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Assessment of environmental impacts of vehicle wash centres at Olakha, Thimphu Bhutan

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Abstract

Vehicle washing consumes lot of freshwater and generates potentially toxic wastewater. This study comprising of a survey and physico-chemical analysis were carried out in commercial vehicle wash centres located at Olakha, Thimphu. Survey questionnaire focused on current washing practices and management of wastewater. Physico-chemical compositions of vehicle wash wastewater and potential ramifications of this wastewater on receiving stream Olarong Chhu were investigated. Vehicle wash wastewater from influent and effluent of Effluent Treatment Plant (ETP) and water samples of Olarong Chhu were collected on monthly basis and analysed for pH, temperature (T), electrical conductivity (EC), turbidity, total suspended solids (TSS), total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD_5), chemical oxygen demand (COD), oil and grease, total nitrogen (TN), total phosphorous (TP), alkalinity, and Heavy metals (As, Cd, Cr, Cu, Cu, Fe, Mn, and Zn). Findings showed that vehicle wash centres are operated with poor environmental ethics despite of restrictive laws and regulations. In effluent pH(8.45), TSS(364.29mg/l), TDS(204.45)mg/l), oil and grease(154.57mg/l), Cu(0.11mg/l), Fe(15.06mg/l) and Mn(0.73 mg/l) were not within the permissible limits of Environmental Standards[ES] (2010) of Bhutan. Physico-chemical analysis of Olarong Chhu depicts degradation in water quality especially at wastewater discharging zone. However analytical results and statistical testing revealed that existing ETP is efficient in reducing the contaminants levels of TSS, BOD_5, COD, oil and grease, Fe and Mn. These findings are excellent baseline database for the policy makers as provisions pertaining to management of wastewater are not implemented properly in Bhutan. Other recommendations include compliance with guidelines for establishment of vehicle wash centres, establishment of ETPs, physico-chemical analyses of wastewater prior to discharge and environmental safety education for the wash centres' operators.

Keywords: Bhutan, vehicle wash centres, vehicle wash wastewater, physico-chemical parameters, wastewater management.

Introduction

Wastewater generation and its poor management practice is one of the biggest challenges associated with increasing economic activities, urbanisations, and populations in developing countries. Though the composition of wastewater varies depending on the sources, disposal of untreated wastewater into the environment degrades surface and groundwater water quality which pose threat to human health and wellbeing, as well as to ecosystems. Poor management of wastewater would lead to negative impact of ecosystem services on human and other beneficiaries like animals[1]. As per the global statistics of wastewater generation and treatment, over 80% of global wastewater is released back to the environment without adequate treatment[2,3] and in Asia-Pacific countries 80–90% is released untreated bringing about more pollution in the vicinities of their immediate discharge points[4]. Sato et al.[5] reports that in low-income countries, only 8% of industrial and municipal wastewater are treated before its disposal to the environment. Such trend is prevalent in developing countries due to lack of appropriate legislations, limited technical and financial resources for managing wastewater[6].

Bhutan, where places were connected only by footpaths and mule tracks until 1961, today has 86,304 vehicles[7]. Road construction received paramount importance to ease transportation and elevate economic activities in the country with the launching of first five-year plan in 1961. Thus vehicles gained entrance into this tiny Himalayan Kingdom with the construction of first highway from Phuentsholing (neighbouring town to India) to Thimphu in 1962. Over the years, economic activities gained momentum, the road networks expanded into other highways, feeder and farm roads and the vehicle numbers escalated. Transforming economy with roads and vehicles required vehicle wash centres in various parts of the country to maintain an aesthetic appeal and lifespan of the vehicles.

In Bhutan, vehicle wash centres are usually constructed along the rivers for drawing water as well as discharging wastewater into the same river[8]. Vehicle washing is a potential source of pollution either as a surface runoff or inappropriate discharge but vehicle wash centres in Bhutan discharge their wastewater either on the open ground or into the surface water bodies without any conventional treatment. Vehicle washing involves the use of chemicals and large amount of water thereby generating potentially toxic wastewater[9] that can damage environment and pollute rivers, streams, and groundwater[10]. Vehicle wash wastewater contains pollutants such as petroleum hydrocarbon wastes (petrol, diesel, and motor oil), nutrients (phosphorous and nitrogen), surfactants, mud, sand, asphalt, salts, organic matter and so on[11-13].

