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Assessment of water quality and pollution in Gurunagar fishery harbour, Jaffna, Sri Lanka

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Abstract

Coastal marine water pollution is caused by anthropogenic activities either directly or indirectly. Substances released into marine coastal environment result in deleterious effects such as harmful to living resources, hazards to human health, hindrance to marine activities including fishing. As such, Gurunagar harbour is often polluted by several waste effluents generated within the region. Research was conducted with the objective to determine the quality of water in the fish landing site at Gurunagar and type of wastes discharged into the main water stream. Investigations were carried out for six months period from January to June 2020. Three potential sampling locations were selected along three main drainages where amalgamation takes place at the coastal region. Samples were collected from 10 m, 30 m and 60 m at the interior portion of the harbour whereas control unit was kept at 500 m at the exterior portion of harbour. Fifteen water quality parameters were analyzed to find out the level of contamination in the water. Results showed that physical parameters such as temperature, salinity, total suspended solids, colour and turbidity were kept under the tolerance level. Chemical parameters such as BOD, COD, Nitrate, and Phosphate were accounted above the limit as 139.00 ± 29.57 mg/l, 306.70 ± 70.5 mg/l, 78.70 ± 8.03 mg/l, and 1.42 ±0.2448 mg/l, respectively. There was no significant difference between three main drainage channels considered. Hazardous wastes of oil and grease accumulated as 14.333 ± 2.345mg/l in the harbour water and, the Noxious heavy metals namely Hg and Pb were estimated as 0.03544 ± 0.02845 mg/l and 1.97 ± 0.1815 mg/l, respectively; and these concentrations are crucially above the tolerance limits. The Hg concentration in Jaffna Teaching Hospital drainage was reported as 0.0315 ±0.02247 which is inevitably higher than the threshold level. It was found parameter variables along with the sampling distances and significantly high value was obtained at the distance of 10 m from the coast. The present study recommends that initiatives should be made by the government officials to adopt an effective waste disposal and management system among the coastal communities, in the future.

Keywords: Harbour pollution; BOD; COD; Nitrate; Phosphate; Oil and grease; Noxious heavy metals

1. Introduction

Jaffna coastal ecosystems along the coastline of peninsula is a variety of coastal ecosystems, the total land area of Jaffna is 929 Sq.Km. The inland water captures 96 Sq.Km consisting of estuaries and lagoons (extending over 260 ha), mangroves (45525 ha), .(Dept.of Fishery Performance Report 2019). These ecosystems are important constituents of the country's biological wealth (CZMP, 2006). Coastal fishery in Jaffna contribution was estimated at about 10 % of the total marine fish landings in Sri Lanka in 2017 (NARA, 2017).

There are two potential landing sites located in the Northern Peninsula. One is situated in the Northern part in Point-Pedro and the other one is at the Southern coastal ends up with Gurunagar. Both are major fisheries landing site located

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in Jaffna. Gurunagar landing site belongs to Jaffna west Fishery Inspector (FI) division within 14 FI divisions (Ministry of Fisheries, 2019). This coastal site consists operation of 686 Out Boat Motor (OBM) fishing crafts, 388 In Boat Engine (IBE) crafts and 148 Non - Mechanic Traditional Boats (NTRB) (Dept.of Fishery Performance Report, 2019).

As per census of 2020, the total population of Gurunagar is 3,386 families of which 3,117 families consisting of 10,760members are doing fishing as their sole income generations. It's obvious that approximately90% of people are depending on fishing for their major source of income. There are nearly 5,261 active fishermen. The annual fish production is 7,192MT and the dry fish production is 562MT. Fishery sector is the major economic driver as it contributes to the GDP to a considerable extent.

Coastal and marine ecosystems at Gurunagar are being severely affected by dense human population and intensive habitat in this coastal region. Most of the fishing operational industries are settled in the coastal belts of the Jaffna East, especially, fishery landing site, fishing gears factories and ice producing factory because of ease of operation and trade. The emissions and waste generated from these factories located in the vicinity of harbour area in turn contribute to severe marine pollution.

