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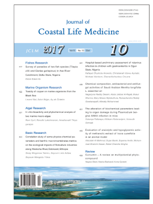

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Correlation study of some physico-chemical parameters and benthic macroinvertebrates metrics on the ecological impacts of floriculture industries along Wedecha River, Debrezeit, Ethiopia

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ABSTRACT

Objective: To assess the quality of water using biological and chemical information correlation study.
Methods: A total of 6 sites, one reference site less impaired to represent natural conditions from upstream, and 5 impaired sites in the downstream were sampled for macroinvertebrates and physicochemical parameters.
Results: In the polluted sites with high nutrient enrichment and organic loading, only organisms with special physiological and morphological adaptations were found, such as Hydrobiidae, Physidae and Viviparidae snails. Physicochemical parameters: electrical conductivity, chemical oxygen demand, biological oxygen demand, sulphate, orthophosphate and nitrate-nitrogen and metrics: percent of Mollusca, percent of Physidae and percent of dominant taxa were used for monitoring, and expected to have strong positive relation with increasing disturbance.
Conclusions: Therefore, floriculture industries wastewater discharged to the nearby rivers has enormous effect on the degradation of the ecosystem. To sustain the ecological conditions of the nearby rivers, wastewater treatment and environmental audit were suggested. Environmental assessment and environmental audit enable the floriculturist to keep humans and the environment safe. Taking care of workers, soil, water and the environment has to be seen with great care and caution because it is difficult to maintain a healthy community and carry out development in a degraded environment.

1. Introduction

Ethiopia is a new country in the floriculture industry. Addis Ababa means “new flower” in Amharic and the city is now surrounded by blooming flower industries, most of which are found in Oromia region. The sector’s contribution to export revenue and employment generation has been progressively increasing over the last few years in Ethiopia[1,2].

Despite the floriculture industries have made significant contribution to the national economy, social and environmental problems may exist, almost in the same way as occurred in Colombia and Ecuador. Use of various chemicals by the sector may cause damage to the environment[2,3].

The effect of water pollution due to floriculture industries can be detected using physicochemical parameters and macroinvertebrates. Increased concentrations of pollutants in the water runoff affect the benthic community. Pollutants of concern include nutrients and toxins. Temperature may affect the strength of pollutants and dissolved oxygen effects may also be present due to discharged pollutants. The geomorphic, hydrologic, riparian zone and water quality parameters affecting the invertebrate community make isolation of a single agent difficult. Therefore, the combination of the biological community and physicochemical parameters assessment can provide an ideal indication serving as measure for water quality monitoring[4,5].

The integrity of streams requires the management of water quality factors. To restore and maintain the environment, the factors (chemical, physical and biological integrity of the water

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bodies) should be monitored[6]. Of the three characteristics, biological integrity may be the most important since organisms not only integrate the full range of environmental influences (chemical, physical, and biological), but also complete their life cycles in the water and as such are continuous “monitors” of environmental quality. Thus, evaluation of benthic conditions and development of benthic stress or relationships are of great importance to meet water quality goals[7].

Each water body is a delicately balanced ecosystem in continuous interaction with the surrounding air and land. If this water ecosystem becomes unbalanced or contaminated, it can destroy aquatic life and, eventually, eradicate the surrounding ecosystems that it interacts with. This can cause fish and wildlife to experience reduced fertility, genetic deformities, immune system damage and death. This also poses human health problem. In the end, nothing escapes the effects of water pollution[8].

Methods that have been put in place to measure the impacts of human activities on the integrity of water resources include chemical, physical and biological measures. Biological communities integrate the effects of different stressors that water resource agencies are struggling to address, such as reduced oxygen, excessive nutrients, toxic chemicals and habitat degradation. This integration occurs through time, a dimension difficult to measure with chemical information among others[9,10].

This study was designed along Wedecha River near Debrezeit. There are many floriculture industries established along Wedecha River. These industries discharge their effluent wastewater to the nearby water bodies including Wedecha River. The industries are known to use different toxic chemicals, and the effluent water may pollute the surrounding water bodies. The study was designed to assess the effect of these floriculture industries on the surrounding rivers by correlation study of physcochemical parameters and benthic macroinvertebrates.

2. Materials and methods

2.1. Study area

This study was conducted near floriculture projects, at Debrezeit along Wedecha River. Debrezeit is found in Oromiya administrative region, East Shewa Zone, Adaa Chukala Wereda, 50 km west of the zonal capital, Nazaret and 45 km east of Addis Ababa. Its central coordinates are 038°05'53'' E, 08°44'52'' N at an altitude of 1 925 m (Figure 1). It is characterized with a humid tropical climate and intense precipitations from June to August. The air temperature varies around the year from a minimum of 6 °C to a maximum of 36 °C (Ethiopian National Metrological Services Agency, personal communication).

