *Filinia terminalis*, *Keratella ticninensis*, *proales* sp., *trichocerca ruttneri*, *brachionus quadridentatus*, *spirostomium* sp., *Loxodes* sp., and *centropyxis aculeate* (*Table 3*), while 10 species were recorded only from other stations, with 5 species from downstream, 3 species from upstream, and 2 species from both stations (*Table 3*). Despite the variations in abundance and diversity recorded among the stations, only 3 species, namely *Coleps* sp., *Ostracoda* sp., and *Arcella vulgaris*, showed significant difference in mean abundance (*Table 4*). The t-test performed to find the main effect of the season also showed that the abundance of 11 species of the 31 species recorded varied significantly with season ($0.05 \geq p \geq 0.001$) (Table 4).

Table 3. Spatial and temporal total abundance of zooplankton species

Organisms	TEMPORAL		SPATIAL			
	Rainy season	**Dry season**	**Upstream**	**Discharge Point 1**	**Discharge Point 2**	**Downstream**
Anuraeopsis fissa	0	800	0	300	500	0
Asplanchnopus	300	400	200	300	0	200
Brachionus ureolaris	100	800	0	200	0	700
Ascomorpha ovalis	500	500	0	200	300	500
Asplanchna sp.	300	200	300	0	100	100
Elosa worrali	800	800	0	1100	300	200
Hexarthra mira	1,100	0	700	0	100	300
Synchaeta stylata	400	0	0	200	100	100
Filinia terminalis	100	0	0	100	0	0
Keratella ticinensis	100	0	0	0	100	0
Asplanchna sieboldi	100	0	0	0	0	100
Notholca accuminata	300	0	0	0	0	300
Proales sp.	400	0	0	200	0	200
Brachionus dimitiatus	400	0	0	0	0	400
Trichocerca ruttneri	300	0	0	200	100	0
Brachionus quadridentatus	100	0	0	0	100	0
Asplanchna brightwelli	100	0	100	0	0	0
Asplanchna priodonta	600	0	100	0	0	500
Arganotholca faliaea	500	0	300	0	0	200
Lecane leotina	400	0	200	200	0	0
Testudinella berzinzi	100	0	0	0	0	100
Epiphane brachionus	100	0	0	0	0	100
Conochilus unicornis	300	300	0	0	100	500
Spirostomium	100	0	0	100	0	0
Loxodes sp.	100	0	0	0	100	0
Coleps sp.	900	400	800	0	300	200
Ceratopogonid larva	200	200	100	100	100	100
Ostracoda sp.	200	100	300	0	0	0
Centropyxis aculeate	200	0	0	200	0	0
Arcella vulgaris	400	100	500	0	0	0
Amoeba radiosa	400	300	500	200	0	0
Mean	**330**	**418**	**342**	**257**	**177**	**267**
Total Abundance	**9,900**	**4,900**	**4,100**	**3,600**	**2,300**	**4,800**
Number of species identified	**30**	**12**	**12**	**14**	**13**	**18**
Margalef's index (r1)	**3.15**	**1.30**	**1.32**	**1.59**	**1.55**	**2.01**
Simpson's index (ƛ)	**0.05**	**0.12**	**0.12**	**0.13**	**0.12**	**0.08**
Shannon's index (H)	**3.15**	**2.29**	**2.27**	**2.36**	**2.36**	**2.69**
Hill's 1st diversity number	**23.22**	**9.89**	**9.72**	**10.59**	**10.55**	**14.69**
Hill's 2nd diversity number	**19.07**	**8.68**	**8.38**	**7.46**	**8.70**	**12.55**
Evenness index 4	**0.82**	**0.88**	**0.86**	**0.71**	**0.83**	**0.85**
Evenness index 5	**0.81**	**0.86**	**0.85**	**0.67**	**0.81**	**0.84**

Table 4. Spatial and temporal variation in the abundance of recorded zooplankton species

