EFFECTS OF GUMUSHANE MUNICIPAL WASTEWATERS ON THE STREAM HARSIT WATER QUALITY, TURKEY
INFLUENCE DES EAUX USEES MUNICIPALES DE GUMUSHANE SUR LA QUALITE DE L'EAU HARSIT EN TURQUIE

Adem BAYRAM, Karadeniz Technical University, Faculty of Engineering, Department of Civil Engineering, 61080, Trabzon, Turkey. abayram@ ktu.edu.tr
Hizir ONSOY, Karadeniz Technical University, Faculty of Engineering, Department of Civil Engineering, 61080, Trabzon, Turkey. honsoy@ ktu.edu.tr
Volkan Numan BULUT, Karadeniz Technical University, Macka Vocational School, 61750, Macka-Trabzon, Turkey. vnbulut@ktu.edu.tr
Mehmet TUFEKCI, , Karadeniz Technical University, Faculty of Science, Department of Chemistry, 61080, Trabzon, Turkey. mtufekci@ktu.edu.tr
Adem AKPINAR, Gumushane University, Faculty of Engineering, Department of Civil Engineering, 29000, Gumushane, Turkey. aakpinar@ ktu.edu.tr

ABSTRACT: The aim of this study was to examine effect of municipal wastewaters of the city of Gumushane within the Eastern Black Sea Basin on the stream Harsit water quality. For this reason, a study was fortnightly conducted during the four seasons between March 2009 and February 2010. The water samples collected in three monitoring stations along the main branch of stream Harsit were analyzed for six parameters, nitrite-nitrogen (NO_2^--N), nitrate-nitrogen (NO_3^--N), ammonium-nitrogen (NH_4^+-N), total nitrogen (TN), orthophosphate phosphorus (o-PO_4^{3-}-P), chemical oxygen demand (COD), in laboratory. Four parameters, dissolved oxygen (DO), water temperature (T), pH, electrical conductivity (EC), were also determined in situ. According to the Turkish Water Pollution Control Regulation (TWPCR), the stream Harşit was classified and the obtained results were evaluated.

Keywords: The stream Harsit, municipal wastewaters, water quality

RESUME : Le but de cette étude est d'analyser les influences des eaux usées municipales de la ville Gumushane sur la qualité de l'eau Harsit en Turquie. Dans ce contexte, une campagne de travail a été effectuée du Mars 2009 au Février 2010 d'un intervalle de temps de quinze jours pendant quatre saisons. Les échantillons d'eau en trois postes sur le cours principal Harsit ont été analysés au laboratoire. Les paramètres étudiées sur les échantillons sont le nitrite nitrogène (NH_4^+-N), le nitrate nitrogène (NO_3^--N), l'azote ammoniacal (NH_4^+-N), l'azote total (NT), l'ortho phosphate phosphorés (o-PO_4^{3-}-P) et la demande chimique en oxygène (DCO) e de plus, l'oxygène dissous (OD), la température de l'eau (T), le pH et la conductivité électrique (CE). Les résultats du laboratoire ont été analysés et par la suite, une classification du Cours d'Eau Harsit a été faite suivant les Critères de la Pollution d'Eau en Turquie (CPET).

Mots clés: Cours d'eau Harsit, eaux usées municipales, pollution d'eau

INTRODUCTION

Rapid population growths, land development along river basin, urbanization and industrialization have subjected the rivers to increase stress, giving rise to water pollution and environmental deterioration (Sumok 2001). The surface water pollution issue has been enlisted as one of the most serious problems in developing countries. Most of the rivers in urban areas of the developing world are the end point of effluents discharged from the industries (Phiri et al. 2005, Suthar et al. 2010).

In recent years, a lot of studies related to stream water quality were conducted in different parts of Turkey and some of them focused on water pollution (Akkoyunlu 2002, Erdem and Topkaya 2004, Elhatip and Güllü 2005, Karaer and Kucukballi 2006, Tarcan et al. 2010).

The aim of this study was to investigate effect of municipal wastewaters of the city of Gumushane within the Eastern Black Sea Basin on the stream Harsit water quality, and to determine the water quality according to TWPCR for different points of the stream.