Wedecha River is found about 7 km north of Debrezeit town. It originates in the central highlands of Ethiopia and flows through populated area, the central rift valley and discharges to the Awash River in the southeast. Streams throughout the area generally have moderate to high flows and narrow floodplains including Wedecha River. There is intensive agricultural activity including cattle grazing and establishment of floriculture industries in the surrounding of Wedecha River. There are more than 15 floriculture industries. The effluent of floriculture industries is directly discharged to the river.

Sampling sites S_0 to S_5 are upstream to the downstream in the region bounded by latitudes 08°46'21'' N to 08°47'49'' N and by longitudes 039°00'53'' E to 039°01'02'' E, and ranging in altitude from 1 872 to 1 885 m. This was measured using Global Positioning System. The upstream site was considered a reference site (S_0). Sites were chosen near the relevant discharge point along 100 m (S_1, S_2, S_3 and S_5) in the downstream near the newly established floriculture industries. But site S_4 is about 1 km away from the discharge points in the downstream between S_3 and S_5 (Figure 1).

The water quality of Wedecha River was studied on the basis of its agricultural and domestic activities (drinking, washing *etc.*) as floriculture industries are discharging the wastewater into the river.

2.2. Reference conditions

To address levels of impact to any given river, impacted site and reference approach are very essential to compare the level of impact. The reference approach is based on minimal human impact[11]. The objectives of the reference are to collect and summarize data from least disturbed site using as a framework in order to develop appropriate criteria for bioassessment interpretation[4]. Finding reference sites in streams is a difficult task, because no regions are entirely without areas of human disturbance. Therefore, the reference site has to be selected based on minimally disturbed attributes[12,13].

According to Selvanayagam and Abril, reference sites for each location must meet 11 criteria[5]: 1) pH ⩾ 6 if black water stream, then pH < 6 and dissolved organic carbon ⩾ 8 mg/L; 2) dissolved oxygen ⩾ 7 mg/L; 3) nitrate ⩽ 300 mg/L; 4) urban land use ⩽ 20% catchment area; 5) forest land use ⩾ 25% catchment area; 6) remoteness rating: optimal or suboptimal; 7) aesthetics rating: optimal or suboptimal; 8) instream habitat rating: optimal or suboptimal; 9) riparian buffer width ⩾ 15 m; 10) no channelization; 11) no point source discharge.

However, as there was a problem getting a reference site that fulfills all the above criteria; it was identified based on minimally disturbed criteria as indicated by Martínez-Sanz *et al.*[10]: 1) same water body type, size, and chemical characteristics as treated site, 2) within same watershed as treated site, 3) minimal application of aquatic pesticides within the last few years, and 4) limited anthropogenic inputs.

A reference site, S_0, was selected to compare against the contaminated sites in all impacted sites. Chemical and biological measures taken in impacted sites were compared to this reference site. S_0 was chosen because it is found in the upper stream of the river with no floriculture impact and has some of the lowest levels of the contaminants from agricultural activities and grazing animals and it fulfills some of the above criteria.