Thimphu is the capital city of Bhutan, with 44621 vehicles[7], and 35 vehicle wash centres[8]. ETP at Olakha automobile workshops area, Thimphu meant for segregating an oil and grease and sludge remains dysfunctional most of the time[14] forcing the release of raw vehicle wash wastewater directly into the stream Olarong Chhu. Though many issues of Bhutan's national newspaper *Kuensel*[14-16], has reported ongoing pollution in Olarong Chhu due to discharge of untreated vehicle wash wastewater no attempt has been made to study this issue. Therefore, there is a pressing need for comprehensive study of vehicle washing activities taking place at Olakha and assess ongoing pollution at Olarong Chhu. The main objectives of this study were to study the vehicle washing practices and management of wastewater in these wash centres, determine the level of contaminants in wastewater and assess ongoing pollution in Olarong Chhu. It is expected that the findings would be an excellent baseline database for the policy makers as provisions pertaining to management of wastewater are not implemented properly in Bhutan.

Materials and methods

Study area: Olakha, a part of Thimphu City (27°27′57″ N: 89°38′30″ E) is located towards the south of the city (Figure-1). In 2008, the government took a decision to shift automobile workshops catering to washing and mechanical services from Chamgamtog to Olakha with an aim of managing wastewater in an environmental friendly manner without contaminating the nearby stream Olarong Chhu[17]. Olakha automobile workshops area harbours around 67 private automobile workshops (wash and mechanical service centres) spread on about 13 acres of land[18]. The Olarong Chhu is a tributary of the Wang Chhu, one of the major river systems of Bhutan. The population in Thimphu has undergone substantial growth to 128,195 in recent years[19], resulting in an increase of vehicles washings in Olakha wash centres and amount of wastewater produced.

Research strategy: Data were collected through survey questionnaire, direct observations of vehicle washing activities, and physico-chemical analyses of wastewater and stream water. A total of 15 respondents from 15 vehicle wash centres were randomly selected for this survey to collect information on washing processes, number of vehicles washed per week, chemical and water usages, management of wastewater and their knowledge on policies governing management of wastewater. Physico-chemical analyses of vehicle wash wastewater and water from Olarong Chhu were conducted monthly from November, 2015 to November, 2016 as described below.

Analytical methods: Vehicle wash wastewaters from influent to ETP, its effluent and water samples of Olarong Chhu from upstream, impact zone and downstream (Figure-1) were collected on monthly basis and analysed for physico-chemical parameters like pH, T, EC, Turbidity, TSS, TDS, DO, BOD_5, COD, oil and grease, TN, TP, alkalinity, sulphate and heavy metals (As, Cd, Cr, Cu, Cu, Fe, Mn, and Zn). Time composite samplings[20,21] were used in view of variations in number of vehicles washed and resultant volume and composition of wastewater. Once in a month, 1 litre of wastewater was collected every 15 minutes and composited in a plastic bucket for a period of 2 hours from all the sampling points when wash centres were in operation.

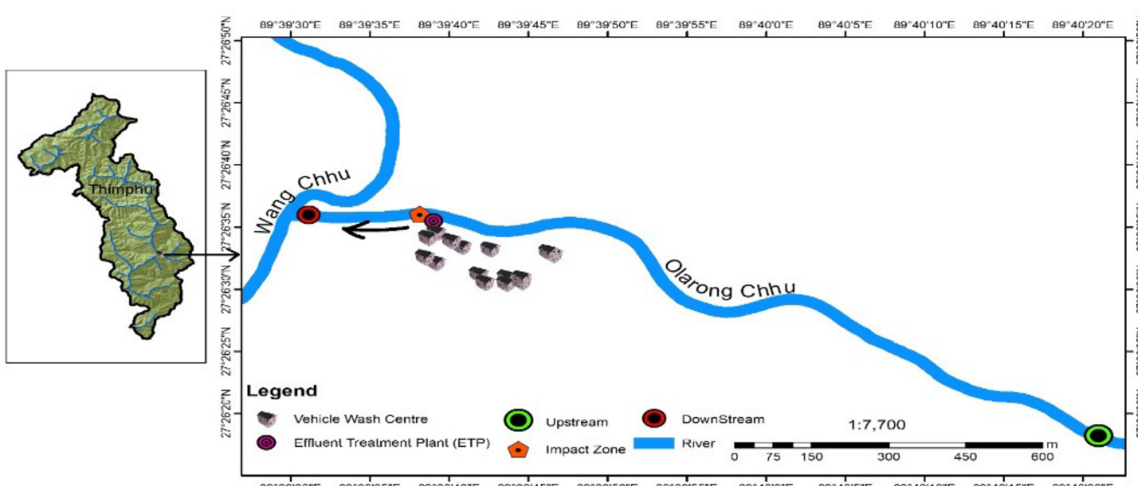

Figure-1: Map showing the study area and sampling stations at Olakha, Thimphu.

