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Status of Contamination and Distribution of Effluents in Tasik Chini, Pahang, Malaysia

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ABSTRACT

The study investigates the spatial variation and index of water quality in Tasik Chini (Chini Lake), Pahang, Malaysia. Water samples were taken from 12 representative sites within the lake and two major feeder rivers. Physico-chemical parameters and heavy metal concentrations were analyzed using standard procedures. Observed data were calculated according to Department of Environment Water Quality Index (DOE-WQI) and classified to compare with National Water Quality Standard, Malaysia (NWQS). TSS, TDS and nitrate were categorized under class I. Water temperature, DO, BOD and turbidity were categorized under class II. Among others, pH, ammonical nitrogen (AN) and COD was under class III. Study revealed that station T2 was worse in condiion followed by stations T1 and L7. Heavy metals estimated by ICPMS indicated that Fe and Mn concentration were high in the mining zone station T2, whereas sites L4 and L8 had the highest concentration of Ba and Pb. The lake water quality was classified as class II based on WQI Malaysia. That is quite suitable for body contact and recreational purpose. In general, water quality varied over space of the catchment and most affected indicators were AN, COD and pH.

Key Words: Water Quality Index (WQI); Tasik Chini; Catchment and Tributaries; Water Quality

INTRODUCTION

Malaysia is growing rapidly for the past two decades based on economic growth. Development is associated with increased land use, urbanization for expanding population, replacing forest for industry or agriculture and others that affect and degrade water quality of natural reservoirs (Ho 1994). Knowledge of the present water condition status and estimation of its mechanism are prerequisites to formulate a sound solution to this complex problem (Maznah and Makhlough 2015). The increasing population has a high demand of water, where fresh water sources are definite. Multiple reservoirs and anthropogenic activities in the watershed transform the nutrient inputs which alter the reservoirs trophic level and physicochemical properties (Molisani et al. 2010). Hence, it is important to detect the present condition and protect the existing freshwater reservoirs.

Tasik Chini is the second largest natural freshwater lake in Peninsular Malaysia. It is located 100 km away from the state capital Kuantan city and south-east of the Pahang state. The lake plays an effectively important role for reduction of the frequency, level and velocity of flood and river bank erosion acting as a natural wetland ecosystem. Among another significant roles of this lake is as a natural fish reservoir for various moribund species, basic means for daily life and household and transportation for the locals living there. Three indigenous Jakun tribe communities living around the lake are called Orang Asli (Hanif et al. 2009). The reservoir has great tourism value due to its diversified natural architectural view. The basin drains through the sole zigzag Chini River into the Pahang River, the longest watercourse in Peninsular Malaysia (Ebrahimpour and Mushrifa 2010). The lake and swamps are awashed and incorporated with suspended solids and nutrients (such as AN) by the strong intertidal current of Pahang River during monsoon season. Nitrogen has a significant impact on the process of eutrophication (Geng et al. 2014). A 2 m high weir was built at the end of the Chini River to facilitate navigation for tourism purpose along the lake. Though the water level has risen as expected but, stagnant condition changed the lake ecosystem from semi-lotic to lentic. For last two decades, Tasik Chini experienced rapid anthropogenic activities in agriculture, building PLKN at the lake riparian area, re-activation of iron mine etc. around the catchment areas (Mir et al. 2015). Deforestation and land degradation are common scenarios for the conversion of primary forest to oil palm and rubber plant and moreover illegal logging activities. The adverse impact of these changes impaired the flora and fauna of the ecosystems and increased sedimentation rate in the lake. Once famous lake for lotus (*Nelumbo nucifera*) and water lily is now infested with *Cabomba furcata* - an aquatic weed (Shuhaimi-Othman et al. 2007). Therefore, the goal of this study is to assess the present lake water quality at different places.

