Jurnal Geografi, Edukasi dan Lingkungan (JGEL) Vol. 9, No. 2, Juli 2025:168-179
P-ISSN: 2579–8499; E-ISSN: 2579–8510
Doi: https://doi.org/10.22236/jgel.v9i2.18374
Website: http://journal.uhamka.ac.id/index.php/jgel

Ecological Restoration Capacity Of River Nakiyanja Wetland System From The Effects Of Motor Vehicle Washing Bays, Along River Nakiyanja, Central Uganda

Remigio Turyahabwe[1], Edward Andama[2], Sowedi Masaba[3], Mulabbi Andrew[4*], And Alwin[5]
[1]Department of Geography, Faculty of Science and Education, Busitema University, Tororo, Uganda
[2]Department of Biology, Faculty of Science and Education, Busitema University, Tororo, Uganda
[3]Department of Environmental Planning and Management, Faculty of Natural Resources and Environmental Sciences, Busitema University, Tororo, Uganda
[4]Department of Education, Faculty of Education, Muni University, Arua, Uganda
[5]Pendidikan Geografi, Fakultas Keguruan Dan Ilmu Pendidikan, Universitas Muhammadiyah Prof. Dr. Hamka, Jakarta, Indonesia

*Email: mulabbiandrew@gmail.com
Received: 18 02 2025 / Accepted: 22 06 2025 / Published online: 24 07 2025

ABSTRACT
Washing bays are associated with a wide range of contaminants, which end up in the water bodies, thereby contaminating and degrading water quality, hence affecting aquatic ecosystems. The research sought to study the impact of the motor vehicle washing bays on the ecology of the River Nakiyanja wetland system and assess the capacity of the wetland system to restore the ecosystem health from the effects of the washing bays. Data analysis employed the one-way ANOVA test. The findings revealed that the cumulative effects of degraded water quality on benthic macroinvertebrate assemblages were supported by low South African Score System –Average Score Per Taxon (SASS-ASPT) indices, and the resultant poor ecological status of the river at impact sites was compared to sites upstream and downstream of the washing bay. The SASS and resultant ASPT at the sampling sites differed significantly at $P<0.05$. The study findings further reveal that the River Nakiyanja wetland was capable of restoring over 60% of the ecosystem's health. The study concludes that the Nakiyanja wetland has a high restoration capacity from the effects of motor vehicle washing bays. There is, however, a need to regulate motor vehicle washing bay activities by enforcing environmental legislation related to wastewater disposal to protect the River Nakiyanja.

Keywords: *Ecological Restoration Capacity, River Nakiyanja Wetland System, Motor Vehicle Washing Bays, Benthic Macroinvertebrates, Degraded Water Quality.*

ABSTRAK
Tempat pencucian kendaraan bermotor dikaitkan dengan berbagai macam kontaminan, yang berakhir di badan air, dapat mencemari dan menurunkan kualitas air, serta mempengaruhi ekosistem perairan. Penelitian ini bertujuan untuk mempelajari dampak dari tempat pencucian kendaraan bermotor terhadap ekologi Sungai Nakiyanja dan menilai kapasitas sistem lahan basah untuk memulihkan kesehatan ekosistem dari dampak tempat pencucian. Analisis data menggunakan uji ANOVA satu arah. Temuan ini mengungkapkan bahwa efek kumulatif dari penurunan kualitas air terhadap kumpulan makroinvertebrata bentik didukung oleh indeks Sistem Skor Afrika Selatan - Skor Rata-rata Per Takson (SASS-ASPT) yang rendah, dan status ekologi sungai yang buruk di lokasi yang terkena dampak dibandingkan dengan lokasi di hulu dan hilir teluk pencucian. SASS dan ASPT yang dihasilkan di lokasi

pengambilan sampel berbeda secara signifikan pada P<0,05. Temuan penelitian lebih lanjut mengungkapkan bahwa lahan basah Sungai Nakiyanja mampu memulihkan lebih dari 60% kesehatan ekosistem. Studi ini menyimpulkan bahwa lahan basah Nakiyanja memiliki kapasitas restorasi yang tinggi dari dampak pencucian kendaraan bermotor. Namun, ada kebutuhan untuk mengatur kegiatan tempat pencucian kendaraan bermotor dengan menegakkan undang-undang lingkungan yang terkait dengan pembuangan air limbah untuk melindungi Sungai Nakiyanja

Kata kunci: Restorasi Ekologi, ASPT, Tempat Pencucian Kendaraan Bermotor Limbah, Lahan basah.

INTRODUCTION

The increased worldwide contamination of freshwater systems due to the continuous discharge of industrial and chemical effluent materials into their channels, typically micro-pollutants, is one of the major environmental issues affecting humanity (Inyinbor et al., 2018). Commercial car washing bay activities consume large amounts of water daily, which are emptied into the surface waterways, presenting a high potential for contaminating water sources and rendering them unsafe for humans, terrestrial and aquatic ecosystems (Reeta et al., 2020).