Composited samples were segregated into different sample bottles and transported to laboratories according to preservation and transportation protocols outlined in APHA[20]. Separate grab samples of wastewater and stream water were also taken in pre-acidified (HCl) wide mouthed glass bottles for analysis of oil and grease[20]. Physical parameters (T, pH, DO, and EC) were measured in situ using HACH portable multi-parameter probe (HQ40d). Turbidity and TDS were measured with turbidimeter (HACH 2100Q) and TDS meter (WQTL01510). TSS, heavy metals, oil and grease, alkalinity, TP, TN, BOD_5, COD and sulphate were analysed following the standard procedures outlined in APHA[20]. TSS was analysed gravimetrically using pre-dried Whatman 4 GF/C filter paper. Heavy metals were determined in Atomic Absorption Spectrophotometer (AAS). Oil and grease were determined gravimetrically after extracting with Hexane. Alkalinity was determined titrimetrically with 0.02N sulphuric acid using mixed indicator (Bromocresol Green and Methyl Red). TN was measured by Kjeldahl digestion and TP by potassium persulphate digestion followed by spectrophotometer reading. Iodometric Winkler's method was used to determine BOD_5 (mg/l) and COD was determined by Open reflux method. Concentration of sulphate was determined in Spectrophotometer (DR5000) after reacting samples with SulfaVer 4 Reagent Powder Pillow.

Statistical analysis: Open ended responses of survey questionnaires were analysed thematically and close ended in Microsoft office excel 2010. Statistical analyses were done using SPSS software (Version 20) and Minitab 17. The results of physicochemical analyses of vehicle wash wastewater were compared with ES[22] of Bhutan. Two sample t-test was done to find out the significant differences between physico-chemical parameters of influents and effluents. One-way analysis of variance (ANOVA) was used to examine significant spatial differences in upstream, impact zone and downstream of Olarong Chhu for all the physico-chemical parameters. Significant differences were tested at 95% confidence level.

Results and discussion

State of vehicle wash centres: As per the survey, there are 20 semi-automated and one automatic vehicle wash centres at Olakha. In an automatic wash centre, the driver drives the vehicle through an automated rinsing, washing, and drying processes while an interior is cleaned manually. Semi-automated included blowing away interior and exterior dusts with high pressured air, removal of foot mats, lifting of vehicle with hydraulic jack for underneath washing, bringing down of vehicle for initial high pressure rinsing of exterior body from a hose followed by shampooing with a sponge, final rinsing, and drying with a dry cloth. Common chemicals used during washing were shampoo, surf, and kerosene. 80% of respondents said kerosene is used as degreasing agent to remove traffic grimes and particulate matter from the vehicles on customers' demands only due to its high cost. Wax polishes are also used to polish the body of vehicles and interior desk board after washing the vehicles.

