PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 26 (6) 1173-1177 June 2022

Impact of Commercial Car Washing Bay on Water Quality of River Nakiyanja in Central Uganda

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ABSTRACT: Car washing bays discharge a wide range of pollutants into water bodies which degrade water quality and affect aquatic ecosystem functions. The study examined the influence of the motor vehicle-washing bay on water quality of River Nakiyanja wetland system. Physicochemical water quality was measured by both *in-situ* and *x-situ* following standard protocols. Data was analyzed using one-way ANOVA. The study revealed higher concentrations of contaminants such as oil and grease, biochemical oxygen demand, chemical oxygen demand, total suspended solids, and turbidity at impact sites associated with vehicle washing compared to the pre-washing bay sites, and these differed significantly. This affects aquatic ecosystem functions and probably posing health impacts to the direct users of water resources. The study recommended enforcement of water and environmental legislations and constructions of wastewater treatment facilities at each of the car washing bays to protect aquatic ecosystems.

DOI: https://dx.doi.org/10.4314/jasem.v26i6.26

Impact factor: http://sjifactor.com/passport.php?id=21082

Google Analytics: https://www.ajol.info/stats/bdf07303d34706088ffffbc8a92c9c1491b12470

Dates: Received: 21 March 2022; Revised: 25 June 2022; Accepted: 30 June 2022

Keywords: Car washing bay; physicochemical water parameters; water contaminants; River Nakiyanja wetland

Outdoor vehicle washing bays especially those established along waterways and wetlands has become major environmental concern in urban areas in situations were the effluents are discharged directly into the water system without treatment (Danha *et al*, 2014). Given that commercial car washing bay activities require the use of large amounts of water that returns into surface waterways daily, it presents high potential of contaminating water sources making them unsafe for humans, terrestrial, and aquatic ecosystems (Reeta,*et al*., 2020). In Uganda, car-washing bays has become popular and lucrative among the urban youth as a source of livelihood due to the low start-up requirements. This has resulted in establishment of large number of washing bays along river courses, and wetland shores. The waste water from the car-washing bays are discharge directly into the water system (Turyahabwe, *et al.*, 2021). Motor vehicle washing activities, due to their potential adverse environmental effects are enlisted as regulated by the National Environment Management Authority (NEMA) where the decision to or not to permit the trade should be reached after undertaking thorough environmental impact assessments. Most vehicle washing bays along the swamp and river systems and are not monitored by NEMA. In addition the rapid and uncontrolled urbanization which often expands into the nearby swamp and river reserves result in shrinking of wetland sizes which limits the sustainability of the wetlands as purifier of the discharged wastes (Turyahabwe, *et al.*, 2020). With the daily increase in the number of second hand vehicles imported into

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Uganda, there will be an increase in the washing bay activities making the challenge to become even a serious concern in wetland health especially in urban areas.

The River Nakiyanja wetland system in central Uganda is one such ecosystem hosting a large number of motor vehicle washing activities despite its biodiversity conservation status. The system also absorbs the effluents from industrial establishments in the Namanve industrial park, other anthropogenic activities like crop cultivation, brick laying, sand mining, in addition to the car washing bays. Consequently, the wetland system has shrunk and become stressed to levels beyond its filtration capacity (NEMA, 2010). Due to the Nakiyanja wetland system's hydrological connectivity to Lake Kyoga, the continued effect of the above-mentioned activities is likely to spread further, causing eutrophication and growth of algal blooms and hyacinth in Lake Kyoga. Assessment of water quality is the first step to revealing the likely impacts of the contaminants on the ecosystem health and ecological functioning of wetlands. This study examined the influence of commercial washing bay on physicochemical water quality of River Nakiyanja in central Uganda.