Motor vehicle parts like engines, exhaust pipes, tires, rims, and brakes are associated with pollutants like surfactants, heavy metals, and hydrocarbon wastes like petroleum, grease, and oil discharged into watercourses during car washing. Since these are usually untreated, they not only degrade the water quality but also impair ecosystem health, thereby limiting the sustainability of the aquatic environment (Danha *et al*., 2014; Antoinette, 2020). Polluted water greatly impacts the organisms, plants, humans, and the climate, and alters the ecosystem's functioning (Inyinbor *et al.*, 2018). This is because some organic and heavy metal pollutants may enter the food chain system and eventually negatively affect living organisms, including fish, macroinvertebrates and humans that depend on the freshwater sources (Popa and Petrus 2017).

Wastes from car washing bays are the primary cause of water quality deterioration in streams. Zaneti et al. (2012) observed that in Malaysia, accumulated sediments from car washing bays flow into the stormwater system without undergoing treatment, thereby endangering the ecosystem. Sediments from car washes enter the streams, leading to environmental pollution. Antoinette (2020) found that water released into adjacent streams from the car washing bays in South Africa was of low quality, putting the ecosystem's health and users at risk. Danha et al. (2014) observed that the effluent disposal downstream of a washing bay in River Nyahode had water quality indicators below the recommended local and WHO water quality threshold values hence degrading the ecosystem which may require ecological restoration.

According to Prasanya et al., (2024), ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Healthier ecosystems, with richer biodiversity, yield greater benefits such as bigger yields of macroinvertebrates and fish, and chlorophyll-a. Wetland systems play a crucial role in the restoration of aquatic ecosystems by acting as natural sponges, purifying water, and providing habitats for diverse plant and animal life. They can improve water quality, buffer against floods, and contribute to biodiversity.

On the other hand, according to Turyahabwe et al., (2022), ecological restoration capacity of wetlands refers to the ability of a wetland to effectively purify water by filtering out sediments, pollutants, and excess nutrients from water sources and preventing harmful substances from entering rivers, lakes, and other water bodies, thereby recovering and enhancing the degraded habitats for aquatic living organisms.

In East African water bodies, oil and grease associated with car washing form a coating layer on the water surface that acts as a barrier to sunlight, affects photosynthesis, and limits plankton growth. It prevents oxygen replenishment, increases Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), temperature, and pH of the water, thus triggering aquatic habitat degradation, reduced productivity, and loss of biodiversity (Reeta *et al*., 2020). Debris cleaned from the motor vehicles and motorcycles contributes to dissolved and suspended solids in wastewater, creating a stressful aquatic ecosystem by increasing BOD and turbidity, reducing available habitat, and clogging the gills of fish and macroinvertebrates, leading to respiratory difficulties. Sensitive macroinvertebrates, including Ephemeroptera, *Plecoptera*, and *Trichoptera* (EPT), are vulnerable to all these effects (Harding, 2005).

Car-washing activities are a lucrative business in Uganda among urban youth, and several washing bays have been established along river courses and wetland shores to minimize costs associated with purchasing water from commercial providers. The dirty water from cars and motorcycles flows back into water streams (Turyahabwe et al., 2021). Car and motorcycle washing activities are regulated by law by the National Environment Management Authority (NEMA) due to their potential adverse effects on the environment. NEMA regulates these activities through the issuance of permits, with decisions based on detailed environmental impact assessments. However, motor vehicle washing bays continue to be established along river and stream banks, albeit with limited monitoring by NEMA. For those permitted to operate, the sizes of car washing bay establishments along most urban streams in central Uganda have exceeded both the permitted area and the purification capacities of the rivers or streams and the respective receiving wetland systems. Moreover, the sizes of the wetlands have shrunk, limiting their sustainability (Turyahabwe et al., 2020). This is because rapid and unregulated development continues to extend into adjacent swamps and river reserve buffers.

The Nakiyanja wetland system in Goma division, Mukono Municipality, Uganda, harbours many motor vehicles washing bays along its entire stretch, which impact its biodiversity conservation status. The wetland system is a buffer for the effects of industrial effluents from the Namanve industrial park and other anthropogenic activities like crop cultivation, bricklaying, sand mining, and car washing bays. Accordingly, the wetland area continues to shrink and become stressed due to pollution levels exceeding its absorption capacity (NEMA, 2010). Given the hydrological connectivity of the Nakiyanja wetland system to Lake Kyoga, the above anthropogenic activities are likely to affect many more wetlands within the basin. It is estimated that eutrophication, the growth of algal blooms and hyacinths in Lake Kyoga, will continue to thrive.