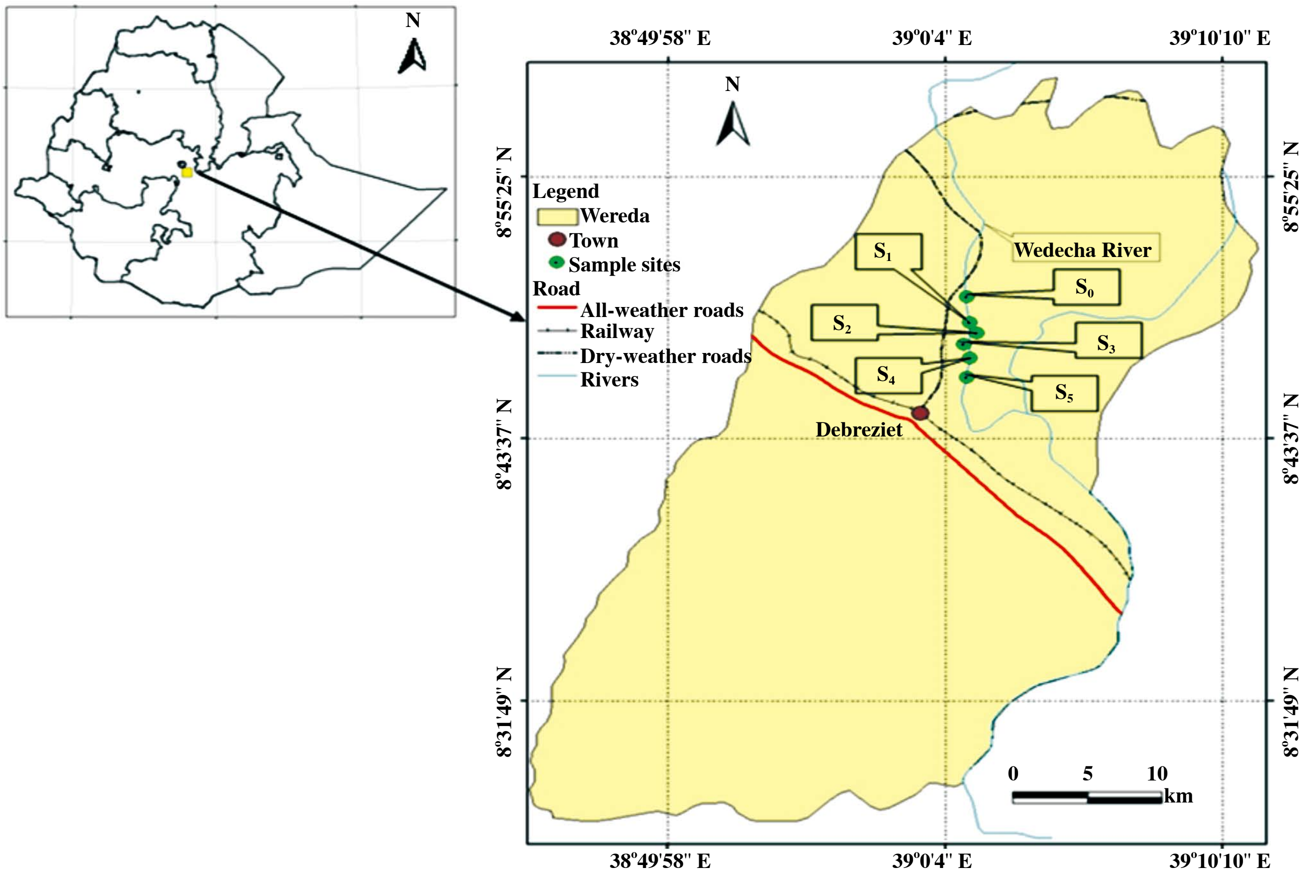

Figure 1. Map of Wedecha River showing study sites, S_0 to S_5 from upstream to downstream.

2.3. Sampling

Samples were collected three times at each site (two replicates per site per sampling date, six samples per site) at approximate monthly interval from November 2006 to May 2007 following the protocols used for wadable rivers[14].

Sampling sites covered 100 m stretch (for impacted sites starting from point sources of discharge). Water samples were taken simultaneously with the macroinvertebrates samples.

Benthic macroinvertebrate and water quality sampling were conducted in the dry season, when the benthoses are thought to be reliable indicators of environmental stress; there is no rain dilution factor.

2.4. Physico-chemical analysis

Water samples were collected for analysis of sulphate (SO_4^{2-}), nitrate-nitrogen (NO_3-N), ammonia (NH_3-N), orthophosphate (PO_4^{3-}), sulphide (S^{2-}), chemical oxygen demand (COD) and biological oxygen demand (BOD_5) as chemical variables and temperature, pH, and conductivity included as physical variables were measured following water quality assessment protocols. Dissolved oxygen was fixed by the azide modification of the Winkler method to reduce consumption of oxygen by microorganisms after samples were taken from the site until it is prepared for BOD_5 measurement. Water temperature was measured by using a glass thermometer, pH was measured using Jenway model 3305-pH meter and electrical conductivity (EC) was measured using Jenway Model 470 conductivity meter.

NH_3-N, PO_4^{3-}, S^{2-}, SO_4^{2-} and COD were determined with spectrophotometer (Hach DR/2010, USA) according to Hach instructions and using pillow (prepared reagents). BOD_5 and nitrate were determined using outlined standard methods for examination of wastewater manual that uses standard chemicals and measured using Jenway Model 9200 DO Meter and Jenway Model 6305 UV/Vis Spectrophotometer, respectively[15].

2.5. Macroinvertebrate sampling and identification

Benthic macroinvertebrates were collected to provide a qualitative description of the community composition at each sampling site. Samples were collected at each of the six sites by disturbing the substrate within a distance of about 0.5 m above the mouth of a net. The kick (disturbed) samples were collected in a standard aquatic scoop net and Surber sampler (mesh size = 500 µm, sampling area = 0.9 m^2). Sampling was continued for 30 min for a distance of 100 m following the wadeable rivers protocols for streams[14,16]. The kick samples of all members of a group in one site were composited in a single bottle and preserved with 96% ethanol with a label identifying the location, date and time.