MATERIALS AND METHODS

Study area: Nakiyanja River is the main source of water for the Nakiyanja swamp. The river originates from Namilyango in Mukono district, central Uganda. The River flows through a series of dambo wetlands intercepted by some arable farms and settlements, and enters Lake Kyoga basin in Kayunga District. This vast area receives tropical rainfall ranging between 1300 to 1520mm p.a, and temperature ranges between 21to 24.5^{0}C (NEMA, 2010). Due to its location within the Greater Kampala Metropolitan Area, the wetland was crossed by many roads and dense traffic hence a boom in the motor vehicle washing industry. Two study sites were purposively selected based on locations of commercial car washing bays along the River Nakiyanja wetland system. One was located in the "pristine" stage of the river at Kiwanga washing bay in the Mukono district. This site was located at latitude 0°22'13.17"Nand longitude 32°42'7.26"E. The site is characterized by dense emergent aquatic macrophytes dominated by exotic weeds and trees particularly the *Psidium guajava*, and the streambed dominated by sand, shingle and some stony clay. The velocity of 0.4±0.1 m/s, average wet depth of80.0±10.4cm, wet width of 6.7±0.1m, discharge of 2.11M^3/s. The study site covered a 1.3km stretch. The second site was located at Namugongo in Wakiso district at latitude0°23'52.57"N and longitude32°40'17.36"E where the river was in the middle stage. At this site, the stream exhibits high streambed roughness with the predominant substratum being a mixture of cobble, pebble and boulders, and some mud. Along its length, the river was bordered by papyrus grass and palm tree vegetation. The water velocity was 0.4±0.1m/s, average wet depth109.0±18.2cm, wet width 6.1±0.8m, and discharge of 2.7 M^3/s. This second site covered a 2.3km stretch.

Data collection: Four sampling campaigns took place from June to December 2021. Table1 shows the sizes of the washing bays in terms of weekly number of vehicles washed and the amount of water used part of which returns into the stream system.

Table1. Sizes of the washing bays in terms of number of vehicles washed and the amount of water used

Type of vehicle	*Kiwanga site*		*Namugongo site*	
	Average Number per week	*Average Amount of water used (Ltrs)*	*Average Number per week*	*Average Amount of water used (Ltrs)*
Motor cycles	56±3.2	89±4.1	125±9.1	106±5.3
Saloon cars	107±5.5	197±2.2	298±3.2	360±10.3
Pick ups	27±1.9	77±1.1	79±1.6	182±6.4
Mini-buses	19±3.0	96±2.6	183±2.2	220±7.1
Heavy trucks	0±0	0±0	92±2.1	190±2.9

For the two selected washing bay sites, all the effluents were discharged directly into the wetland without treatment.

Physicochemical Water quality sampling: Four sampling were undertaken in both wet and dry seasons. At each site, water samples were drawn from three different locations that is, at 50meters to the upstream, inside, and 50 meters downstream of the washing bay to reveal the influence of the bay on water quality and how much contamination the wetland would filter. A 10-meter interval was considered for the intermediate sampling points. On each sampling occasion, physico-chemical water quality variables were measured in triplicate at randomly selected points at each of the sampling sites. Conductivity, pH, and Total Dissolved Solids (TDS) were measured (*in-situ*) using a combined

Conductivity/TDS/pH/Temperature Meter (HANNA Hi 991300 Model). Dissolved oxygen was measured using a multi-parameter analyzer (Consort C3010/C3030 Model) and turbidity was measured using a Turbidity Meter (AL 450T-IR Model).Nutrients (nitrates and phosphates), surfactants (Grease and oil, copper and zinc), B.O.D, and TSS were analysed in the laboratory (*x-situ*) following APHA (1998) protocols. The width and depth of the river at sites were measured using a wading rod and tape measure. The velocity and resultant discharge were obtained by timing of buoyant sticks over a 5-m stretch (Gore, 2007).GPS coordinates were recorded using GPS- *Germin Oregon e-60* type.

Data Analysis: To compare the differences in physicochemical water quality at the two sampling sites, parametric (ANOVA) statistics were used. Before the comparison, a normality test using Shapiro-Wilk was applied to ecological health variables and physicochemical water quality variables. All the data having passed the normality test, one-way ANOVA was performed to assess the differences between means of dependent variables from the two study sites. For those models where it was found to be significant under ANOVA, a post hoc test using Turkey's Honestly Significant Difference (HSD) test was done all generated from STATA version 14.01.

RESULTS AND DISCUSSION

Influence of washing bay on the physico-chemical water quality of Nakiyanja wetland: The results of the analysis of the chemical and physical water parameters were summarized in the table 2. At the Kiwanga site, the washing bay increased the oil and grease by 268±44mg/l. This effect was more elevated at the Namugongo site where, the washing bay increased oil and grease by 848mg/l. The distribution of oil and grease concentration at each of the two sites varied significantly at P<0.05 (Table2). The concentration of B.O.D at the Kiwanga site was highest at the end of the washing bay. The study findings reveal that at this site, the washing bay increased the B.O.D by 3.8±0.9 ppm accounting for 16.3% negative effect of which the recipient Nakiyanja wetland eliminated only 11.5%.