The urgency for the current research on the restoration capacity of River Nakiyanja wetland system was driven by the significant role the wetland plays in water quality management amidst the increasing threats that have been imposed on riverine wetland ecosystems resulting from establishment of a large number of car washing bays. According to Sileshi et al., (2020), wetlands act as natural filters, removing pollutants and excess nutrients, which is crucial for maintaining healthy aquatic ecosystems and human health. In doing so, the ecosystem health of the wetland system is restored. According to Alex & Anton (2017) communities around the shores of riverine wetlands have been required to re-plant swamp vegetation for ecological restoration purpose. Nonetheless, no research indicates how much of the ecosystem can be recovered or restored by the wetlands that they encouraging communities to restore or re-plant. Therefore, research was needed to check how much restoration or recovery capacity a riverine wetland system like that of Nakiyanja can have for effective wetland conservation.

Whereas a host of literature exists on the impact of car washing activities on stream water quality, none provides a comprehensive understanding of how the natural purification process of these effluents goes on from the access point into the water body (point source) at the washing bay to the neighbouring wetland systems along the same waterway. Previous studies (Danha *et al.*, 2014; Buss *et al*., 2015; Antoinette, 2020) mainly give a snapshot of the water quality parameters while ignoring other entities of ecosystems, such as macroinvertebrates and fish that have fared against the same effects. The study, therefore, examined the effects of motor vehicle washing on water quality and aquatic macroinvertebrates as indicators of ecological health and the capacity of the Nakiyanja wetland system to ameliorate such effects, thus restoring the system. Because the physicochemical water quality indicators reflect conditions only for that period of sampling, macroinvertebrates were used to assess the ecological trend in the stream since they have been proven the best indicators of the quality of aquatic environments, and habitats and they integrate physicochemical and biotic conditions of lotic systems (Buss, *et al*., 2015).

The purpose of this study therefore was to measure or quantify the amount of ecosystem health restoration capacity that a riverine wetland system can provide even when the river flowing through it has been subjected to the intensity of degradation specifically from commercial motor vehicle washing bays on the River Nakiyanja wetland system. This knowledge will be important in showing the urgency of the wetland conservation of River Nakiyanja wetland system.

RESEARCH METHODS

Study area

River Nakiyanja and the Nakiyanja wetland are located in Mukono district, central Uganda, as part of the Lake Victoria and Kyoga Basin wetland system. It is situated between latitudes 0.39221 - 0° 23' 31" N and longitudes 32.67506 - 32° 40' 30" E (Figure 1). The Nakiyanja stream flows from Namilyango in Mukono and serves as the main water source for the Nakiyanja swamp. The River winds through the dambo wetlands, interrupted by crop farms, clay mining activities, settlements, and industrial establishments before emptying its water into L. Kyoga in Kayunga District. The area experiences a tropical climate characterized by rainfall totals ranging from 1310 to 1530 mm p.a., and temperatures between 21 and 24.5 ^{0}C (NEMA, 2010). The stream is criss-crossed by several roads, including major highways like the Kampala to Jinja Highway, in addition to many other urban roads. It is also located a few meters away from the Namugongo martyrs' shrine, a major historical site attracting multitudes of both local and foreign tourists. This implies heavy traffic and increased demand for car washing services. Based on the location of washing bays along the River Nakiyanja wetland system, we purposively sampled 2 study sites. We selected the washing bay at Kiwanga village or site one (upper stage of the river), in the Mukono district, located at latitude 0°22'13.17"N and longitude 32°42'7.26" E (Figure 1). The selection of the two sites was because these were the sites that are most busy and were easy to access. The remaining four sites were used for 2 to 4 motor vehicles per week and so the effect of the washing bay would not easily be felt. On the other hand, the ones that were selected were as busy as indicated in Table1. Several dense emergent aquatic macrophytes made up of wild weeds and trees characterize the study site, e.g., the *Psidiumguajava,* and sand, shingle, and claystone are the dominant streambed material. The speed of 0.4±0.2 m/s, average wet depth of 80.0±10.3 cm, wet width of 6.7±0.2 m, and discharge of 2.12 m^3/s. The study site stretches 1.3 km long. We selected the second site along the Namugongo – Sonde road in Wakiso district/site two (middle stage of the river) at latitude 0°23'52.57"N and longitude 32°40'17.36"E. Here, the stream is characterized by a rough streambed dominated by a mixture of cobble, pebbles, boulders, and mud. Papyrus grass and palm tree vegetation are the dominant vegetation in the wetland. The water speed is 0.4±0.1 m/s, average wet depth of 109.0±18.2 cm, wet width 6.1±0.8 m, and discharge of 2.7 m^3/s. This second site covered a stretch of 2.3 km.