In Addis Ababa University, Limnology Laboratory following the collection day, benthic macroinvertebrate samples were cleaned and the samples were transferred to white enamel or plastic tray and a small amount of the sample was randomly placed in a

Petri dish to be identified. Using a dissecting microscope and identification keys, aquatic insects were identified to family level and placed in vials containing 70% ethyl alcohol.

Only the organisms from the sweep were used to estimate the index, based on relative abundances of macroinvertebrates. All sweeps were used to calculate the index based on taxon richness.

Metrics were reviewed based on description in the Environmental Protection Agency (EPA), and Dermott and Pachkevitch[17] from the data. Then Wedecha River index was calculated from the metrics from the data to produce an estimate of aquatic community health at each site.

2.6. Macroinvertebrate metric selection

2.6.1. Biological integrity

The U.S. EPA defines biological integrity as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of the natural habitats of the surrounding region[18]. Changes of the environmental condition resulting from human activities caused a decline in biological integrity and could make the environment uninhabitable for appropriate organisms[4].

A biological integrity approach consists of four steps: 1) defining biological condition in a minimally disturbed area – what the natural condition in the area should be, 2) defining biological attributes that change along the gradient of human influence, 3) associating those changes with specific human impacts, and 4) identifying management practices for improving biological integrity[4,7].

2.6.2. Metrics

A metric is a characteristic of the biota that changes in some predictable way with increased human influence[4]. Various attributes of the benthic macroinvertebrate community have been characterized in the form of quantitative measures called metrics. The attributes of the community that are measured by these metrics fall into several categories of benthic community characteristics and the specific metrics within those categories can indicate different aspects of the community condition[7]. For example, metrics dealing with species richness or diversity, such as total taxa, can be used as indicators of community health because an ecologically healthy system is generally expected to support a more diverse community of fauna that can be supported in an ecologically impaired area. The identifications and counts of organisms collected at each site provide the information used to calculate a suite of metrics for each benthic sample[4,7].

Metrics evaluated for use with benthic macroinvertebrate data in a typical Macroinvertebrate Index of Biotic Integrity are represented in four categories[18].

2.6.3. Metric categories

The categories of metric include 1) richness measures (such as total taxa), 2) tolerance measures (such as percent of tolerant taxa), 3) composition measures (such as percent of dominant taxa), and 4) trophic structure measure (such as percent of shredders)[7,18] as indicated in Table 1.

2.7. Statistical analyses

Pearson bivariate correlation analysis was used to relate benthic macroinvertebrate metrics to physicochemical parameters and macroinvertebrates to each other. All statistical analysis was performed using the SPSS statistical software[19] and Excel spreadsheet.

3. Results

Along Wedecha River a total of 6 sites, one reference site and five impaired sites were surveyed during the study periods (Figure 1). From samples collected for analyses, mean physicochemical data and macroinvertebrates collected from each site are given in Tables 2 and 3, respectively.

Table 1

Candidate metrics and expected direction of metric response to increasing perturbation[5].

Category	Metrics	Description (Definition)	Expected response to increasing impact
Taxonomic richness	No. taxa	Measures the overall variety of the macroinvertebrate assemblages	Decrease
	No. Odonata taxa	Number of dragonflies and damselflies taxa	Decrease
	No. Hemiptera taxa	Number of water or true bugs taxa	Decrease
	No. Diptera taxa	Number of "true" fly taxa, which includes midges	Decrease
	No. Chironomidae taxa	Number of taxa of chironomid (midge) larvae	Decrease
	No. Coleoptera taxa	Number of beetle taxa (adult or larva)	Decrease
	No. Mollusca	Number of taxa of Mollusca	Increase
	No. Physidae taxa	Number of taxa of Physidae	Increase
	No. Planorbidae taxa	Number of taxa of Planorbidae	Decrease
Taxonomic composition	% Odonata	Percent of mayfly nymphs	Decrease
	% Hemiptera	Percent of caddisfly larvae	Decrease
	% Diptera	Percent of dipterans	Decrease
	% Chironomidae	Percent of midge larvae	Decrease
	% Coleoptera	Percent of beetle larvae and aquatic adults	Decrease
	% Mollusca	Percent of Mollusca	Increase
	% Physidae	Percent of aquatic Mollusca	Increase
Tolerance/Intolerance	% Dominant taxon	Percent of the most abundant taxon	Increase

Table 2
Physicochemical values of the six study sites (mean ± SE, n = 3).