DESCRIPTION OF THE STUDY AREA

With a precipitation area of 24077 km^2, Eastern Black Sea Basin is one of the most important hydrological basins. It consists of sub-watersheds such as the stream Melet, Pazar, Karadere and Firtina watersheds.

The stream Harsit watershed is one of these sub-watersheds. The stream is formed by small streams joining together and originated from Vauk Mountains in the east border of Gumushane Province and poured into the Black Sea in Tirebolu town. The length of its main branch is 143 km, and its catchment area is 3280 km^2 (Bayram et al. 2010a, Bayram et al. 2010b, Bayram et al. 2010c). The sampling locations are in the adjacent area of Gumushane Province which lies between the 38° 45′ and 40° 12′ eastern longitudes and 39° 45′ and 40° 50′ northern latitudes. The total population of Gumushane Province is 130976 according to the last census in 2009, and the population of the Gumushane city center is 27215 (TURKSTAT 2010). Generated municipal wastewaters are discharged into the stream Harsit without any treatment, and municipal solid wastes are also dumped to the stream from time to time. Therefore, the stream water quality deteriorates, unpleasant views are revealed, and serious odor problems emerge especially in the summer season.

MATERIALS AND METHODS

Sampling

The water samples were fortnightly collected at three monitoring stations; Akcakale (40° 25' 23.6" N - 39° 31' 37.7" E), Gumushane (40° 29' 36.6" N - 39° 27' 30.4" E), and Torul (40° 32' 55.7" N - 39° 18' 52.5" E), which are located in the course of the stream from the source to the downstream during the study period (March 2009 - February 2010) These stations are shown in Fig. 1.

Sampling, preservation, and transportation of the water samples to the laboratory were as per standard methods (APHA, 1992). After the raw water samples were transported to the laboratory in Trabzon, they were filtered through the cellulose nitrate membrane filters having 0.45 μm pore size under vacuum and stored at 4°C until the analysis. In order to prevent the contamination of the samples, prior to use, all of the plastic bottles (500 ml) were cleaned with 1 M HNO_3 and rinsed with double-distilled water. The bottles were also pre-rinsed with the water before filling.

Fig. 1 Left up: Akcakale; Right up: Discharge point; Left down: Gumushane; Right down: Torul

Analysis

Dissolved oxygen (DO), water temperature (T), pH and electrical conductivity (EC) were measured *in situ* with a water quality checker (Horiba U-10).

Nitrite nitrogen (NO_2^--N), nitrate nitrogen (NO_3^--N), ammonium nitrogen (NH_4^+-N), total nitrogen (TN), orthophosphate phosphorus (o-PO_4^{3-}-P) and chemical oxygen demand (COD) of the water samples were determined on laboratory with a UV-vis spectrophotometer (Dr. Lange Cadas 200) according to the standard methods (APHA 1992). Total kjeldahl nitrogen (TKN) was also calculated as TN - (NO_2^--N + NO_3^--N).

The analyses were carried out in triplicate for each sample in a temperature controlled-room (21 ± 2°C), and the final result was presented as an arithmetic mean of three parallel determinations.
The inland water quality classification according to the studied parameter in this study, following the TWPCR, is presented in Table 1 (TWPCR 2004).

Table 1 Water quality classification levels for the studied parameters according to the TWPCR