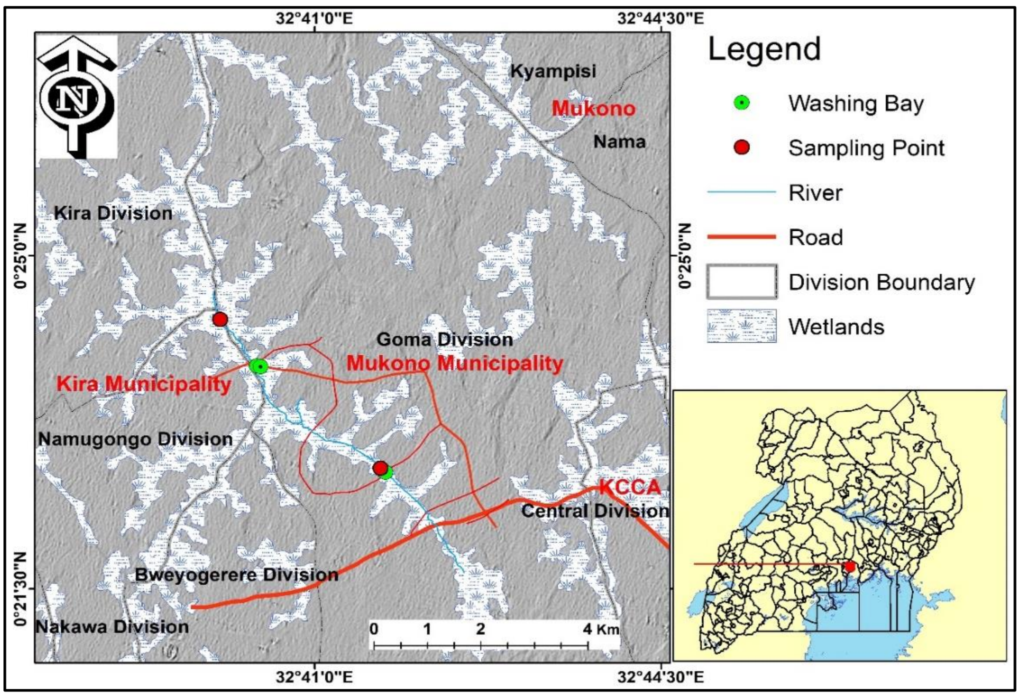

Figure 1: The Nakiyanja River and Its wetlands (The Study area).

Data collection

The sampling was undertaken in 4 phases, covering the time from June to December 2021. Table 1 illustrates the sizes of the washing bays according to the weekly total of vehicles washed and the water consumption, some of which returns into the channel stream.

Table1. Size of the washing bays based on the number of vehicles washed and water consumption

Type of vehicle	Site one		Site two	
	Number per week	water used (Litres)	Number of cars per week	water used (Litres)
Motorcycles	56±4.2	89±3.1	126±9.1	105±5.3
Sedan cars	107±6.5	197±1.2	297±3.2	360±10.2
Trucks	27±2.9	77±2.1	79±1.2	182±6.2
Mini-Vans	19±2.0	96±1.6	181±2.2	220±7.3
Heavy trucks	0±0	0±0	91±2.1	190±2.7

Effluents from the two sites are discharged into the water stream without any form of treatment.

Macroinvertebrate sampling and processing

For macroinvertebrates analysis, sampling was done at 50 meters upstream, within, and at 50 meters away from the washing bay to illustrate the effect of the washing bay on ecosystem integrity and the ecosystem restoration capacity of the wetland (Figure 2). Macroinvertebrate sampling was conducted at the two sites using the ‘kick net sampling’ method, with a standard collection net of 1000 µm mesh size (Dickens & Graham, 2002) in triplicate, with emphasis on runs, riffles, pools, and riparian vegetation. Macroinvertebrate sampling was done for a standard time of 3 minutes by disturbing $1m^2$ areas for each microhabitat. Samples were sorted live on a white sorting tray before inserting them into sample bottles and preserved with 70% ethanol.

The samples were then pooled together to make one sample for a station, which was later taken to Kyambogo University Biology laboratory for further processing. While in the laboratory, samples were identified up to the family level following the procedures by Dickens and Graham (2002). Each macroinvertebrate family was assigned a tolerance score called the South African Score System version 5 (SASS5) score, indicating its tolerance towards pollution. The scores ranged from one (high tolerance, low sensitivity) to 15 (low tolerance, highly sensitive). Per site, the SASS scores of all present taxa were summed up and divided by the number of taxa obtained on the site. This gave the average score per taxon (ASPT) and represented the average tolerance of the biological community at each site. Due to a lack of a nationally specific tuning to reference conditions, default quality classes adopted from Rossouw (2004) were assigned to values of the ASPT as: ASPT <5 = poor quality health, 5-6 = moderate health, and 7^+ = natural or good quality.

To measure the ecological restoration capacity of the wetland system, we based on macroinvertebrate assemblage metrics on each site. This was done by looking at the assemblage at the start of a washing bay, inside the washing bay, and then at the end of a washing bay. This was to determine how much effect the washing bay had on the ecosystem's health. Then we allowed water to flow for 50 m downstream through the wetland system. At this point (50m), we also measured the macroinvertebrate assemblage metrics. After this, we measured the wetland system restoration capacity by subtracting the assemblage metrics at the 50m downstream from those at the end of the washing bay. We later subjected this to percentages for easy interpretation, which therefore gave the percentage restoration capacity of the wetland system of Nakiyanja (Table 1).