Table2: Variation in physicochemical water quality values (mean ± standard deviation) on the two washing bay sites in River Nakiyanja

Sampling points at washing bay sites	Average values of Physico-chemical water quality parameters from two sampling sites											
	Oil & grease	BOD	DO	pH	NIT	PO_{4-}	TSS	TDS	EC	Turb	Zn	Cu
	Mg/l	Ppm	Ppm		Mg/l	Mg/l	Mg/l	Ppm	µS/cm	NTUs	Mg/l	Mg/l
KIWANGA CAR WASHING BAY SITE												
Before	2 ± 0b	23.3 ± 0.2a	11.1 ± 0.1a	7.2 ± 0.1c	0.4 ± 0a	1.2 ± 0d	72.6 ± 0c	124 ± 1.2a	52 ± 2.8a	109 ± 0.8c	0.00 ± 0a	0.0 ± 0b
Inside	267 ± 2.2a	26. 0± 2.2ab	9.2 ± 1b	8.4 ± 0.2b	2.2 ± 0.1d	1.4 ± 1b	105 ± 1.8a	132.0 ± 6.1b	83.2 ± 1.9a	245 ± 6.2b	0.91 ± 1b	1.1 ± 0.1a
End	271 ± 0.1c	27.1 ± 1.1c	8.9 ± 0.2c	8.4 ± 0.1ac	3.3 ± 1c	3.9 ± 0a	162 ± 0.1b	142 ± 0.3c	122 ± 2.1c	373 ± 4.5a	1.5 ± 1c	1.8 ± 4c
Effect	268 ± 44	3.8 ± 0.9	2.2 ± 0.1	1.2 ± 0.1	2.9 ± 1	1.7 ± 1	89. 4± 0.1	18 ± 0.9	70 ± 0.7	264 ± 44	0.6 ± 1	1.8 ± 3.9
% effect	13400	16.3	19.8	16.7	725	141.7	123	14.5	134.6	242	75	28
NAMUGONGO CAR WASHING BAY SITE												
Before	18 ± 0.1a	18.2 ± 0.1a	11 ± 1c	5.6 ± 1.1b	1 ± 0.1c	1 ± 0.1b	69.7 ± 1.3a	110 ± 1.2c	29 ± 0.0c	62 ± 0.2a	0.01 ± 0.1b	0.01 ± 0a
Inside	721 ± 0.1c	26 ± 0.2b	6.3 ± 0.2a	7.9 ± 1.1c	4 ± 0.1c	2.5 ± 1c	207 ± 0.3	198 ± 0.3a	166 ± 1.0	199 ± 1.1	2.6 ± 0.1a	3.2 ± 0a
End	866 ± 0.0c	26 ± 1.1c	5.9 ± 0.2b	7.9 ± 0.0a	4.5 ± 0.2b	3.9 ± 2.1a	256 ± 1.6c	210 ± 0.1b	182 ± 1.5 C	218 ± 0.3b	2.9 ± 0.1c	3. 6± 1a
Effect	848	1.44	5.1	2.3	3.5	2.9	186.3	100	153	156	2.89	3.6
% effect	4711	7.9	46.4	41	350	290	267	90	527.6	251	28900	36000

Key: BOD (Biological Oxygen Demand), DO (Dissolved Oxygen), COD (Chemical Oxygen Demand), TDS (Total Dissolved Solids), NT (nitrates), PHOSP (phosphates), EC (electrical conductivity), TURB (turbidity), TSS (total suspended solids). Mean values with the different letters (a, b, c and d) in the same column are significantly different One Way ANOVA at p≤ 0.05

This effect was however less at the Namugongo site where the washing bay increased the B.O.D by only 1.44ppm accounting for only 7.9% which was less than half of that at the Kiwanga site. The distribution of the B.O.D at each site differed from each other significantly at $P<0.05$. At the Kiwanga sampling site, the washing bay reduced dissolved oxygen (D.O) by 2.2±0.1ppm, accounting for 19.8% reduction. At the Namugongo site, the washing bay reduced the dissolved oxygen by 5.1ppm (46.4%), an amount more than twice that at the Kiwanga site. The washing bay maintained the pH with in the neutral ranges of 7.2±0.1 to 8.4±0.1 at the Kiwanga washing bay. At the Namugongo site, the washing bay activity increased the pH from acidic levels to neutral levels up to 7.9±0.0. This increment was by 41%. At the Kiwanga site, the washing bay increased the amount of nutrients of Nitrates and Phosphates in the stream by 2.9±1 and1.7±1 respectively. At the Namugongo site, the washing bay effect was more visible since there were more nutrients in the stream than was at the Kiwanga site. The distribution of these nutrients varying from site to site and from point to point at $P<0.05$.