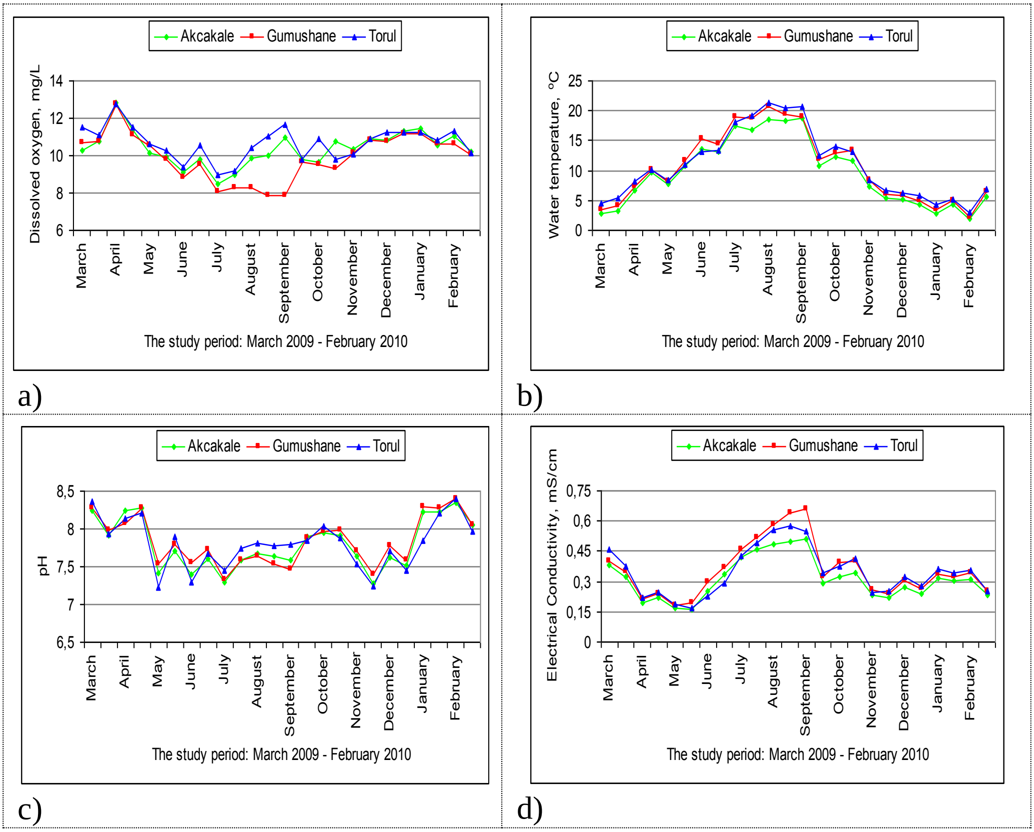
Water quality parameters		Water quality classes			
		I	II	III	IV
DO	(mg/L)	8	6	3	< 3
T	(ºC)	25	25	30	> 30
pH		6.5 - 8.5	6.5 - 8.5	6.0 - 9.0	< 6.0 - > 9.0
EC	(mS/cm)	-	-	-	-
NO_2^--N	(mg/L)	0.002	0.01	0.05	> 0.05
NO_3^--N	(mg/L)	5	10	20	> 20
NH_4^+-N	(mg/L)	0.2	1	2	> 2
TKN	(mg/L)	0.5	1.5	5	> 5
o-PO_4^{3-}-P	(mg/L)	-	-	-	-
COD	(mg/L)	25	50	70	> 70

The TWPCR divides inland waters into four classes:

Class I refers to high-quality water,
Class II refers to slightly polluted water,
Class III refers to polluted water,
Class IV refers to too much polluted water.

RESULTS AND DISCUSSION

Distribution of both *in situ* and laboratory studied parameters for each monitoring station are shown in Fig. 2. Also, seasonal change of the water quality parameters for each sampling station is provided in Tables 2, 3 and 4, respectively. Additionally, a classification for the stream Harsit is presented in Table 5 according to the TWPCR.