A parametric (ANOVA) statistical test was used to study the variances in physicochemical water quality and ecological status (represented by the average number of individuals, SASS scores, and ASPT) at the two sampling sites. The Shapiro-Wilk normality test was applied before comparing ecological health and physicochemical water quality variables. The data was found to satisfy the normality test, and the one-way ANOVA was done to evaluate the variations between the means of dependent variables from the two sites. A Turkey’s Honestly Significant Difference (HSD) post hoc test was done for those models that exhibited significant differences under ANOVA. The procedure was implemented using the STATA software version 14.01.

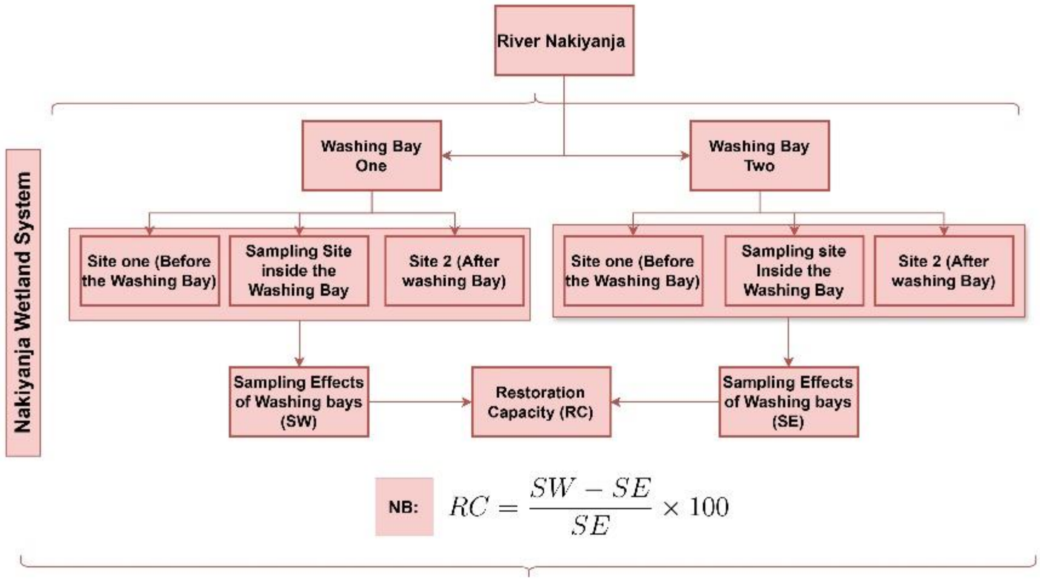

Figure 2: Schematic flow of the Research Procedure

RESULTS AND DISCUSSION

Impact of car washing activity on the ecological status and ecological restoration capacity of the Nakiyanja wetland system

Results of the ecological restoration capacity of the wetland system were based on macroinvertebrate assemblage, which was expressed in terms of ecosystem health status at the two sites. In this study, ecological health and ecosystem health were used synonymously to mean the same thing. In the same vein, the percentage restoration indicated in Table 2 was the restoration capacity of the wetland system.

Table 2. Macroinvertebrate families, sensitivity to pollution, and number of individuals harvested per site

Macroinvertebrate family	Sensitivity to pollution	Number of individuals at site one	Number of individuals at site two
Hydropsychidae	T	14	48
Hydrophilidae	M	80	4
Heptageniid	S	55	7
Trycorithidae	M	10	-
Chironomidae	T	216	63
Simulidae	M	105	-
Aeshnidae	M	10	6
Oligochaeta	T	35	-
Leeches	T	11	13
Calopterigydae	S	2	5
Ephemerelidae	S	2	3
Glossossomatidae	S	4	-
Libellulidae		-	12
Total = 13 Families		**570**	**161 3T, 2M, 3S**
	4S,4T, 3M		

T= Tolerant families, M= moderately sensitive families, S= sensitive families

Results of ecosystem health status can be obtained from the harvested macroinvertebrates based on their numbers and sensitivity to pollution. The metrics of these macroinvertebrates were then used to explain the ecosystem health status of the wetland. The results of macroinvertebrate distribution per site and their respective sensitivity to pollution were summarized in Table 2 before analysis in Table 3. From Table 2, 831 macroinvertebrate individuals from the two study sites belonging to 13 families were harvested. Four of these taxa were sensitive to pollution, 4 were moderately sensitive, and 4 were tolerant to pollution. Site one at Kiwanga was associated with more taxa (11), of which 4 were sensitive,3 were moderately sensitive, and 4 were tolerant to pollution, compared to the site two at Namugongo, which had only 8 taxa, 3 of which were tolerant, 2 were moderately tolerant, and 3 were sensitive to pollution.