Three major wastewater drainages such as Jaffna Teaching Hospital drainage, Guarnagar fish market drainage, and Gurunagar main domestic drainage, which are mixing up at the Gurunagar coastal sea and carrying heavy polluted effluents from upstream residential areas and Jaffna city. These coastal waters are the ultimate receivers of the organic waste materials generated by Jaffna city.

Gurunagar sea water quality has serious risk relating fishery operations due to untreated waste effluents generated as a result of land based external sources such as human settlements around coastal fishery landing site premises. The degree of water pollution is also raised by anthropogenic activities by dumping untreated wastewater in the coastal sea area which acts as a reservoir for reactive chemicals and lead to bioaccumulation in long-run.

This research was carried out at Gurunagar major fisheries landing site to assess pollution status, and to identify information about anthropogenic activities attributed to pollution at fishery landing site. The aim of the study is to gather information while focus on improving the current status and management of this fishery landing site in the consecutive years to come.

2. Material and methods

The research topic was conceptualized to identify the water quality status and pollution load of Gurunagar fishery harbour. Two major steps were fixed to prove the analysis such as quantitative and qualitative methods. The water quality parameters were examined under quantitatively, and the household fisher's intervention were analyzed through qualitatively.

Two types of data such as primary and secondary were used to analyze the results. Primary data were collected directly from fishery harbourby water sampling and testing water quality parameters at the laboratory. The results were then compared by using statistical analysis. Secondary data were derived from past research papers and used for comparison.

2.1. Site description

Gurunagar landing site is located between the geological coordinates of 9°38'57" N latitude and 80°1'8" E longitude and is situated in the southern coast of Jaffna. Gurunagar landing site belongs to Jaffna west Fishery Inspector (FI) division. Nearly 3,386 families live in Gurunagar area among them 3,117 are fishing families consisting of 10,760members. There are nearly 5,261 active fishermen in this area. Approximately 90% of people from this area depends on fishing directly or indirectly, which is their major source of income. Fisheries sector is the major economic driver of this area, and its annual fish production is 7,192MT and the dry fish production is 562MT.In this fishery landing site 686 out boat motor (OBM) fishing crafts, 388 in boat engine (IBE) crafts and 148 non mechanic traditional boats (NTRB) are in operation. (Dept.of Fishery Performance Report 2019).

Figure 1 Engineering map of study area at Gurunagar fishery harbor

2.2. Selection of sampling stations, and sample collection

The research was carried out for a period of six months from January to June 2020. Three Sampling locations such as Jaffna Teaching Hospital drainage point, Guarnagar fish market drainage point, and domestic drainage channels' point were selected for the present study. These are major wastewater drainage channels which discharge effluents into the interior end of Southern coastal region and ultimately mixing up at the Gurunagar coastal landing site. These effluents are carrying heavy pollutants from upstream residential areas and Jaffna city. The Standard Operating Procedure is used for seawater sampling as per the standard regulations adopted by National Water Supply and Drainage Board (NWSDB).