Parameter	Sites					
	S_0 (Site 0)	S_1 (Site 1)	S_2 (Site 2)	S_3 (Site 3)	S_4 (Site 4)	S_5 (Site 5)
pH	7.8 ± 0.4	7.2 ± 0.1	7.3 ± 0.2	7.3 ± 0.3	7.6 ± 0.2	8.1 ± 0.2
Temperature (°C)	23.3 ± 0.3	21.3 ± 0.3	21.0 ± 0.6	20.7 ± 0.3	20.7 ± 0.7	19.0 ± 0.6
EC (μS/cm)	351.0 ± 20.7	1 798.7 ± 19.3	1 882.7 ± 88.4	1 653.0 ± 120.0	452.0 ± 27.6	619.3 ± 23.4
COD (mg/L)	19.3 ± 2.7	46.4 ± 6.6	60.3 ± 6.5	58.5 ± 5.3	24.6 ± 2.5	37.1 ± 3.4
BOD_5 (mg/L)	12.8 ± 1.5	28.7 ± 2.9	46.7 ± 5.4	45.3 ± 5.2	19.9 ± 2.5	31.4 ± 2.8
S^{2-} (mg/L)	0.3 ± 0.1	0.01	0.01	0.01	0.12	0.09
SO_4^{2-} (mg/L)	0.7 ± 0.7	280.0 ± 20.0	313.3 ± 14.5	276.7 ± 14.5	28.0 ± 12.0	92.0 ± 30.3
PO_4^{3-} (mg/L)	2.3 ± 0.1	8.4 ± 2.2	19.6 ± 4.0	11.9 ± 1.9	4.5 ± 0.6	3.9 ± 0.3
NH_3-N (mg/L)	1.1 ± 0.3	0.8 ± 0.1	0.7 ± 0.1	0.6 ± 0.0	0.7 ± 0.1	0.9 ± 0.1
NO_3-N (mg/L)	0.4 ± 0.4	699.7 ± 28.5	719.5 ± 87.3	549.0 ± 102.0	42.1 ± 15.1	78.4 ± 7.6

3.1. Physicochemical parameters

In this study, the average results for the 10 physicochemical parameters that differentiate impacted from unimpaired sites are given in Table 2. pH and temperature had no significant difference between the reference site and the impaired sites but EC, COD, BOD_5, PO_4^{3-} and NO_3-N had high significant difference.

3.2. Biological parameters

A total of 17 373 macroinvertebrate individuals of 34 families were collected from all 6 sites of the study area (Table 3). Macroinvertebrate sample sizes ranged from 77 (S_5) to 6 309 (S_4) individuals per site and taxa richness ranged from 7 (S_1 and S_5) to 30 families (S_0). Physidae (Mollusca) was the most abundant family collected (5 992 individuals), followed by Hydrobiidae (Mollusca, 715 individuals), Coenagrionidae (Odonata, 467 individuals), Viviparidae (Mollusca, 354 individuals), Gerridae (Hemiptera, 308 individuals), Chironomidae (Diptera, 128 individuals), Notonectidae (Hemiptera, 126 individuals), others are below 100 individuals. Among the 34 families collected (Table 3), 15 were found only in the reference site, 4 were commonly found in impaired sites, and 2 were common in impaired and the reference site. The abundance of organisms is given in Tables 4-6.

3.3. Correlation between physico-chemical parameters and macroinvertebrate metrics

From this study, nutrient enrichment, pesticides and organic loading were important in shaping community index in Wedecha River. The distribution of macroinvertebrates and the disappearance of some sensitive taxa were associated with depletion of dissolved oxygen and availability of food; and also pesticide toxicity might have effect on it.

From the result of Pearson correlation analysis (Table 7) at α = 0.05, metrics expected to decrease with perturbation and had strong negative correlation with physicochemical parameters (Table 8).

From the Pearson correlation analysis (Table 7) at = 0.05, metrics expected to decrease with perturbation and had strong positive relationship with some physicochemical parameters (Table 9). On the other hand, metrics expected to increase with disturbance and had strong negative relation with physicochemical parameters (Table 10). In this study, temperature and pH were almost the same and sulphide and ammonia were very low in amount with increasing pollution load.

Table 3
Total number of macroinvertebrate taxa collected at 6 sites on Wedecha River.