Table 3. Macroinvertebrate Assemblage And Indicative Ecosystem Health Status Values (Mean ± Standard Deviation) For The Two Sites And The Ecosystem Health Restoration Capacity Of Nakiyanja Wetland

Sampling points at washing bay sites	No. of sensitive Families	No. of moderately sensitive Families	No. of tolerant Families	No. of Families	No. of individuals	Total SASS	Total ASPT	Ecosystem Health Status	Av. Ecosystem Health
KIWANGA SITE									
Before	4±0.1a	2±1a	0±0a	6±1a	170±3.5a	37±11a	6.2±5a	Good	**6 (Good)**
Inside	0±0b	1±0.1b	4±1b	5±0.6b	97±2.9b	44±1.7c	4.3±1.1b	Poor	
End	0±0b	2±0.5c	3±0.4c	5±0.1b	103±10c	26±7b	5.2±1c	Fair	
Range	-4	-1	4	-1	-73		1.9		
%age effect	100	50	100	17	43	19	31		
50-metres downstream	2±0.1a	2±1.1c	2±0.3b	6±1.4c	200±16.9c	50±8.2b	8.3±1.4a	Natural	
Restoration effect	+2	+1	-1	+1	+103	+24	+4		
% restoration	50	50	33	20	106	92	93		
NAMUGONGO SITE									
Before	3±0.2a	2±1a	1±0.1b	6±1a	61±4.6a	49±2.9a	8.2±1.1a	Natural	**6.2 (Good)**
Inside	0±0b	1±0.2c	5±0.6a	6±2.1a	31±1.2b	28±3c	4.7±0.3b	Poor	
End	1±0.3c	1±0.1c	2±0.3c	4±0.2c	20±2.4c	13±1.2b	4.3±0.2b	Poor	
Range	-2	-1	4	-3	-41	-36	-3.9		
% effect	100	50	400	50	67	74	48		
50-metres downstream	3±0.1a	1±0a	0±0c	4±0.1c	49±2.5c	30±0.2b	7.5±0.4c	Natural	
Restoration effect	+2	+1	-5	00	+29	+17	+3.2		
% restoration	75	100	100	00	145	131	74		

Mean values for a, b, c and d in each column show significant differences based on the One-Way ANOVA at p≤ 0.05.

The car washing activities at the Kiwanga sampling site led to the complete extinction of pollution-sensitive taxa. The four sensitive families found at the point upstream of the washing bay did not continue to survive at the sampling point downstream of the washing bay. 50 metres downstream, however, the wetland restored half of the previous pollution-sensitive taxa. At the site two (Namugongo), all three pollution-sensitive taxa were eliminated from the middle of the washing bay, but the wetland restored 75% of the taxa.

At both the Kiwanga and Namugongo sites, the washing bays reduced the number of moderate taxa by 50%, but the wetland restored half of the lost taxa. On the other hand, the washing bay activities increased the number of pollution-tolerant species by 4±1 at site one and by 5±0.6 at site two. The results reveal that the wetland at site one (Kiwanga) reduced these tolerant taxa by 50%, while that at the Namugongo site was able to eliminate 100% of the tolerant taxa from the stream system.

The total number of families and individuals at the Kiwanga site was reduced by 17% and 43%, respectively, resulting from motor vehicle washing activities. At 50 meters downstream of the washing bay, the wetland was, however, able to restore 20% and 106% of the total number of taxa and individuals, respectively. At the downstream site at Namugongo, the total number of families and individuals reduced by 2 and 41, respectively, because of washing bay activities. The wetland 50 meters downstream of the site restored only 29 individuals, but maintained the number of taxa as in the washing bay.

Automobile washing at the Kiwanga site dropped the total SASS score and respective ASPT from a good ecosystem health status of Good to Poor. However, at 50 meters downstream of the washing bay, the wetland managed to recover over 90% of the ecosystem health status, thereby restoring the ecosystem to a state near its natural state. This restoration capacity covered up the specific aspects of ecosystem degradation to make the washing bay generally associated with a good ecosystem health status. At the Namugongo site, the total SASS score and resultant ASPT dropped from a Natural ecosystem health status to poor. The wetland managed to restore the ecosystem health by 74% from poor at the washing bay site back to Natural. This overshadowed the effect of the washing bay to generally exhibit a good ecosystem health status (Table 3).

Discussion

At the Kiwanga sampling site, the wetland restored half of the previous pollution-sensitive taxa. While at the Namugongo site, the wetland restored 75% of the pollution sensitive taxa that had been lost to the washing bay activities. This does not differ from Laura et al's (2014) assertion that; Constructed wetlands in Parco Pineta (Northern Italy) became valuable ecological elements in the area due to fast colonizing invertebrates which were pollution sensitive. This colonisation was due to supportive environment for the type of taxa created by wetlands in the current study just like the study in Italy noted in this paragraph.

At both the Kiwanga and Namugongo sites, the washing bays reduced the number of moderate taxa by 50%, but the wetland restored half of the lost taxa. This is in agreement with anna &Vanessa (2022), who observed that, Wetlands serve as critical habitats and nutrient sinks, indirectly benefiting moderately sensitive macroinvertebrate taxa in rivers through habitat provision, flood attenuation, and nutrient cycling. These benefits help maintain stable water quality and favorable conditions for these organisms, including those that may be more vulnerable to changes in water quality or flow.