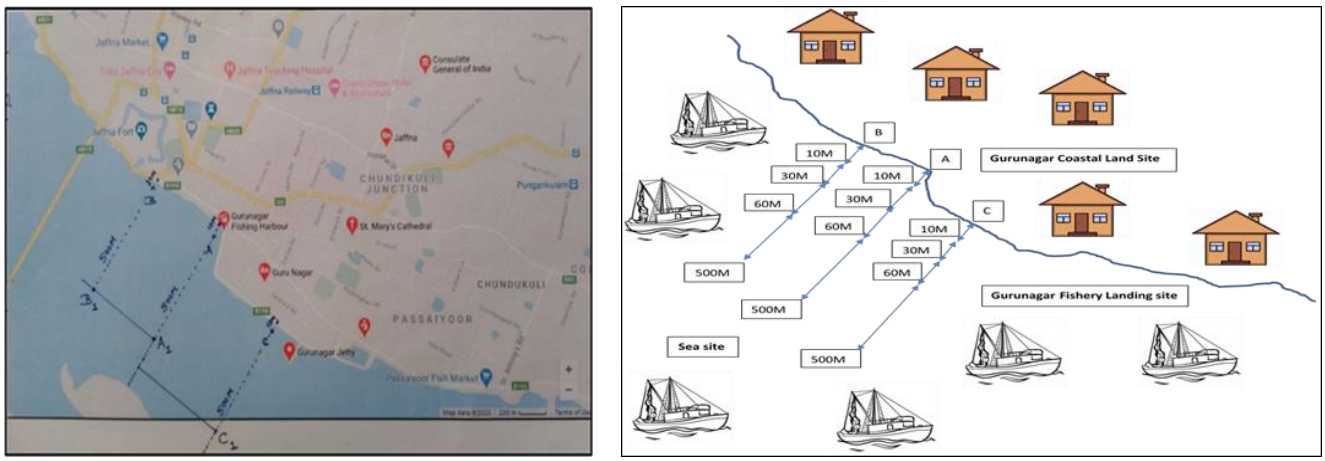

Figure 2 Mapping of sampling stations from coastal sea

In the aforesaid figure.

- Channel A - Gurunagar fish market and domestic drainage mixing point at Gurunagar harbour basin.
- Channel B - Jaffna Teaching Hospital drainage mixing point at harbour basin.
- Channel C – Gurunagar main household domestic drainage mixing point at harbour basin.

Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrate, Phosphate, oil and grease and heavy metals were analyzed according to the standard procedures of examination for water and wastewater standard. The containers were sealed, pre - sterilized glass bottles were used to collect samples for examining BOD, Coli form colonies and oil and grease whereas polypropylene bottles were used for examining other water quality parameters.

Table 1 Description of each sampling locations of the study area

Landing sites	**Sampling location inside the Harbour**			**Sampling location as control test unit**		
Gurunagar	A Gurunagar fish market and domestic drainage channel mixing up to coastal sea	B Jaffna Teaching Hospital drainage channel mixing up to coastal sea	C Gurunagar main domestic drainage channel mixing up to coastal sea	500m from station A	500m from station B	500m from station C

2.3. Laboratory analysis of water quality parameters

Water samples collected in the field were subjected to laboratory analysis using standard methods. The samples were analyzed for various water quality parameters. Physical parameters were analyzed by the following methods. Temperature was measured using portable thermometer consisting of mercury column. Colour of water was assessed by spectrophotometer (Spectrometric Pt-Co method). Salinity was measured by Electrode's salinity meter (Electrometric method). Turbidity was measured through Nephelometric *turbidity meters* (turbidimetric method). Total Dissolved Solids (TDS) of collected samples was determined by gravimetric method (103-105 'C).

Chemical parameters were observed via the undermentioned methods. BOD of seawater samples was measured by using BOD Track kit method. COD was determined by COD reactor (high range vials). Nitrate (NO_3^-) and Total Phosphate (PO_4^{---}) concentrations were determined using Spectrometric method. Fecal coliform and Total coliform counts were detected through membrane (0.45 μm) filter method.

The contaminant of oil & grease in the coastal sea water was detected through gravity n-Hexane method. Moreover, the heavy metal contaminations for Pb & As of aforesaid landing site was measured under atomic absorption spectroscopy method calibrated by graphite furnace method whereas Hg was measured through Hydride method.

2.4. Statistical analysis

Data obtained from laboratory analysis were fed on one – way analysis of variance (ANOVA) to derive the comparable mean values of physicochemical parameters of water in the sampling stations. The derivatives of ANOVA were compared with the standard values declared by Central Environmental Authority of Sri Lanka (CEASL), as well as with International coastal sea water standards to determine the degree of pollution at the study area.

3. Results and discussion

The quality of coastal water is mostly influenced by natural, geological and oceanographic processes, as well as by human activities in marine and terrestrial. It was observed that certain coastal pollution arises due to anthropogenic land-based activities and inappropriate fishing operations at the landing sites.