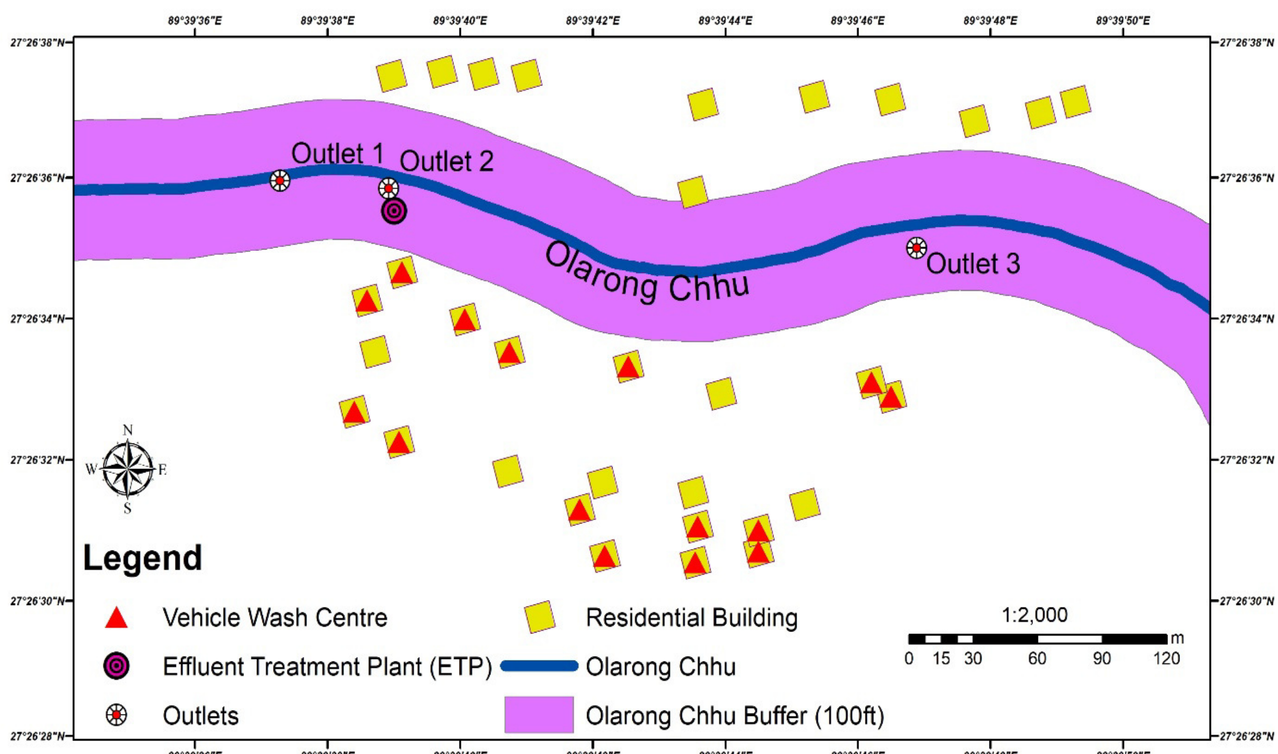

Figure-2: Map showing infrastructural details at Olakha automobile workshop area, Thimphu.

There are three wastewater outlets into the Olarong Chhu (Figure-2), from vehicle wash centres and only one passes through ETP installed in 2010. Zangmo[14] had reported occassional dysfunctionality of this plant likewise during the monthly data collection visits from November 2015 to Novemeber 2016 the plant was dysfunctional for 6 times. The channels to separating chambers were clogged with debris, plastic bottles and sludges. Only 34% of respondents had knowledge about this existing facility, 53% claimed that wastewater is directly discharged into the nearby stream while remaining 13% didn't know where the wastewaters really go. Owing to its underground network it wasnot possible to find out as which vehicle wash centers were actually channelling their wastewater into this plant.

Though automobile workshops were shifted from Changzamtok to Olakha in 2008 with an aim of addressing environmental concerns[17], environmental safety has not been considered except this small oil and grease separator that also remains dysfunctional most of the time.

As per the," Guidelines for Vehicle Wash Facility",[23] the vehicle wash centre should be at least 100 feet away from any water body and all the sampled vehicle wash centres fulfilled this requirement (Figure-2). Also, it must be located at least 50 feet away from any residential area, hospital, school and commercial area[23]. However, all the wash centres are located in close proximity to residences belonging to proprietors and employees (Figure-2).

In many cases wash facilities are stationed on the ground floor of the buildings. Only 5 wash centres cater to washing of vehicles solely while remaining 10 carry out both washing and mechanical servicing. When washing and servicing are carried out together there would be more pollution due to spillage of grease, spent oil, radiator fluid, battery fluids, engine oil, and coolant during servicing[23], which would be washed down the drain while washing vehicles.

Automobile workshop environment is also prone to hazards like fire, explosion and chronic chemical poisoning. Auto mechanics exposed to polycyclic aromatic hydrocarbons (PAH) formed by incomplete combustion of organic material are at risks of lung, urinary tract, brain and skin cancers[24]. Risks assessment of the health status of auto mechanics carried out by Khan et al.[25] in Pakistan has reported significant ill effect on liver and kidney functions. Similarly in South India, Philip et al.[26] has reported morbid conditions of an auto mechanics like reduced pulmonary functions and peripheral neuropathy significantly associated with exposure to heavy metals and petroleum products. Therefore health of people residing at Olakha automobile workshop area are at risks.