Taxon		Site					
		S_0	S_1	S_2	S_3	S_4	S_5
Ephemeroptera	Baetidae	13	0	0	0	0	0
	Caenidae	2	0	0	0	0	0
	Heptageniidae	3	0	0	0	0	0
Plecoptera		0	0	0	0	0	0
Trichoptera		0	0	0	0	0	0
Lepidoptera	Pyralidae	0	0	1	0	0	0
Odonata	Aeshinidae	33	0	0	2	0	0
	Calopterygidae	13	0	0	0	0	0
	Coenagrionidae	442	20	3	2	0	0
	Cordulegastridae	4	0	0	0	0	0
	Gomphidae	8	0	0	0	0	0
	Lestidae	1	0	0	0	0	0
Coleoptera	Dytiscidae	6	0	4	0	4	1
	Elmidae	2	0	0	0	0	2
	Gyrinidae	10	1	0	0	10	0
	Haliplidae	1	0	0	0	1	0
	Hydrophilidae	5	25	8	5	27	0
Diptera	Ceratopogonidae	2	0	0	0	0	0
	Chironomidae	116	10	0	0	0	2
	Psychodidae	26	0	0	1	0	0
	Simuliidae (black flies)	13	0	0	0	0	0
	Tabanidae	0	0	1	0	1	0
Hemiptera	Belostomatidae	46	4	2	2	7	0
	Corixidae	31	0	0	0	1	2
	Gerridae	298	0	1	0	9	0
	Hydrometridae	2	0	0	0	0	0
	Naucoridae	14	0	2	0	11	0
	Nepidae	2	0	0	0	0	0
	Notonectidae	103	6	6	4	7	0
	Pleidae	2	0	0	0	0	0
	Veliidae	49	0	0	0	0	0
Mollusca	Hydrobiidae	0	0	0	343	372	0
	Physidae	180	2 536	2 974	3 420	5 656	36
	Planorbidae	57	0	0	1	1	1
	Viviparidae	0	0	0	119	202	33
	Collembola	1	0	0	0	0	0
Total number of taxa collected over the sample period		30	7	10	10	14	7
Total abundance		1 485	2 602	3 002	3 899	6 309	77

Table 4

Taxa very common at the reference site.

Taxa		Abundance	%*
Order	Family		
Ephemeroptera	Baetidae	13	100.0
Odonata	Aeshinidae	33	94.3
	Calopterygidae	13	100.0
	Coenagrionidae	442	94.6
Diptera	Chironomidae	116	90.6
	Psychodidae	26	100.0
	Simuliidae (black flies)	13	100.0
Hemiptera	Belostomatidae	46	75.4
	Corixidae	31	91.2
	Gerridae	298	96.8
	Notonectidae	103	81.7
	Veliidae	49	100.0
Mollusca	Planorbidae	57	95.0

*: Percent of the total family.

Table 5

Taxa common in impaired sites.

Taxa		Abundance	%*
Order	Family		
Coleoptera	Hydrophilidae	65	92.9
Mollusca	Hydrobiidae	715	100.0
	Physidae	14 622	98.8
	Viviparidae	354	100.0

*: Percent of the total family.

Table 6

Taxa common to reference and impaired sites.

Taxa		Abundance		%*
Order	Family	Reference	Impaired	
Coleoptera	Gyrinidae	10	11	47.6, 52.4
Hemiptera	Naucoridae	14	13	51.9, 48.1

*: Percent of the total family.

Table 7

Significant associations (tested at the α = 0.05 level) between macroinvertebrate metrics and physicochemical parameters.

Parameter	No. taxa	No. Odon	No. Hemi	No. Dipt	No. Chiro	No. Coleo	No. Mollu	No. Phys	No. Planor	% Odon	% Hemi	% Dipt	% Chiro	% Coleo	% Mollu	% Phys	% DT
pH	0.301	0.328	0.344	0.330	0.326	-0.138	-0.539	-0.575	0.362	0.337	0.402	0.534	0.594	0.869	-0.426	-0.773	-0.867
Temperature (°C)	0.828	0.827	0.824	0.826	0.826	0.418	-0.116	-0.111	0.807	0.822	0.780	0.664	0.598	-0.425	-0.761	-0.370	-0.175
EC (μS/cm)	-0.593	-0.506	-0.545	-0.507	-0.500	-0.358	0.188	0.233	-0.538	-0.515	-0.556	-0.609	-0.631	-0.532	0.564	0.735	0.753
COD (mg/L)	-0.698	-0.648	-0.678	-0.655	-0.657	-0.631	0.180	0.203	-0.658	-0.651	-0.669	-0.685	-0.687	-0.375	0.675	0.674	0.628
BOD_5 (mg/L)	-0.654	-0.615	-0.641	-0.623	-0.628	-0.648	0.134	0.163	-0.623	-0.616	-0.630	-0.643	-0.644	-0.336	0.636	0.634	0.589
S^{2-} (mg/L)	0.955	0.999	0.999	0.998	0.997	0.176	-0.510	-0.528	10.000	10.000	0.998	0.971	0.946	0.112	-0.995	-0.838	-0.710
SO_4^{2-} (mg/L)	-0.647	-0.556	-0.596	-0.558	-0.552	-0.441	0.163	0.205	-0.585	-0.564	-0.599	-0.638	-0.653	-0.472	0.606	0.728	0.727
PO_4^{3-} (mg/L)	-0.389	-0.421	-0.432	-0.431	-0.438	-0.297	0.315	0.357	-0.436	-0.423	-0.458	-0.545	-0.581	-0.641	0.478	0.684	0.725
NH_3-N (mg/L)	0.652	0.790	0.780	0.801	0.811	0.178	-0.731	-0.730	0.783	0.789	0.811	0.874	0.893	0.584	-0.830	-0.839	-0.791
NO_3-N (mg/L)	-0.563	-0.476	-0.514	-0.475	-0.468	-0.291	0.193	0.242	-0.511	-0.485	-0.529	-0.588	-0.614	-0.549	0.538	0.737	0.767

Odon: Odonata; Hemi: Hemiptera; Dipt: Diptera; Chiro: Chironomidae; Coleo: Coleoptera; Mollu: Mollusca; Phys: Physidae; Planor: Planorbidae; DT: Dominant taxon.