Several studies have been made on water quality. Shuhaimi-Othman et al. (2007) investigated the representing part of lake water quality over time and space. Abas et al. (2008) explored the seasonal variance of lake water quality over seven feeder rivers. Mir et al. (2016) studied sediment loading from the feeder rivers over the year. Latif et al. (2015) detected the sources of dust fall into the Tasik Chini watershed. In a different experiment Sujaul et al. (2013) projected the nutrient and sediment loading from a feeder (Melai River) river sub-catchment. Ahmad and Shuhaimi-Othman (2010) analyzed the context of heavy metals in sediments and fishes from different parts of the lake. Yet there is no study integrating the lake with its feeder rivers water quality. Therefore, this paper reports on a detailed study of the current water quality status of the reservoir over space.

MATERIALS AND METHODS

Study Area

Current research area includes Tasik Chini and its catchment, covering 12565 acres (=5235 ha; Latif et al. 2015) 70km west from the state capital of Pahang in Peninsular Malaysia. Totally humid tropical climate bears/causes annual rainfall ranging from 1,488 to 3,071 mm (Ebrahimpour and Mushrifah 2008). It has 12 protruding opened water bodies which give it shape like finger. Among them 12 sampling stations - ten in the lake and two in the rivers- were selected for sampling during monsoon period. The locations of these stations and their sources of pollution are described in Table 1, and the stations are shown in Figure 1.

Sampling Program

Surface water samples were taken in three replications from about 10-15 cm below the surface, according to Bartram and Ballance (1996) and APHA (2012) during January to May 2015. 1-L high-density polythene (HDPE) Niskin bottles (General Ocenics, Germany) were used to collect the surface water samples for physicochemical observations. Properly acid cleaned (15% HNO_3) and metal free HDPE bottles were rinsed

Table 1. Geographical description of sampling positions at the Tasik Chini

Station	Name	Latitude	Longitude	Sources of pollution
L1	Laut Jemberau	3 25 331″	102 55 662″	Uphill iron mining
L2	Laut Batu Busuk	3 413″	102 55 385″	NATP. Logging and forest
L3	Laut Melai	3 24 877″	102 54 727″	Uphill mining, settlement and agriculture
L4	Laut Serodong	3 24 970″	102 54 642″	Mining and agriculture
L5	Laut Kenawar	3 25 940″	102 54 653″	Forest
L6	Laut Gt. Teratai	3 26 283″	102 54 726″	Forest
L7	Laut Tg Jeranking	3 26 512″	102 54 773″	Draining point of the lake
L8	Laut Cenahan	3 26 248″	102 55 89″	Settlement and agriculture
L9	Laut Pulai Balai	3 25 986″	102 55 334″	Tourist activates, hotels and restaurants
L10	Laut Gumum	3 26 131″	102 55 707″	Village and agriculture
T1	River Jemberau	3 25 175″	102 55 869″	Exposed mining zone
T2	River Kura-Kura	3 25 981″	102 55 884″	Uphill agriculture and settlement