Vehicle wash counts and water consumption were monitored for one week in winter (December, January and February) and summer (June, July and August months). All the vehicle wash centres had maintained a register for recording the numbers and types of vehicles washed so it was easy to draw the statistics of numbers and types of vehicles washed. The average numbers of vehicles washed per week were 59 ±12 in winter and 75 ±11 in summer which signifies there is more washing in summer season.

The busiest day for all the centres was Saturday in winter as well as in summer. None of the centres had any record of water used during washing as 9 vehicle wash centres had free direct source of water from stream and remaining 6 depended on municipal supplied water which charges minimal fee on monthly basis. Therefore amount of water used was estimated through technical means[27]. A measuring cylinder of 1L was filled up with the same pressured washer nozzle used to spray water on vehicles and noted the time with a stopwatch for three consecutive times. Then time consumed for washing of three different types of vehicles (alto, hilux and coaster bus) were noted in three different wash centres and amount of water used were calculated (Table-1).

Thus, vehicle washing requires a higher amount of water compared to household uses and also it generates a significant volume of wastewater containing various pollutants. Respondents felt that since Bhutan is endowed with rich water resources reusing wastewater is not necessary but according to Bhatti et al.[28] and Lau et al.[29], reusing of vehicle wash water is important for protecting environment and effective utilisation of water resources. Netherlands and the Scandinavian countries actually restrict a maximal fresh water consumption of 60–70 l per car wash to minimise the wastewater[30].

Table-1: Water consumption during vehicle washing.

Type of vehicle	Time (min) required for filling up measuring cylinder of 1L. Mean±SD	Time(min) required for outer washing Mean±SD	Time(min) required for final rinsing Mean±SD	Total volume of water consumed (L) Mean±SD
Alto	0.18±0.01	7.63±0.78	3.85±0.34	61.6±3.84
Hilux	0.2±0.01	15.72±0.67	5.95±0.23	120.37±4.57
Coaster bus	0.17±.01	40.55±0.61	20.82±0.44	361.02±3.20

When inquired about respondent's awareness on environmental impacts of improper management of wastewater 40% respondents feel that vehicle wash wastewater mainly contains mud and sand and is not severely contaminated compared to other industrial wastewaters. This is, an undermining of an eco-toxicological potential of vehicle wash wastewater. Lau et al.[29] has also reported such perception of people in Malaysia. However any kind of wastewater poses a threat to the human and environment due to its harmful constituents. Health of some residents of Olakha automobile workshop area are at risks since they use the water from the Olarong Chhu for domestic purposes like washing and bathing. Remaining 60% feel that chemicals like oil, grease, and detergents will affect surface water quality and aquatic biota like fishes. It was also discovered that there are no advocacies or awareness programs on environmental impacts and management of wastewater by the regulatory authorities as only two respondents had attended such program long time back. Therefore, beside formulating environmental policies there should be an awareness programs on environmental issues for the benefits of common people and employees working in vehicle wash centres considering their educational status (Table-2).

Table-2: Educational status of employees at vehicle wash centres (n =187).

Qualification	Frequency (%)
Uneducated	27 %
Class PP-VI*	16 %
VII -X**	30 %
XI-XII***	25 %
Graduate	2 %

*Primary education from pre-primary to grade 6, **Middle secondary education from grade 7 to 10, and ***Higher secondary education from grade 11 to 12.

It was learnt that every year the wash centre's operators are required to renew their licence for which they have to comply with the guidelines stated in the license. Two clauses mention that, vehicle wash wastewater should be recycled/reused wherever feasible or properly treated prior to discharge into the water bodies. However all respondents said regulatory authorities just make sure that solid wastes are not littered in their surrounding and wastewater should be channelised into the drain. This depicts complacencies of the regulatory authorities also. All the respondents expressed that it would be very expensive for them to build their own ETP and if the government constructs for them they are ready to cooperate for its sustainability. With the present scenario of existing ETP that is mostly dysfunctional because of ignorance, stringent policies and compliance monitoring might help to manage the wastewater cooperatively.

Results of wastewater analysis: The results of wastewater analysis for both influent and effluent of ETP are presented below (Table-3) as means and compared with ES[22] of Bhutan. There are no specific standards for vehicle wash waste water in ES[22] of Bhutan and results have been compared with generic standards.