Table 8

Physicochemical parameters that have strong negative relationship with macroinvertebrate metrics expected to decrease with perturbation.

Parameter	No. taxa	No. Odon	No. Hemi	No. Dipt	No. Chiro	No. Coleo	No. Planor	% Odon	% Hemi	% Dipt	% Chiro	% Coleo
EC (μS/cm)	-0.59	-0.51	-0.545	-0.51	-0.50		-0.54	-0.52	-0.56	-0.61	-0.63	-0.53
COD (mg/L)	-0.70	-0.65	-0.68	-0.66	-0.66	-0.63	-0.66	-0.65	-0.67	-0.69	-0.69	
BOD_5 (mg/L)	-0.65	-0.62	-0.64	-0.62	-0.63	-0.65	-0.62	-0.62	-0.63	-0.64	-0.64	
SO_4^{2-} (mg/L)	-0.65	-0.56	-0.60	-0.567	-0.55		-0.59	-0.56	-0.60	-0.64	-0.65	
PO_4^{3-} (mg/L)										-0.55	-0.58	-0.64
NO_3-N (mg/L)	-0.56		-0.51				-0.51		-0.53	-0.59	-0.61	-0.55

Odon: Odonata; Hemi: Hemiptera; Dipt: Diptera; Chiro: Chironomidae; Coleo: Coleoptera; Planor: Planorbidae.

Table 9

Physicochemical parameters that have strong positive relationship with macroinvertebrate metrics expected to decrease with perturbation.

Parameter	No. taxa	No. Odon	No. Hemi	No. Dipt	No. Chiro	No. Planor	% Odon	% Hemi	% Dipt	% Chiro	% Coleo
pH									0.534	0.594	0.869
Temperature (°C)	0.828	0.827	0.824	0.826	0.826	0.807	0.822	0.780	0.664	0.598	
S^{2-} (mg/L)	0.955	0.999	0.999	0.998	0.997	10.00	10.00	0.998	0.971	0.946	
NH_3-N (mg/L)	0.652	0.790	0.780	0.801	0.811	0.783	0.789	0.811	0.874	0.893	0.584

Odon: Odonata; Hemi: Hemiptera; Dipt: Diptera; Chiro: Chironomidae; Coleo: Coleoptera; Planor: Planorbidae.

Table 10

Physicochemical parameters that have strong negative relationship with macroinvertebrate metrics expected to increase with perturbation.

Parameter	No. Mollusca	No. Physidae	% Mollusca	% Physidae	% Dominant taxon
pH	-0.539	-0.575		-0.773	-0.867
Temperature (°C)			-0.761		
S^{2-} (mg/L)	-0.510	-0.528	-0.995	-0.838	-0.710
NH_3-N (mg/L)	-0.731	-0.730	-0.830	-0.839	-0.791

Metrics expected to increase with perturbation and had a strong positive relationship with some physicochemical parameters (Table 11).

Table 11
Physicochemical parameters which have strong positive relationship with macroinvertebrate metrics expected to increase with perturbation.

Parameter	% Mollusca	% Physidae	% Dominant taxon
EC (μS/cm)	0.564	0.735	0.753
COD (mg/L)	0.675	0.674	0.628
BOD_5 (mg/L)	0.636	0.634	0.589
SO_4^{2-} (mg/L)	0.606	0.728	0.727
PO_4^{3-} (mg/L)		0.684	0.725
NO_3-N (mg/L)	0.538	0.737	0.767

As seen from the above correlations, physicochemical parameters: EC, COD, BOD_5, SO_4^{2-}, PO_4^{3-} and NO_3-N and metrics: percent of Mollusca, percent of Physidae and percent of dominant taxa could be used for rapid monitoring, and expected to have strong positive relation with increasing disturbance.

The study was limited to correlation of macroinvertebrates metrics and physiochemical analysis. These may not tell the overall condition of the Wedecha River. But this result might show picture of the Wedecha River and floriculture industries pollution that could give clue for future investigations.