Zooplanktons	Rainy season Mean ± SD	Dry season Mean ± SD	F- Value	Prob.	Upstream Mean ± SD	Discharge Point 1 Mean ± SD	Discharge Point 2 Mean ± SD	Downstream Mean ± SD	F -Value	Prob.
Anuraeopsis fissa	0.00 ± 0.00	40.00 ± 99.47	25.979****	0.000	0.00 ± 0.00	25.00±86.60	41.67 ± 99.62	0.00 ± 0.00	0.559	0.646
Asplanchnopus	10.71 ± 56.70	20.00 ± 61.56	1.044	0.312	16.67 ± 57.74	25.00 ± 86.60	0.00 ± 0.00	16.67 ± 57.74	0.653	0.587
Brachionus ureolaris	3.70 ± 19.25	40.00 ± 82.08	30.771****	0.000	0.00 ± 0.00	18.18 ± 60.30	0.00 ± 0.00	58.33 ± 90.03	2.339	0.093
Ascomorpha ovalis	17.86 ± 66.96	25.00 ± 55.01	0.217	0.644	0.00 ± 0.00	16.67 ± 57.74	25.00 ± 86.60	41.67 ± 66.86	0.526	0.668
***Asplanchna* sp.**	10.71 ± 31.50	10.00 ± 30.78	0.025	0.876	25.00 ± 45.23	0.00 ± 0.00	8.33 ± 28.87	8.33 ± 28.87	1.045	0.386
Elosa worrali	28.57 ± 71.27	42.11 ± 183.53	0.979	0.328	0.00 ± 0.00	91.67 ± 239.16	25.00 ± 86.60	16.67 ± 38.93	1.285	0.297
Hexarthra mira	40.74 ± 144.81	0.00 ± 0.00	6.721**	0.013	58.33 ± 202.07	0.00 ± 0.00	8.33±28.87	25.00 ± 86.60	1.063	0.379
Synchaeta stylata	14.29 ± 44.84	0.00 ± 0.00	8.699**	0.005	0.00 ± 0.00	16.67 ± 57.74	9.09 ± 30.15	8.33 ± 28.87	0.559	0.646
Filinia terminalis	3.57 ± 18.90	0.00 ± 0.00	3.062	0.087	0.00 ± 0.00	8.33 ± 28.87	0.00 ± 0.00	0.00 ± 0.00	0.970	0.415
Keratella ticinensis	3.57 ± 18.90	0.00 ± 0.00	3.062	0.087	0.00 ± 0.00	0.00 ± 0.00	8.33 ± 28.87	0.00 ± 0.00	0.820	0.493
Asplanchna sieboldi	3.57 ± 18.90	0.00 ± 0.00	3.062	0.087	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	8.33±28.87	0.960	0.424
Notholca acuminata	10.71 ± 31.50	0.00 ± 0.00	11.880****	0.001	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	25.00 ± 45.23	2.193	0.109
***Proales* sp.**	14.29 ± 52.45	0.00 ± 0.00	6.921**	0.012	0.00 ± 0.00	16.67 ± 57.74	0.00 ± 0.00	16.67 ± 57.74	0.638	0.595
Brachionus dimitiatus	14.29 ± 59.09	0.00 ± 0.00	5.065*	0.029	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	33.33 ± 88.76	0.960	0.424
Trichocerca ruttneri	10.71 ± 41.63	0.00 ± 0.00	5.952*	0.019	0.00 ± 0.00	16.67 ± 57.74	8.33 ± 28.87	0.00 ± 0.00	0.820	0.493
Brachionus quadridentatus	3.57 ± 18.90	0.00 ± 0.00	2.906	0.095	0.00 ± 0.00	0.00 ± 0.00	8.33 ± 28.87	0.00 ± 0.00	0.820	0.493
Asplanchna brightwelli	3.70 ± 19.25	0.00 ± 0.00	3.186	0.081	8.33±28.87	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.378	0.268
Asplanchna priodonta	21.42 ± 95.67	0.00 ± 0.00	4.191*	0.046	8.33±28.87	0.00 ± 0.00	0.00 ± 0.00	41.67 ± 144.34	0.847	0.476
Arganotholca faliaea	18.52 ± 68.15	0.00 ± 0.00	6.833**	0.012	25.00 ± 86.60	0.00 ± 0.00	0.00 ± 0.00	16.67 ± 57.74	0.931	0.437
Lecane leontina	14.82 ± 53.38	0.00 ± 0.00	7.240**	0.010	16.67±57.74	16.67 ± 57.74	0.00 ± 0.00	0.00 ± 0.00	0.960	0.424
Testudinella berzinzi	3.57 ± 18.90	0.00 ± 0.00	3.062	0.087	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	8.33 ± 28.87	0.960	0.424
Ephiphanes brachionus	3.57 ± 18.90	0.00 ± 0.00	3.062	0.087	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	8.33 ± 28.87	0.960	0.424
Conochilus unicornis	11.11 ± 42.37	15.00 ± 67.08	0.311	0.580	0.00 ± 0.00	0.00 ± 0.00	8.33 ± 28.87	45.45 ± 103.57	0.820	0.493
***Spirostomium* sp.**	3.57 ± 18.90	0.00 ± 0.00	2.906	0.095	0.00 ± 0.00	8.33±28.87	0.00 ± 0.00	0.00 ± 0.00	0.970	0.415
***Loxodes* sp.**	3.57 ± 18.90	0.00 ± 0.00	3.062	0.087	0.00 ± 0.00	0.00 ± 0.00	8.33 ± 28.87	0.00 ± 0.00	0.820	0.493
***Coleps* sp.**	32.14 ± 86.30	21.05 ± 63.06	0.963	0.332	72.73 ± 127.21	0.00 ± 0.00	25.00 ± 62.16	16.67 ± 57.74	3.719*	0.022
Ceratopogonid larva	7.41 ± 26.69	10.00 ± 30. 78	0.380	0.541	9.09 ± 30.15	8.33±28.87	8.33 ± 28.87	8.33 ± 28.87	0.023	0.995
***Ostracoda* sp.**	7.41 ± 26.69	5.00 ± 22.36	0.435	0.513	25.00 ± 45.23	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.307*	0.033
Centropyxis aculeate	7.41 ± 38.49	0.00 ± 0.00	3.186	0.081	0.00 ± 0.00	16.67 ± 57.74	0.00 ± 0.00	0.00 ± 0.00	0.960	0.424
Arcella vulgaris	15.39 ± 54.35	5.26 ± 22.94	2.652	0.111	45.45 ± 82.02	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.307*	0.033
Amoeba radiata	14.29 ± 44.84	15.00 ± 15.08	0.046	0.832	41.67 ± 99.62	16.67 ± 38.93	0.00 ± 0.00	0.00 ± 0.00	1.018	0.398