Physically, both influent and effluent samples were found to be very turbid, oily and greasy. In influent the mean values of pH(8.98), TSS(1568.86mg/l), TDS(202.17mg/l), oil and grease (1394.86mg/l), Cu(0.21mg/l), Fe(52.72mg/l), Mn(1.53mg/l), and in effluent TSS(364.29mg/l), TDS (204.45mg/l), oil and grease(154.57mg/l), Cu(0.11mgl), Fe(15.06mg/l), Mn(0.73mg/l) were not within the permissible limits of ES[22] of Bhutan. Studies elsewhere have also reported oils, greases, nutrients, suspended and dissolved solids, detergents and heavy metals in vehicle wash wastewater[28,29,31-33]. An average pH of various brands of shampoos (n=6) used for washing vehicle's body was 7.5 while an average pH of detergents (n=4) used for washing foot mats was 10.2. Therefore use of detergents must have increased the pH of wastewater.

Oil and grease in a vehicle wash wastewater can come from any of the petroleum products on the vehicle's surface or leakage of petroleum products and other lubricants from the vehicles[34]. Oil and grease film in water bodies block sunlight, impair photosynthesis, prevent oxygen replenishment of water bodies and develop growth of oil consuming microbes[35]. Since existing ETP was set up to remove oil and grease and sludge prior to discharge into the water bodies, the findings proved its efficiency in reducing the concentration of TSS by 77% and oil and grease by 89% (Figure-3). With regular maintenance it is still capable of performing adequate segregation.

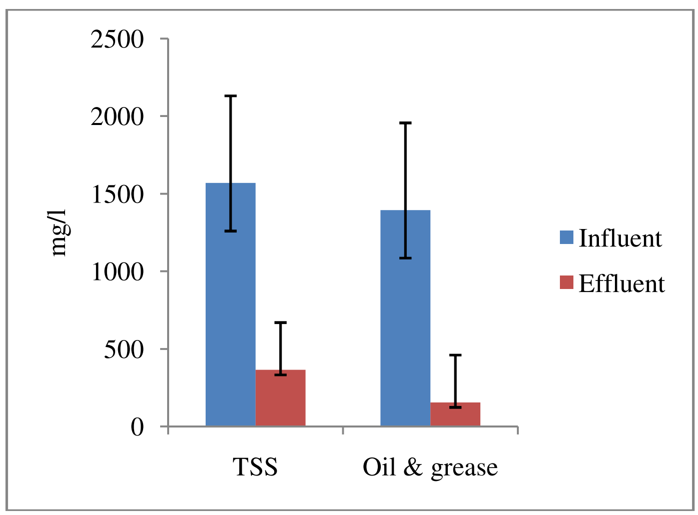

Figure-3: Separation efficiency of existing ETP.

A 2-sample t-test was also conducted to test the efficiency of existing ETP by comparing mean values of pollutants in influents and effluents. There was a significant differences in the scores for DO, TSS, BOD_5, COD, oil and grease and Fe (Table-4).

Table-3: Physico-chemical results of influent, effluent and comparison of effluent with ES.

Parameters	Units	Mean ± SD influent	Mean±SD effluent	ES(2010)	Remarks
T	^{0}C	16.31± 6.72	14.70 ±3.93	--	No standard
pH		8.98±0.95	8.45±1.00	6.50-8.50	Over in influent
EC	µs/cm	165.04 ±137.98	306.00±151.95	--	No standard
DO	mg/l	5.46± 0.92	6.59±0.58	--	No standard
TSS	mg/l	1568.86± 562	364.29±308.78	80	Over
TDS	mg/l	202.17± 30.51	204.45± 38.02	150	Over
Turbidity	NTU	87.11± 17.17	43.44±29.88	--	No standard
BOD_5	mg/l	19.36± 5.44	7.35±0.92	30	Within
COD	mg/l	72.59± 13.11	20.49±7.66	150	Within
TN	mg/l	2.90± 1.35	2.37±1.25	20	Within
TP	mg/l	2.30± 1.30	1.19±0.96	--	No standard
Oil and grease	mg/l	1394.86±307	154.57±30.28	5	Over
Total Alkalinity	ppm	160.86± 15.56	150.96±52.69	--	No standard
Sulphate	mg/l	97.14± 15.76	51.28±25.18	500	Within
Ar	mg/l	ND	ND	0.10	Within
Cd	mg/l	0.03 ± 0.02	ND	0.05	Within
Cr	mg/l	0.01 ± 0.01	ND	0.50	Within
Cu	mg/l	0.21± .0.10	0.11±0.17	0.10	Over
Fe	mg/l	52.72± 16.49	15.06±12.15	2	Over
Mn	mg/l	1.53± 0.59	0.73±0.97	0.50	Over
Pb	mg/l	0.04± 0.01	0.03±0.03	0.10	Within
Zn	mg/l	0.42±0.16	0.33±0.39	3	Within

Note: ND implies not detected.