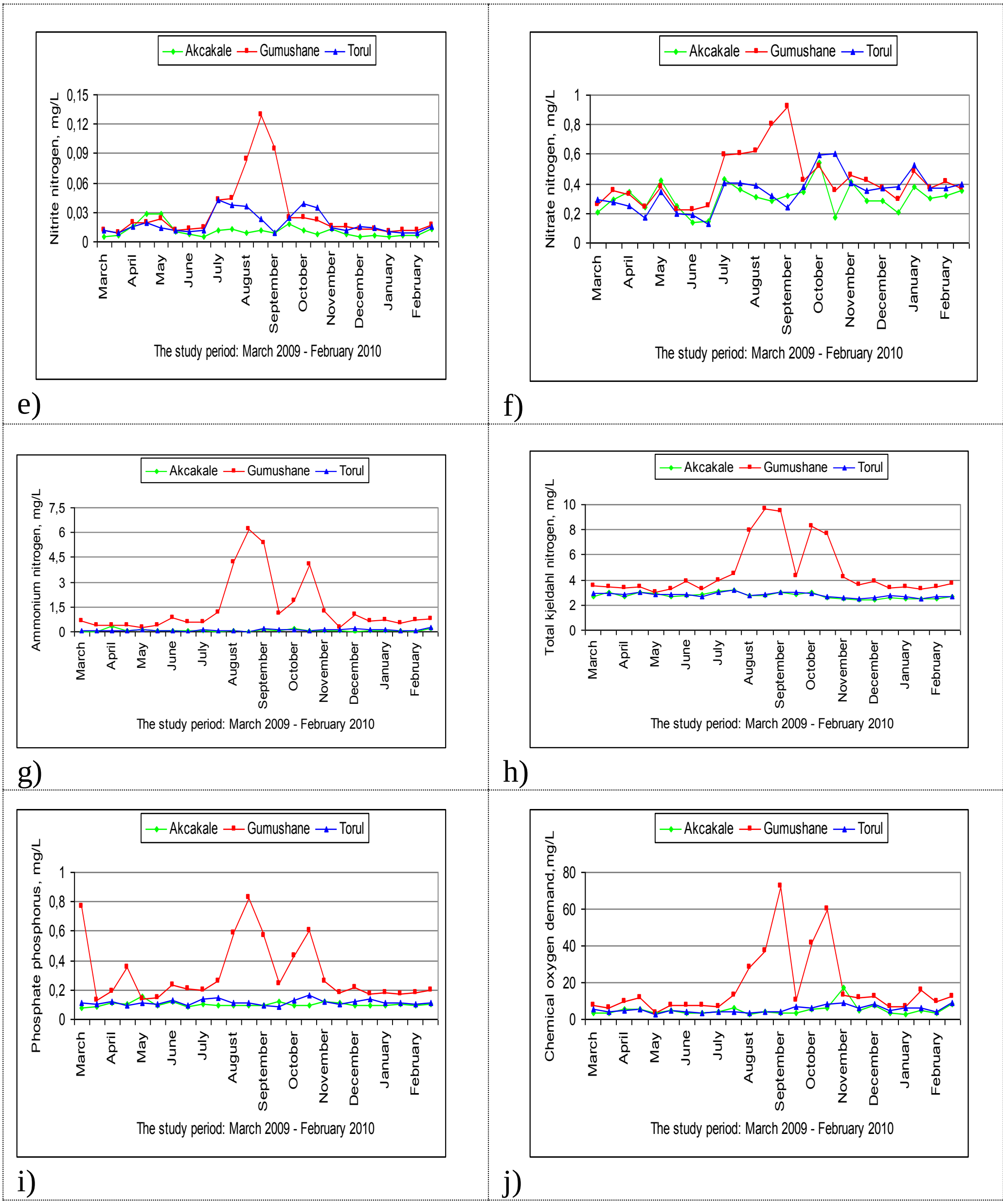


Fig. 2. (a,b,c,d,e,f,g,h,i,j) The yearly distributions of the studied parameters in the stream Harsit

Table 2. Seasonal change of the water quality parameters for Akcakale station in the stream Harsit