The findings revealed that the wetland at the Kiwanga site was able to reduce the tolerant taxa by 50%, while that at the Namugongo site was able to eliminate 100% of the tolerant taxa from the stream system. The differences in this elimination rate can be attributed to the differences in the riparian vegetation, with differences in filtration capacities that created different qualities of physical habitats. In addition, the wetland at the Namugongo site is denser and more to the waterway than that at the Kiwanga site. This does not differ from the Danha et al. (2014) finding that upstream sites that had denser riparian vegetation showed a good proportion of macroinvertebrates sensitive to pollution, hence better ecosystem health than downstream the washing bay with scant vegetation and less sensitive taxa.

In terms of total number of individuals,at the Namugongo site, the wetland restored only 29 individuals, but maintained the number of taxa as in the washing bay. This reasonates with Anna &Vannesa (2022) who observed that, Wetlands play a significant role in influencing river macroinvertebrate numbers by providing crucial habitats and food sources. They act as nurseries for many species, increase habitat diversity, and contribute to nutrient cycling, all of which support larger and more diverse macroinvertebrate communities in rivers.

In terms of general health, at the Kiwanga site the wetland managed to recover over 90% of the ecosystem health status, thereby restoring the ecosystem to a state near its natural state.in the same way, at Namugongo site, the wetland managed to restore the ecosystem health by 74% from poor at the washing bay site back to Natural. This overshadowed the effect of the washing bay to generally exhibit a good ecosystem health status (Table 3). The improvement/restoration in the ecological health status is attributed to increased filtration of water by the riparian wetland vegetation, which not only improved water quality but also improved physical microhabitats for the macroinvertebrates. Memory et al. (2016) observed that pollutant removal from washing bay sites by any means, more so pre-treatment of wastewater ahead of disposal into streams, had the potential to improve the water quality and respective aquatic habitats for living organisms.

CONCLUSION

Based on evidence from the impact sites directly affected by the effluent discharge, the ecology of the Nakiyanja wetland has been degraded. Findings showed that the effluent discharge into the Nakiyanja stream has changed the water chemistry, reduced the ecological diversity, and affected macroinvertebrate assemblages. As the total number of motor vehicles in metropolitan Kampala increases, the extent of washing bay effluent discharge is expected to rise further. However, the wetland has attempted to restore a significant percentage of the ecosystem health that had been lost to car washing activities.

To be specific, the wetland system of Nakiyanja has an ecological capacity of restoring more than 50% of the ecological health of the river that had been lost to commercial moto vehicle washing bay. This it does by acting as nurseries for many species, increase habitat diversity, and contribute to nutrient cycling, all of which support larger and more diverse macroinvertebrate communities in rivers

We recommend that NEMA undertake to update regulations and operational requirements for washing bays along the water systems and sensitize the concerned masses to the harmful effects of effluents from the washing bays into the ecosystem. Washing bay managers ought to develop all possible strategies to have the washing bay effluent treatment plants before the effluent is discharged into the stream system. Washing bays should also be located at least 10 meters away from the river or recipient wetlands, as this will reduce the pollutant concentrations directly entering the stream rather than pushing whole cars into the stream for washing.

ACKNOWLEDGMENT

Special gratitude is extended to the Department of Biology at Kyambogo University for providing laboratory space, equipment, and expertise in water quality analysis and macroinvertebrate sampling, and identification. Grateful to Busitema University's small grants section for funding this project.

REFERENCES

Antoinette (2020). An assessment of water quality, soil degradation, and water purification ability of Khubelu Wetland in Mokhotlong, Lesotho, and the implications of climate change, a PhD thesis, University of South Africa.

Alex Barakagira and Anton De Wit (2017). Community livelihood activities as key determinants for community based conservation of wetlands in Uganda. Environmental & Socio-economic Studies 5(1) DOI: 10.1515/environ-2017-0002.

APHA, American Public Health Association (1998). *American Water Works Association, Water Environment Federation*, L. S. Clesceri, A. E. Greenberg and A. D. Eaton, Eds., Standard Methods for the Examination of Water and Wastewater,20th ed., Washington, D.C.

Anna Elisa Piña &Vanessa L Lougheed (2022). Macroinvertebrate Community Composition in Wetlands of the Desert Southwest is Driven by Wastewater-associated Nutrient Loading Despite Differences in Salinity. Wetlands (Wilmington). 2022 Dec 13;42(8):128. doi: 10.1007/s13157-022-01647-2.

Arimoro, F. O., Odume, O. N., Uhunoma, S. I., &Edegbene, A. O. (2015). Anthropogenic impact on water chemistry and benthic macroinvertebrate-associated changes in a southern Nigerian stream. *Environmental Monitoring and Assessment*, 187(2), 14.