This chapter clarifies the laboratory analysis of water quality parameters at the Gurunagar harbor area. A total of twelve sampling locations were fixed in the study area including three control units. In order to analyze the variation in the physical, chemical and biological parameters, three main drainage channels were selected as A, B and C which implied the drainage waste of Gurunagar fish market, Teaching Hospital and the residents from the study area of Gurunagar, respectively. The sampling distances were fixed in each sample stations A, B and C at the distances of 10, 30, 60 meters from the coastal line and with the control units set at 500m towards sea area. The samples were analyzed at the Regional Laboratory of National Water Supply and Drainage Board (NWSDB) in Jaffna district. Three round sampling was carried out to confirm the level of pollutants present in the sea water.

In this analysis physical parameters such as temperature, colour, salinity, turbidity and total suspended solids, chemical parameters such as BOD, COD, Nitrate, Phosphate, heavy metals, oil and grease, and biological parameters such as *E. coli* & *T. coli* were examined.

Factor analysis showed that there was significant difference in loading between interior and exterior portion of harbor based on the distances from coastal belt. The contaminants were concentrated at a high degree in the sea area where assimilation of waste drainage channels (A, B and C) took place. The results astonishingly expressed that the internal

landing site acquired more contaminated water when compared with the external landing site which was located 500m apart from the coastal line. The tendency of pollution was as high as in the shipment area when compared the distance towards deep sea area.

3.1. Description of results

Sampling stations were pointed out with the aid of GPS. The sampling locations with GPS coordination and the results of each parameter during three round sampling are cited under Table 2, 3 and 4, respectively.

Three – round samplings were carried out to derive accurate output. The first set of samples were collected at the distance of 10 m from the coastal area while a control test was performed by taking sample at the distance of 500 m away from coastal. Likewise, second and third sets were obtained by collecting samples at 30 m, 60 m, respectively while keeping the control test as same as mentioned above for all instances. All fifteen parameters were tested for each instance. Three replicates were recorded for each water quality parameters and the P value is driven from the analysis for comparison of the pollution level whether significant or not. If the P value is less than 0.05 ($P<0.05$), there would be significant variation among the factors to be considered.

Table 2 Statistical analysis of three drainage channels and its significance

		Drainage			
S.No	**Parameters**	**P-value**	**A Guarnager fish market and domestic drainage mixing at Gurunagar coastal sea**	**B Jaffna Teaching Hospital drainage mixing at Gurunagar coastal sea**	**C Gurunagar main domestic drainage mixing at Gurunagar coastal sea**
		P-value	**Mean±SD**		
1	Temperature (^oC)	0.230	30.317^a±1.399	29.667^a ±0.753	29.983^a ±1.115
2	Colour	0.745	112.70^a±112.7	115.20^a ±115.2	147.20^a ±147.2
3	Salinity (mg/l)	0.108	36517^a± 1357	36156^a ±3989	34750^a ±1586
4	Turbidity (NTU)	0.464	27.04^a±29.05	23.29^a ±18.27	15.960^a ±31.92
5	TSS (mg/l)	0.183	21.33^a ±12.96	28.00^a ±13.79	28.50^a ±11.59
6	BOD 20-5(mg/l)	0.591	62.30^a ±69.7	54.70^a ±53.6	43.50^a ±37.25
7	COD (mg/l)	0.582	135.70^a ±154.6	119.20^a ±118.1	93.70^a ±80.8
8	Nitrate (mg/l)	0.956	24.27^a ±31.48	22.79^a ±29.71	21.23^a ±30.15
9	Total Phosphate (mg/l)	0.405	0.853^a ±0.553	0.8483^a ±0.3173	0.6783^a ±0.4209
10	*E. coli*	0.045	0.00^a ±0.0000	0.833^a ±1.948	0.00^a ±0.0000
11	*T. coli*	0.067	0.833^a ±1.295	4.50^a ±7.64	1.50^a ±3.468
12	Oil & grease(mg/l)	0.87	3.67^a ±4.85	4.33^a ±6.31	4.67^a ±6.08
	Heavy Metal				
13	Pb (mg/l)	0.000	1.52^b ±0.691	2.17^a ±0.3606	2.055^a ±0.1738
14	As (mg/l)	0.126	0.297^a ±0.426	0.155^a ±0.02744	0.14^a ±0.0674
15	Hg (mg/l)	0.000	0.02889^a ±0.01680	0.0315^a ±0.02247	0.00711^b ±0.00544

Note: * a, b, c, d expressed the significant variation among them at 95 % confidence interval.