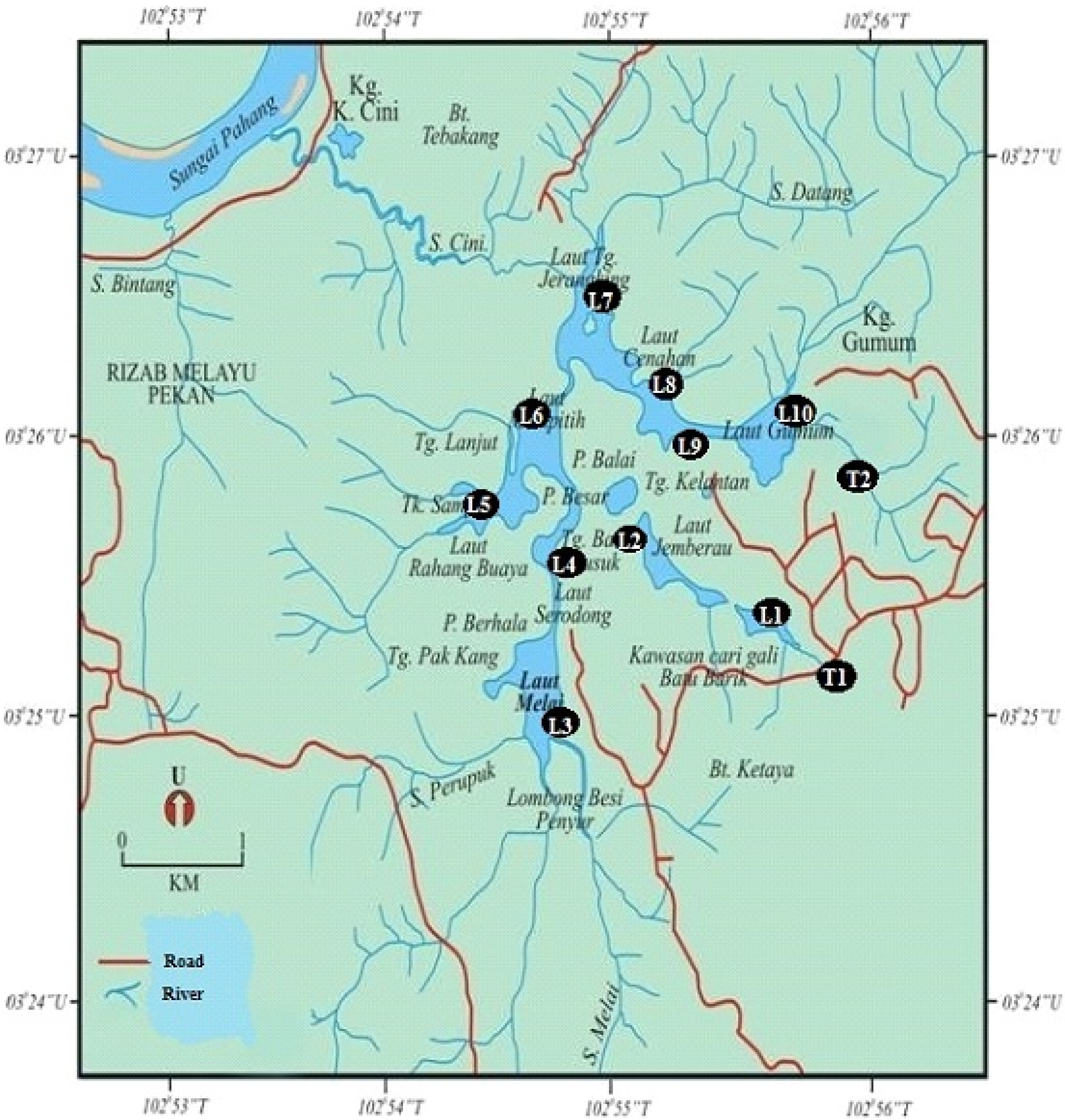

Figure 1. Study area and catchment at the Tasik Chini

with the corresponding sampling water before use. Amber rubber coated 300 mL BOD bottles were used to collect BOD water samples to protect them from sunlight. Immediately after collection the samples were stored in Coleman cooler box (The Coleman Company Inc.) with ice, until it was transported and preserved into the laboratory below 4^0C for further analysis.

Physicochemical Analysis

The data for in-situ parameters (temperature, DO, EC, pH, total dissolved solid and turbidity) were recorded by using a portable YSI multisensor (model 6600-M). All probes of the multiparameter were calibrated before every sampling program. Spectrophotometer (HACH DR5000 model) was used for analysis of Nitrate, AN, Sulphate, Phosphate and COD (HACH 2010). Standard methods were followed accordingly for all lab analysis (APHA 2012 and ISO 1986). BOD was calculated using DO meter and suspended solids (TSS and TDS) were measured by gravimetric method in the laboratory. Selected heavy metals (copper, cobalt, chromium, cadmium, manganese, iron, zinc, arsenic, barium and lead) were estimated by using ICP-MS (Inductively Coupled Plasma Mass Spectrometry) (AOAC 1984).

Statistical Methods

Primary data were arranged and descriptive analysis made by Microsoft Office 2010. All other tests were performed using Statistical Package for Social Scientists (IBM SPSS Statistics). Pearson regression and correlation (two tailed Pearson correlation) were calculated to identify the significant relationship among the physico-chemical water quality variables. Two-way ANOVA was conducted to show significant differences in water quality indicators between sampling stations.