Buss, D.F., Carlisle, D.M., Chon, T.S., Culp, J., Harding, J.S., Keizer-Vlek, H.E., Robinson, W.A., Strachan, S., Thirion, C., and Hughes, R.M. (2015). Stream biomonitoring using macroinvertebrates around the globe: a comparison of large-scale programs. *Environmental Monitoring and Assessment*, 2015, 187(1), 4132. http://dx.doi.org/10.1007/s10661-014-4132-8.

Danha C, Utete B, Soropa G, Rufasha SB (2014) Potential impact of washing bay effluent on the water quality of a subtropical river. *J Water ResourProt* 6:1045–1050

Dickens, C.W. and Graham, P.M. (2002).The South African Scoring System (SASS) Version 5: rapid bioassessment method for rivers. *African Journal of Aquatic Science*, 2002, 27(1), 1-10. http://dx.doi.org/10.2989/16085914. 2002.9626569.

Diphare MJ, Pilusa J, Muzenda E, Mollagee M (2013). A review of waste lubricating grease management. 2nd *International Conference on Environment, Agriculture and Food Sciences* (ICEAFS’2013) August 25–26, 2013 Kuala Lumpur (Malaysia)Gore, 1996).

Harding, J. S. (2005). Impacts of metals and mining on stream communities. In T. A. Moore, A. Black, J. A. Centeno, J. S. Harding, & D. A. Trumm (Eds.), *Metal contaminants in New Zealand* (pp. 343–357) Christchurch, NZ: Resolutionz Press.

InyinborAdejumoke A., AdebesinBabatunde O., OluyoriAbimbola P., Adelani-Akande Tabitha A., Dada Adewumi O., and OreofeToyin A. 2018. *Water Pollution*: Effects, Prevention, and Climatic Impact. http://dx.doi.org/10.5772/intechopen.7.

Laura. S,Sergio.C, Riccardo.C, Riccardo. F, and Valeria M (2014). Macroinvertebrate assemblages and biodiversity levels: ecological role of constructed wetlands and artificial ponds in a natural park. Journal of Limnology Vol. 74 No. 2 (2015) https://doi.org/10.4081/jlimnol.2014.1018

Memory Tekere, Timothy Sibanda, and Khumbudzo Walter Maphangwa (2016). An assessment of the physicochemical properties and toxicity potential of carwash effluents from professional carwash outlets in Gauteng Province, South Africa. *Environ SciPollution Res*. DOI 10.1007/s11356-016-6370-5.

Moores J, Pattinson P, Hyde C (2010) Enhancing the control of contaminants from New Zealand's roads: results of a road runoff sampling programme. *New Zealand Transport Agency research report* 395, pp 161.

NEMA (2010). *The state of environment report for Uganda*, NEMA Kampala, Uganda.

Popa C, Petrus M. 2017. Heavy metals' impact on plants using photo-acoustic spectroscopy technology with a tuneable CO2 laser in the quantification of gaseous molecules. *Microchemical Journal*. 2017; 134:390-399.

Prasanya.J, S. Kanmani; P. Senthil Kumar (2024). A review of the wetland's restoration mechanisms and its economic and social benefits. Water Practice and Technology (2024) 19 (11): 4355–4377. https://doi.org/10.2166/wpt.2024.241.

Reeta Rai, Subodh Sharma, and D.B. Gurung, Bishal K. Sitaula& Ram Devi Tachamo Shah (2020): Assessing the impacts of vehicle wash wastewater on surface water quality through physico-chemical and benthic macroinvertebrates analyses, *Water Science*, DOI: 10.1080/11104929.2020.1731136.

Turyahabwe Remigio, Muhamud Wambedde Nabalegwa, Joyfred Asaba, and Andrew Mulabbi (2022). Influence of In-stream Ecosystem Restoration Techniques on the Fish Ecology of the River Nabongo in Eastern Uganda. Jurnal Perikanan Universitas Gadjah Mada, Volume 24 Issue 2Pages 173-184.

Rossouw, J.N. (2004). *Water quality in the ecological reserve for river ecosystems*. Proc. Water Institute of Southern Africa (WISA) Biennial Conference, 2-6 May 2004, Cape Town, South Africa.

Sablayrolles C, Vialle C, Vignoles C, Montrejaud-Vignoles M (2010). Impact of carwash discharge on stormwater quality (Toulouse, France). *Water SciTechnol* 62:2737–2746. doi:10.2166/wst.2010.92.

Sileshi A, Awoke A, Beyene A, Stiers I and Triest L (2020) Water Purifying Capacity of Natural Riverine Wetlands in Relation to Their Ecological Quality. Front. Environ. Sci. 8:39. https://doi.org/10.3389/fenvs.2020.00039.

Turyahabwe. R., Mulabbi. A., AsabaJ., Olowo M (2021). Ecological responses of macroinvertebrates to an in-stream ecosystem restoration technique in a tropical Stream in Eastern Uganda. *East African Journal of Environment and Natural Resources*https://doi.org/10.37284/2707-4242.