* significant; ** highly significant; **** very highly significant

4. Discussion

The discharge from carwash effluent, as revealed by the concentration of essential nutrients (nitrate, sulphate, and phosphate) and the slight acidic range of the pH (5.80–7.55) recorded, could lead to increase in the primary productivity of water bodies, while the acidic pH recorded upstream could be attributed to sewage discharged at this station from the catchment area of the river containing faecal matter and agricultural waste. This also accounted for the comparatively high turbidity recorded upstream though turbidity was above the recommended values at all sampled stations [22], whereas the high turbidity values recorded at the discharge points have been attributed to the colour of detergent and oil/grease in the wastewater [23].

The gradual increase in apparent colour from discharge points confirmed the alterations of the natural colour of water bodies by inflows [24], establishing the fact that the colour of water bodies is not dependent on its natural components only but on the anthropogenic activities within its catchment area. Moreover, the highly significant difference ($p < 0.01$) in the apparent colour between the investigated stations, which separated upstream from all other stations, is a reflection of the carwash effluent effect on the colour of Odo Ebo River.

The effect of the effluent as recorded in the higher mean values of major ions (phosphate, sulphate, and nitrate) has been reported by researchers such as Sablayrolles et al. (2010) [25], Aisling et al. (2011) [26], Adeyemi-Ale (2014) [27], and Danha et al. (2014) [12]. They attributed the increase in loads of these major ions to the hydrocarbon components of detergents being used at the carwash bay, thus to organic pollution. The high level of COD and electrical conductivity at the effluent receiving points were also indicators of high ionic concentration resulting from the release of ions into the river via the effluents [28]. The pronounced mean concentration of sulphate, most especially during the rainy season, confirms its solubility and persistency in water [29, 30]. Furthermore, sulphate ions as contained in linear alkylbenzene sulphonates (LAS) are very important constituents of detergents being used in the carwash industry, as reported by Sablayrolles et al. (2010) [25].

The higher mean values of dissolved oxygen, BOD_5, turbidity, and true colour recorded upstream and downstream were reflections of higher biological productivity and organic detritus at these stations as compared to discharge points. This was further confirmed by the abundance of *Coleps* sp. at these stations, which is a good indicator of organic detritus and is often less abundant in polluted water than recorded from the effluent receiving points.

The zooplankton abundance was equally more upstream and downstream than the abundance recorded at the discharge points. A decrease of 12% in zooplankton abundance was recorded at the 1st discharge point, which was further reduced to 44%

at the 2nd discharge point as compared to the abundance recorded upstream. This later increased to 109% downstream as against the recorded abundance at the 2nd discharge point. This increase in zooplankton abundance downstream coupled with species richness could be attributed to the eutrophication effect of the carwash effluent, while the nine species recorded specifically from the discharge points were well-known eutrophic species [31].

The effect of the effluent was also revealed in the temporal abundance of the zooplankton with 11 out of the 31 species recorded having highly significant seasonal variation, 9 of which were more abundant in the rainy season. Moreover, zooplankton abundance during the rainy season was twice that of the dry season, which has been attributed to nutrient influx with run-off [32]. Adeniyi and Adedeji (2007) [33] also attributed the qualitative richness to the mixing effects of the run-off, which usually frees organisms from river beds and littoral vegetation.

In conclusion, the study revealed the eutrophic effects of carwash effluent on water bodies through the increase in major nutrient ions at the discharge points, especially phosphate and nitrate ions, leading to reduction in dissolved oxygen and zooplankton abundance, change in apparent water colour, and increase in COD. Therefore, carwash effluents are a potential risk to the receiving water body; hence, the government needs to put measures in place to check the indiscriminate siting of carwash bays by river banks for environmental protection.

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Conflict of interest

There is no conflict of interest as regards the publication of this research finding.

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