4. Discussion

4.1. Physicochemical parameters

Physicochemical variables that are modified by habitat disturbances show short-term pollution effect with impaired sites[20]. Rana reported that conductivity, dissolved oxygen, pH and organic load (which can be expressed in the form of COD and BOD_5) in degraded habitat were significant factors to compare reference and impaired sites in streams. In this study, of the 10 variables, EC, COD, BOD_5, SO_4^{2-} and PO_4^{3-} showed habitat degradation in impaired sites with the comparison of the reference site[21,22].

4.2. Correlation between physico-chemical parameters and macroinvertebrate metrics

Martínez-Sanz and Orwa noted that the variation in the functional organization of macroinvertebrate communities reflects the alterations of physicochemical characteristics such as low dissolved oxygen concentration and food source availability in some stream systems in Ethiopia[7,23].

Martínez-Sanz *et al.* noted that in wadeable streams, the number of Ephemeroptera, Plecoptera and Trichoptera taxa decreased relative to increasing nutrient concentration and they were negatively correlated. In this study also with increasing nutrient concentration, sensitive taxa eliminated, which means they are negatively correlated[7].

As described by Sultana and Seshi Kala, invertebrates (*e.g.* insect larvae) and microorganisms depend on dissolved oxygen. Without sufficient oxygen, they cannot grow and reproduce effectively. High BOD means lower dissolved oxygen; low oxygen levels cause stress, disease, slow growth rates and in severe cases, death. The oxygen requirements of freshwater fish and macroinvertebrates differ between species. Species that need high concentrations of dissolved oxygen, such as mayfly nymphs, stonefly nymphs and caddy flies larvae will move out or die. In this study, Ephemeroptera was limited only in the reference site but Plecoptera and Trichoptera were totally absent in all of the sites and other macroinvertebrates such as Odonata, Diptera, Coleoptera, Hemiptera, and Planorbidae (Mollusca) decreased with relative nutrient load and high BOD_5[24].

Ammonia did not show its negative effect on intolerant taxa; it might be due to presence of low amount as floriculture industries directly used nitrate fertilizers. Orwa *et al.* also reported that ammonia nitrogen accounted for a significant portion of the variation in biotic metric index scores in the headwaters and to a lesser extent, in Great Akaki River[23]. Mean biotic metric index scores at sites having concentration of NH_3-N $\geqslant$ 1.0 mg/L were usually significantly lower than all other categories across streams. In Wedecha River, the mean value of ammonia for the reference site S_0 was 1.08, whereas mean value of ammonia for impaired sites ranged from 0.6 (S_3) to 0.9 (S_5).

Sultana and Seshi Kala noted non-insects were positively associated with increasing nutrient concentration. In this study, Mollusca groups: Hydrobiidae, Physidae and Viviparidae were positively associated with increasing nutrient concentration. Sensitive organisms will be replaced by organisms such as sludge worms, blackfly larvae and leeches, which can tolerate lower dissolved oxygen concentrations. Waters that have low dissolved oxygen sometimes smell bad because of waste products produced by organisms that live in low oxygen environments, due to NH_3 and H_2S production[24].

The increase in nutrients such as nitrates, sulphates and orthophosphate leading to low dissolved oxygen affects the life of some macroinvertebrates as shown from the BOD_5 result. Nutrient enrichment decreases macroinvertebrate richness by elimination of sensitive taxa mostly represented by the insect orders Ephemeroptera, Plecoptera and Trichoptera[7]. In Wedecha River, the absence of most taxa in the rest of the sites except in the reference site supports this explanation. In the polluted sites with high nutrient enrichment and organic loading, only organisms with special physiological and morphological adaptations could be found, such as Hydrobiidae, Physidae and Viviparidae snails.

Floriculture industries have positive impacts on economic development of the country and the surrounding community but to the contrary they have negative impact on the aquatic environment: macroinvertebrates depletion or degradation of biodiversity (species abundance and diversity), disappearance of sensitive taxa in the downstream and food chain of aquatic organisms. This is due to the disposal of wastewater to the nearby rivers. Floriculture industries use a variety of chemicals.

The study revealed that physicochemical parameters such as EC, COD, BOD_5, SO_4^{2-}, PO_4^{3-} and NO_3-N and macroinvertebrate metrics such as total number of taxa, percent of Hemiptera, percent of

Chironomidae and percent of Coleoptera decrease with disturbance. However, number of Mollusca, percent of Mollusca and percent of dominant taxa increase with disturbance. So physicochemical parameters: EC, COD, BOD_5, SO_4^{2-}, PO_4^{3-} and NO_3-N with number of Mollusca, percent of Mollusca and percent of dominant taxa can be used for rapid monitoring in the presence of resource limitations.

From the results of the study, floriculture industries are affecting Wedecha River. The water condition can be maintained by using best management practices or wastewater treatment methods.

Conflict of interest statement

We declare that we have no conflict of interest.

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