Parameters	Spring				Summer				Autumn				Winter			
	Min.	Max.	**Ave.**	S.D.	Min.	Max.	**Ave.**	S.D.	Min.	Max.	**Ave.**	S.D.	Min.	Max.	**Ave.**	S.D.
DO	9.94	12.80	**10.89**	1.06	8.47	9.98	**9.37**	0.61	9.65	10.94	**10.39**	0.57	10.18	11.30	**10.90**	0.47
T	2.8	10.7	**6.8**	3.3	13.1	18.6	**16.3**	2.4	5.4	18.7	**11.0**	4.6	2.0	5.6	**4.1**	1.4
pH	7.41	8.28	**7.97**	0.36	7.30	7.68	**7.53**	0.15	7.28	7.94	**7.71**	0.26	7.52	8.35	**8.00**	0.35
EC	0.163	0.379	**0.242**	0.090	0.254	0.495	**0.409**	0.096	0.221	0.512	**0.320**	0.106	0.232	0.317	**0.279**	0.036
NO_2^--N	0.005	0.029	**0.016**	0.011	0.005	0.013	**0.010**	0.003	0.008	0.018	**0.011**	0.004	0.005	0.013	**0.007**	0.003
NO_3^--N	0.205	0.424	**0.293**	0.081	0.140	0.428	**0.279**	0.115	0.176	0.545	**0.348**	0.125	0.205	0.381	**0.308**	0.062
NH_4^+-N	0.005	0.305	**0.100**	0.112	0.014	0.057	**0.040**	0.016	0.038	0.218	**0.103**	0.068	0.017	0.186	**0.067**	0.063
TKN	2.683	3.012	**2.832**	0.156	2.770	3.195	**2.916**	0.181	2.428	3.054	**2.730**	0.255	2.413	2.671	**2.527**	0.088
o-PO_4^{3-}-P	0.075	0.156	**0.106**	0.028	0.084	0.103	**0.125**	0.076	0.092	0.185	**0.118**	0.035	0.093	0.107	**0.098**	0.006
COD	3.32	5.52	**4.45**	1.00	2.75	6.52	**4.16**	1.26	3.14	17.2	**6.72**	5.29	2.48	8.06	**4.95**	2.28

When the yearly average values obtained for the Akcakale and Gumushane stations are compared, it is seen that there are very serious increases in the NO_2^--N concentration with 165%, NH_4^+-N concentration with 1759%, o-PO_4^{3-}-P concentration with 204% and COD concentration with 247% due to municipal waste water discharge just before the Gumushane station.

When the yearly average values obtained for the Gumushane and Torul stations are compared, it is seen that there are very serious decreases in the NO_2^--N concentration with 35%, NH_4^+-N concentration with 93%, o-PO_4^{3-}-P concentration with 67% and COD concentration with 69% due to the self-treatment capacity of the stream Harsit and the joining of small streams.

Table 3. Seasonal change of the water quality parameters for Gumushane station in the stream Harsit

Parameters	Spring				Summer				Autumn				Winter			
	Min.	Max.	**Ave.**	S.D.	Min.	Max.	**Ave.**	S.D.	Min.	Max.	**Ave.**	S.D.	Min.	Max.	**Ave.**	S.D.
DO	9.78	12.75	**10.94**	0.99	7.86	9.52	**8.47**	0.60	7.85	10.84	**9.54**	1.00	10.09	11.20	**10.75**	0.42
T	3.4	11.6	**7.5**	3.2	14.4	20.6	**17.9**	2.5	6.1	18.9	**11.9**	4.4	2.2	6.5	**4.7**	1.6
pH	7.53	8.28	**7.99**	0.29	7.33	7.73	**7.56**	0.13	7.39	7.99	**7.74**	0.26	7.58	8.40	**8.06**	0.32
EC	0.183	0.402	**0.263**	0.090	0.298	0.639	**0.478**	0.128	0.240	0.659	**0.379**	0.153	0.255	0.345	**0.306**	0.038
NO_2^--N	0.009	0.023	**0.016**	0.006	0.013	0.129	**0.055**	0.045	0.015	0.094	**0.033**	0.030	0.010	0.017	**0.013**	0.003
NO_3^--N	0.221	0.377	**0.296**	0.065	0.228	0.798	**0.516**	0.227	0.351	0.920	**0.516**	0.205	0.295	0.480	**0.384**	0.061
NH_4^+-N	0.233	0.652	**0.414**	0.135	0.576	6.180	**2.265**	2.361	0.270	5.381	**2.322**	1.977	0.549	1.060	**0.749**	0.175
TKN	3.060	3.539	**3.364**	0.170	3.295	9.673	**5.526**	2.612	3.589	9.486	**6.255**	2.509	3.266	3.907	**3.522**	0.247
o-PO_4^{3-}-P	0.133	0.770	**0.288**	0.250	0.195	0.827	**0.385**	0.262	0.108	0.607	**0.370**	0.198	0.172	0.213	**0.187**	0.015
COD	3.27	11.90	**7.65**	2.93	7.02	37.40	**16.98**	12.87	10.40	72.40	**34.80**	27.24	7.09	16.08	**10.89**	3.50