Table-4: 2-sample t-test showing efficiency of ETP in decreasing the pollution load.

	DO	TSS	BOD_5	COD	Oil and grease	Fe
Influent	5.46±0.9	1568.86± 562	19.4± 5	72.59±13	1395±307	52.72±17
Effluent	6.59±0.6*	364.29± 309**	7.35±0.92**	20.49±8***	154.6±30***	15.10±12***

*P<0.05, **P<0.001, ***P<0.000.

Suspended and dissolved solids include both organic and inorganic solids and TSS and TDS in both influent (TSS=1568.86mg/l, TDS=202.17mg/l) and effluent (TSS=364.29mg/l, TDS=204.45mg/l) exceeded ES limit of TSS (80mg/l) and TDS (150mg/l). Muds, sand, debris washed off from the vehicles contribute to high TSS and TDS in wastewater. In addition most of the wash centres carryout washings on open and unpaved surfaces contributing to more solids in the wastewater. Preventing entry of TSS into surface water is very important [36] as heavy metals are known to adsorb to TSS[37]. TSS can also create stressful environment for aquatic life by increasing BOD, turbidity, reduces available habitat and clog gills of fishes and benthic macro invertebrates creating respiratory difficulties[38].

Excessive nutrients like nitrogen and phosphorus in aquatic ecosystem causes eutrophication. In effluent concentrations of nutrients were 2.37 mg/l for TN and 1.19 mg/l for TP. Phosphate must have been derived from the detergents used for washing vehicles. Generic environmental standards in ES[22]for TN is 20mg/l and standard has not been set for TP. In France, environmental standards for TP and TN concentrations in vehicle wash wastewater destined for discharge into freshwater systems are 10 and 30 mg/l respectively[39]. Observed nutrient concentrations have not caused any eutrophication in impact zone and downstream of Olarong Chhu. New Zealand also considers that nutrients from urban catchments are not much problem compared to rural agricultural runoff which contains excess amount of nutrients[36].

Heavy metals are associated with vehicle body parts like brakes and tyres, fuels, and oils[40] and dominant metal contaminants reported in vehicle wash wastewater by Moores et al.[41] were Cu, Pb, and Zn. These metals get into the wastewater due to normal wear and tear of auto brake linings, tires, vehicle exhaust, and fluid leakage[13]. The vehicle fluid spills also result in heavy metals and toxic materials entering ground and surface water supplies, creating public health and environmental risks [42].The trend of mean metal concentrations in influent and effluent were Fe> Mn>Zn>Cu>Pb>Cd>Cr and Fe>Mn>Zn>Cu>Pb respectively (Table-3). Moores et al.[41] have also reported high concentrations of Zn and Cu in vehicle wash wastewater. The level of Cu, Fe and Mn in both the influent and effluent (Table-3) were above the ES[22]. With the increasing number of vehicles in Bhutan, it is likely that heavy metals input into the environment will be higher in near future.

Physico-chemical results of stream water: The results of physico-chemical analyses of Olarong Chhu from upstream, impact zone, and downstream (Figure-3) are presented below (Table-5). Results showed significant spatial variation (ANOVA, $p < 0.05$) in pH, DO, turbidity, BOD_5, COD, oil and grease, and sulphate levels across sampled sites (Table-5).

The mean value of pH (8.48) in impact zone was higher than upstream (7.62), and downstream (7.71). This elevation of pH in impact zone can be attributed to the use of detergents in vehicle wash centres. Detergents used in vehicle washings are acutely toxic to fishes[43]. The report of Asian Development Bank (ADB)[44] on Bhutan's water resources being slightly alkaline matches with findings in upstream and downstream sampling points. Since the vehicle wash wastewater contains heavy metals therefore their discharge into the Bhutan's rivers show potential toxicity to the ecosystem. The particulate state of heavy metals are susceptible to its free state when acidity increases[45], and become available for aquatic biota which can cause bioaccumulation in food chains. Though metals are necessary for physiological processes but higher concentrations are detrimental to aquatic biota and impacts continues to higher trophic levels.