Table 3 Significant variation among the distances

		Distance						
S.No	**Parameters**	**P-value**	**10m from coastal**	**30m from coastal**	**60m from coastal**	**A to 500m towards sea**	**B to 500m towards sea**	**C to 500m towards sea**
		P-value	**Mean ±SD**					
1	Temperature (^oC)	0.000	31.611^a ±0.613	30.922^b ±0.728	30.20^c±0.394	28.90^c ±0.0866	28.70^d ±0.0866	29.60^d ±0.2062
2	Colour	0.000	337.30^a ±161.1	152.70^b ±89.1	175.30^{bc} ±159.3	29.00^c ±3.87	28.33^c ±4.36	27.33^c ±5.87
3	Salinity (mg/l)	0.000	31700^d ±3856	35800^{bc} ±424	37966.7^{ab} ±158.1	35433^c ±656	35678^c ±447	38266.7^a±278.4
4	Turbidity (NTU)	0.000	76.030^a ±17.13	22.130^b ±3.19	22.130^b ±11.10	5.033^c ±1.937	5.724^c ±0.824	1.50^c ±0.401
5	TSS (mg/l)	0.000	49.00^a ±5.48	32.00^b ±5.92	17.333^{cd} ±7.95	23.670^c ±4.18	20.00^{cd} ±5.05	13.67^d ±3.04
6	BOD 20-5(mg/l)	0.000	139.00^a ±29.57	112.00^b ±27.37	24.33^c ±6.84	10.67^c ±4.64	22.00^c ±3.94	13.00^c ±3.91
7	COD (mg/l)	0.000	306.70^a ±70.5	242.80^b ±55.9	50.67^c ±8.28	20.67^c ±3.64	48.33^c ±13.11	28.00^c ±8.92
8	Nitrate (mg/l)	0.000	78.70^a ±8.03	44.18^b ±11.14	4.40^c ±1.573	3.367^c ±2.131	4.70^c ±0.862	1.233^c ±0.381
9	T.Phosphate (mg/l)	0.000	1.42^a ± 0.2448	1.2133^a ±0.0583	0.5467^c ±0.2311	0.81^b ±0.1399	0.5033^c ±0.1054	0.2667^d ±0.1442
10	*E. coli*	0.005	1.667^a ±2.550	0.00^b ±0.0000	0.00^b ±0.0000	0.00^b ±0.0000	0.00^b ±0.0000	0.00^b ±0.0000
11	*T. coli*	0.000	10.67^{ab} ±7.50	3.00^b ±3.32	0.00^b ±0.0000	0.00^b ±0.0000	0.00^b ±0.0000	0.00^b ±0.0000
12	Oil & grease(mg/l)	0.000	14.333^a ±2.345	8.33^b ±3.04	2.667^c ± 1.581	0.00^d ±0.0000	0.00^d ±0.0000	0.00^d ±0.0000
	Heavy Metal							
13	Pb (mg/l)	0.993	1.86^a ±0.768	1.873^a ±0.771	1.857^a±0.775	1.9667^a ±0.170	1.9633^a±0.1748	1.97^a ±0.1815
14	As (mg/l)	0.589	0.1833^a ±0.0485	0.18^a ±0.0541	0.1856^a±0.0707	0.15^a ±0.0324	0.344^a±0.622	0.14^a ±0.0406
15	Hg (mg/l)	0.011	0.03233^a ±0.0234	0.03544^a ±0.028	0.02867^a±0.02179	0.012^a ±0.0016	0.012222^a±0.002438	0.01433^a ±0.006