Table 4. Seasonal change of the water quality parameters for Torul station in the stream Harsit

Parameters	Spring				Summer				Autumn				Winter			
	Min.	Max.	**Ave.**	S.D.	Min.	Max.	**Ave.**	S.D.	Min.	Max.	**Ave.**	S.D.	Min.	Max.	**Ave.**	S.D.
DO	10.29	12.76	**11.30**	0.087	9.00	11.02	**9.92**	0.083	9.78	11.63	**10.51**	0.74	10.17	11.32	**10.99**	0.44
T	4.5	10.9	**7.9**	2.5	13.1	21.4	**17.6**	3.6	6.6	20.6	**12.5**	4.9	3.1	6.9	**5.3**	1.4
pH	7.22	8.37	**7.96**	0.40	7.30	7.81	**7.63**	0.20	7.25	8.03	**7.72**	0.28	7.45	8.40	**7.93**	0.34
EC	0.171	0.460	**0.276**	0.115	0.225	0.577	**0.427**	0.142	0.244	0.549	**0.362**	0.113	0.254	0.364	**0.319**	0.044
NO_2^--N	0.009	0.020	**0.014**	0.004	0.010	0.043	**0.027**	0.014	0.009	0.039	**0.022**	0.013	0.009	0.016	**0.012**	0.003
NO_3^--N	0.174	0.349	**0.255**	0.064	0.131	0.408	**0.306**	0.119	0.240	0.603	**0.429**	0.143	0.367	0.526	**0.401**	0.062
NH_4^+-N	0.067	0.104	**0.081**	0.014	0.030	0.100	**0.048**	0.026	0.095	0.163	**0.125**	0.030	0.085	0.242	**0.150**	0.058
TKN	2.811	2.929	**2.908**	0.074	2.687	3.166	**2.879**	0.178	2.532	3.041	**2.794**	0.224	2.523	2.716	**2.635**	0.083
o-PO_4^{3-}-P	0.099	0.121	**0.109**	0.008	0.094	1.230	**0.304**	0.454	0.089	0.167	**0.116**	0.029	0.101	0.135	**0.115**	0.011
COD	2.68	5.48	**4.59**	1.09	3.48	4.45	**4.02**	0.43	4.04	9.16	**6.68**	1.85	4.38	8.86	**6.37**	1.80

Table 5 Water quality classification levels for the studied parameters according to the TWPCR

Parameters	* : Class I; ** : Class II; *** : Class III; **** : Class IV											
	Spring			Summer			Autumn			Winter		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
DO	*	*	*	*	*	*	*	*	*	*	*	*
T	*	*	*	*	*	*	*	*	*	*	*	*
pH	*	*	*	*	*	*	*	*	*	*	*	*
EC												
NO_2^--N	***	***	***	***	****	***	***	***	***	**	***	***
NO_3^--N	*	*	*	*	*	*	*	*	*	*	*	*
NH_4^+-N	*	**	*	*	****	*	*	****	*	*	**	*
TKN	***	***	***	***	****	***	***	****	***	***	***	***
o-PO_4^{3-}-P	**	***	**	**	***	***	**	***	**	**	***	**
COD	*	*	*	*	*	*	*	**	*	*	*	*

CONCLUSION

The stream Harsit with the 3280 km^2 catchment area receives the wastewaters generated in the residential areas (e.g. Arzular, Kale, Tekke, Baglarbasi, Gumushane, Torul) in the course. Therefore, source of the water pollution in the stream Harsit is substantially anthropogenic.

The stream Harşit water can be classified as *high quality water* for each station according to the TWPCR in terms of DO, T, pH, NO_3^--N and COD (except for Gumushane station in autumn season). Due to municipal wastewater discharge into the stream, great increases were observed in the concentrations of NO_2^--N, NH_4^+-N, TKN, o-PO_4^{3-}-P and COD, especially in the summer and autumn seasons with the decreasing flowrate. However, remarkable change was not observed in the parameters DO, T, pH, EC and NO_3^--N. On the other hand, DO concentration increased in the final station namely Torul despite an increase in the water temperature thanks to reaeration mechanism and joining of small streams.

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