Low DO (7.61mg/l), high BOD_5 (1.84mg/l) and COD (3.75mg/l) in impact zone also indicate that this stretch of river is affected by direct discharge of wastewater. Such conditions indicate risk of oxygen depletion due to degradation of organic matter[46]. Decrease in DO concentrations below 5mg/1 adversely affect the functioning and survival of biological communities[47]. Mean concentration of oil and grease (74.85mg/l) in impact zone depicts discharge of oily wastewater from the wash centres. Discharging oily wastewater into surface water bodies cut off oxygen diffusion from air to water[48] and increases BOD, T and pH of the water which in turn will trigger aquatic habitat degradation, reduced productivity, and loss of biodiversity[49]. Studies elsewhere[31,33] have also reported high BOD_5 and COD of oily vehicle wash wastewater that can subsequently increase the BOD and COD of surface water bodies.

Conclusion

This study revealed that vehicle wash centres were established before formulating the guidelines by NEC and do not meet most of the criteria laid down in the guidelines. The vehicle wash centres perform washing on open and unpaved surfaces and ETP is dysfunctional most of the time. All these practices are bound to contaminate soil, underground water and surface water bodies. The results from this study indicate that surface water pollution from vehicle wash wastewater can be controlled through proper guidelines, routine physico-chemical monitoring and construction of ETPs. It should be mandatory to treat wastewater considering the vulnerability of nearby stream water quality. With the accelerating numbers of vehicles in the country, lack of ETPs indicate poor environmental awareness, because methods like silt traps and phyto-remediation do not involve complex technology and are relatively cheap. Separation of vehicle washing and mechanical servicing activities are strongly recommended for the safety of the workers, residents and environment. If all the washing activities take place in a common designated place then it would be easy to manage the wastewater also. Lastly, findings are excellent baseline database for the policy makers as provisions pertaining to management of wastewater are not implemented properly in Bhutan.

Table-5: Physical and chemical parameters in Olarong Chhu

Parameters	Units	Upstream Mean ±SD	Impact zone Mean ±SD	Downstream Mean±SD	P-value
T	^{0}C	11.70±3.02	13.13±3.58	12.51±3.31	0.549
pH		7.62 ±0.24	8.48±0.55	7.71±0.20	0.000
EC	µs/cm	84.83±50.8	112.52±55.53	118.45±65.47	0.295
DO		8.61±0.47	7.61±0.63	8.32± 0.61	0.000
TSS	mg/l	32.18±25.81	54.54±49.59	44.10±50.68	0.433
TDS	mg/l	51.84±38.68	66.78±54.10	76.14±53.26	0.454
Turbidity	NTU	7.14±3.18	12.33±2.98	9.10±2.44	0.000
BOD_5	mg/l	1.04±0.39	1.84±0.58	1.18±0.46	0.000
COD	mg/l	1.51±0.49	3.75±1.30	1.86±0.68	0.000
TN	mg/l	0.97±0.52	1.13±0.47	0.90±0.44	0.476
TP	mg/l	1.16±1.69	0.77±0.88	0.18±0.13	0.088
Oil and grease	mg/l	0.00±0.00	74.85±11.87	31.92±7.33	0.000
Alkalinity	mg/l	33.52±2.60	50.08±25.82	41.38±23.13	0.124
Sulphate	mg/l	1.62±0.97	7.56±5.35	2.88±1.34	0.000
Ar	mg/l	ND	ND	ND	ND
Cd	mg/l	0.02±0.01	ND	ND	0.393
Cr	mg/l	ND	ND	0.04±0.01	0.378
Cu	mg/l	ND	0.02±0.01	0.02±0.01	0.050
Fe	mg/l	0.79±0.78	0.62±0.28	0.76±0.84	0.817
Mn	mg/l	0.07±0.03	0.05±.01	0.11±0.03	0.764
Pb	mg/l	0.03±0.01	0.03±0.01	0.04±0.02	0.961
Zn	mg/l	0.03±0.02	0.05±0.03	0.04±0.01	0.046

Note: ND implies not detected.

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