Note: *Supper Scripts a, b, c, d expressed the significant variation among them

Table 4 Comparison of high and low values with distance

S.No	Parameters	High value Vs distance (m)	Low value Vs distance(m)	Remarks
1	Temperature (°C)	10m from coastal	B to 500m towards sea	Significant variation among distance
2	Colour	10m from coastal	A to 500m towards sea	Significant variation among distance
3	Salinity (mg/l)	C to 500m towards sea	10m from coastal	Significant variation among distance
4	Turbidity (NTU)	10m from coastal	C to 500m towards sea	Significant variation among distance
5	TSS (mg/l)	10m from coastal	C to 500m towards sea	Significant variation among distance
6	BOD 20-5 (mg/l)	10m from coastal	A to 500m towards sea	Significant variation among distance
7	COD (mg/l)	10m from coastal	A to 500m towards sea	Significant variation among distance
8	Nitrate (mg/l)	10m from coastal	C to 500m towards sea	Significant variation among distance
9	Total phosphate (mg/l)	10m from coastal	60m from coastal	Significant variation among distance
10	*E. coli*	10m from coastal	500m towards sea	Significant variation among distance
11	*T. coli*	10m from coastal	500m towards sea	Significant variation among distance
12	Oil & grease (mg/l)	10m from coastal	500m towards sea	Significant variation among distance
	Heavy Metal			
13	Pb (mg/l)	C to 500m towards sea	60m from coastal	Not Significant variation among distance
14	As (mg/l)	B to 500m towards sea	C to 500m towards sea	Not Significant variation among distance
15	Hg (mg/l)	30m from coastal	A to 500m towards sea	Not Significant variation among distance

4. Conclusion

The research showed that the waste effluents discharge into the coastal area were highly contaminated with pollutant loads which are considered as a real threat to all walks of life in the coastal suburb of Gurunagar. Three main drainage channels were correlated with carrying this hazardous waste into the coastal marine. It was deliberately observed that there was no significant difference in the mean values between the drainage channels A, B & C of the study area. Inside the fishery landing site (less than 500m distance from coastal) all water quality parameters were observed statistically significant. The tendency of waste concentrations declined with increasing distance from coastal area. This is the reason behind that there were no significant values reported at control units set at the distance of 500m far away from coastal area.

Chemical parameters such as BOD, COD, Nitrate, and Phosphate were accounted above the limit as 139.00 ± 29.57 mg/l, 306.70 ± 70.5 mg/l, 78.70 ± 8.03 mg/l, and 1.42 ±0.2448 mg/l, respectively. Noxious heavy metals namely Hg and Pb were estimated as 0.03544 ± 0.02845 mg/l and 1.97 ± 0.1815 mg/l, respectively; and these concentrations are crucially above the tolerance limits. The Hg concentration in Jaffna Teaching Hospital drainage was reported as 0.0315 ±0.02247 mg/l which is inevitably higher than the threshold level. It's clearly understood that these medical wastes contain hazardous materials. Oil and grease accumulated as 14.333 ± 2.345 mg/l in the harbour water at the distance less than 500m from coastal line. Hull and boat repairing engine maintenance leave behind large quantity of engine and hydraulic oil and ultimately ends up with oil pollution.

It's concluded that the water quality of Gurunagar fishery harbour is being degraded and subjected to chemical pollution, oil pollution, and heavy metal contamination. These contaminants in the water column reflect a negative

impact on the water quality and its best use for fishery harbour operations. The present study recommends that initiatives should be made by the government officials to adopt an effective waste disposal and management system among the coastal communities, in the future.

Compliance with ethical standards

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Disclosure of conflict of interest

No competing interests.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

This is to certify that the thesis entitled **"Assessment of water quality and pollution in Gurunagar fishery harbour, Jaffna, Sri Lanka"** submitted by Anandakrishnan Sivanandan for the degree of Master of Science in Environmental Management to the university of Jaffna is a record of original independent research carried out by Mr. Anandakrishnan Sivanandan under the guidelines and direct supervision of Prof. (Mrs). Sivashanthini Kuganathan and Eng. (Dr). Balachandran Ketheesan.

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