At the Kiwanga site, washing bay activities introduced 89.4±0.1mg/l of TSS, which was 123% increment as compared to the amount of TSS at a point before stream reached the washing bay. The Namugongo washing bay introduced more TSS into the stream (186.3±0.1mg/l) which was a 267% increase. The TDS at the Kiwanga site increased by 14.5ppm but 46.5% of this was absorbed by the wetland downstream while at the Namugongo site, TDS increased by 100ppm (90%). Kiwanga washing bay site was associated with very high increment of EC and corresponding Turbidity with 134.6% and 242% increment of the duo. At the Namugongo site, the washing bay introduced 153 µS/cm and 156 NTUs of conductivity and turbidity respectively into the stream system. Kiwanga washing bay introduced 0.6±1 mg/land 1.8±3.9mg/l of the zinc and copper metallic surfactants respectively into the stream system, which accounted for 75% and 28% increment of the duo. At the Namugongo site, higher amounts of surfactant metals from the car washing bay activities were introduced into the stream system (2.9±0.1mg/l and 3.6±1mg/l) of zinc and copper respectively.

Both washing bay sites witnessed a reduction in dissolved oxygen from the point before the washing bay to the end of the washing bay. This may be attributed to the oil and grease that were introduced in the stream water system. Once in waterways, grease and oil rise to the top and form a film that block sunlight, impairing photosynthesis, preventing oxygen replenishment of water body. A similar reason was given for oxygen depletion form the South African water system (Diphare et al., 2013). The concentration of B.O.D at the Kiwanga site was highest at the end of the washing bay. This was probably because all the surfactants that had been washed from the cars at this site had collected at this point. The study revealed that at this site, the washing bay increased the B.O.D by 3.8±0.9 ppm accounting for 16.3% negative effect. The increase in this effect was attributed to the presence of metallic surfactants such as copper and zinc that were introduced in the stream system. The copper and zinc surfactants are extremely oxygen demanding for biodegrading and have capacity to induce oxygen deficiency in a lotic environment. This result agrees with study findings of Sablayrolles et al., (2010) and Turyahabwe et al. (2021), who both observed that some surfactants like linear alkylbenzene sulphonates caused oxygen deficiency in aquatic environments in addition to facilitating the permeation of other pollutants into aquatic organisms. Kiwanga washing bay introduced 0.6±1 mg/land 1.8±3.9mg/l of the zinc and copper metallic surfactants into the stream system, which accounted for 75% and 28% increment of the duo. This is probably why other studies have indicated concentrations of metal surfactants to be higher than other contaminants in waterways. Moores et al. (2010) reported that Zn and Cu were the highest metal contaminants in carwash effluents, derived mainly from tyres and brake pads, respectively. The big range in parameter concentrations observed in this study between the impact pont washing bay and pre-impact point. This finding was not different from the one of Memory et al., (2016) who reported that, the impact of washing bay on surface water chemistry was maximum at the washing bay discharge zones than points earlier and after sampling points along the same river. At the Namugongo site, the washing bay activity increased the pH from acidic levels to neutral levels up to 7.9±0.0. This increment was by 2.3 hence 41% increment. This Elevation in pH at the impact site of Namugongo by 41% can be attributed to the use of detergents during washing of vehicles. The detergents are known to contain hydrocarbon compounds, which increase pH levels in lotic system (Arimoro et al., 2015). In general, the higher concentrations of pollutants in the river were mainly attributed to washing the cars where in most cases the vehicles were pushed directly into the river.

Conclusion: Analyses of physicochemical data reflected that streams and rivers used for discharging washing bay effluent are vulnerable to deterioration in their ecological status. Ecological status of River Nakiyanja has been degraded especially at the impact sites, which receive direct discharge of car washing bay effluents containing various contaminants. Physico-chemical variables related to vehicle washing were present in higher concentrations in impact sites compared to upstream and downstream sites. Low water quality levels observed in this study at impact sites indicating the influence of the washing bay activities on the water quality of the river. The present findings clearly showed that discharge of washing bay effluents in river Nakiyanja changed the water chemistry, which may affect macroinvertebrate assemblages. With the increasing number of second hand vehicles imported into the country, the number volume of washing bay effluent is likely to increase further in future. We recommend NEMA to review guidelines for establishing washing bays along the water systems and also sensitize the stakeholders of the dangers posed by effluents from the washing bays into the wetland ecosystem. Washing bay proprietor should be encouraged to develop car washing bay effluent treatment plants before discharge into stream system.

Acknowledgement: We are grateful to the Biology Department of Kyambogo University for the laboratory space, equipment and expertise in water sampling and analysis which made the study successful. We are thankful to the Department of Geography, Busitema University small grants section for funding this project. To our field research assistants, big thank you.

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