RESULTS AND DISCUSSION

Descriptive statistics for the physico-chemical parameters of water quality measured from the 12 sampling stations along the reservoir are presented in Table 2. Pearson correlation (two-tailed) analysis was conducted to find out the relationship among the water quality parameters (Table 3). r= 0.01 may be accepted as truly 'significant' and r= 0.05 as possibly significant.

Water temperature was 30.22±1.86ºC, beyond the normal limit of national standard (DOE 2014). Sujaul et al. (2015) found similar result having acidic condition in Gebeng area. Since station T1 and T2 are located in the uphill tributaries flowing through a dense forest, the temperature is significantly lower than in the main lake. The pH of the basin was recorded in acidic range (4.72-6.47). The pH and depth had a strong positive relationship with temperature (r=0.87 and r=0.797 respectively).

Mean conductivity was 29.94±18 µS cm^{-1} and ranged from 19.00 to 80.33 µS cm^{-1}. Mean TDS was 18.61±10.22 mg L^{-1} but values ranged from 10.67 to 40.00 mg L^{-1}. The maximum of TDS and conductivity were determined at station L10 followed by station T1. This might be due to sedimentation with heavy rain from the surrounding hills. Conductivity and TDS were positively correlated (r=0.67) (Figure 2).

DO concentrations ranged from 4.08 to 7.76 mg L^{-1}. According to NWQS, Malaysia; mean DO (6.0 ±0.9 mg L^{-1}) was under class II (DOE 2014).

Table 2. Mean and SD of water quality parameters at 12 sampling locations in the study area

S. N.		Temp	pH	EC	DO	TDS	Turbidity	Depth	BOD	COD	NO_3-N	AN	PO_4	TSS	SO_4
	Standards	25±2	6.5-8.5	1	7	500	5	-	1	10	-	0.10	0.20	25	250
L1	Mean	30.99	6.47	21.00	5.96	11.67	32.37	2.12	1.26	27.33	0.10	0.197	0.137	6.33	0.33
	SD	0.54	0.35	3.63	0.09	2.51	7.51	0.31	0.096	3.06	0.04	0.075	0.121	0.31	0.58
L2	Mean	30.83	6.03	24.00	6.00	13.67	30.56	3.23	1.27	30.34	0.17	0.276	0.217	4.67	0.33
	SD	0.11	0.15	2.57	0.04	2.20	3.50	0.12	0.075	1.53	0.06	0.035	0.070	0.15	0.58
L3	Mean	30.03	6.05	51.33	5.20	25.23	43.27	1.60	0.66	23.32	0.23	0.543	0.260	7.00	2.67
	SD	0.17	0.05	6.50	0.34	4.04	11.52	0.10	0.092	1.48	0.09	0.051	0.115	0.10	1.53
L4	Mean	31.38	6.29	28.66	6.67	17.00	50.23	2.13	1.26	32.67	0.07	0.462	1.437	11.00	1.33
	SD	0.08	0.09	4.51	0.08	3.11	17.36	0.15	0.105	2.52	0.02	0.059	0.993	0.10	2.31
L5	Mean	31.35	6.43	22.00	7.76	12.67	43.40	2.07	0.83	24.68	0.10	0.649	0.303	7.33	1.67
	SD	0.08	0.04	2.12	0.19	2.50	9.42	0.15	0.04	2.60	0.02	0.048	0.015	1.53	1.53
L6	Mean	30.31	6.20	22.33	6.19	13.33	56.20	2.17	1.32	29.32	0.27	0.741	0.470	11.00	2.33
	SD	0.18	0.30	2.52	0.13	1.93	12.32	0.21	0.21	0.58	0.11	0.051	0.219	3.51	2.53
L7	Mean	30.86	5.96	23.00	5.82	13.00	55.53	1.70	1.19	27.00	0.52	2.331	0.225	9.67	0.33
	SD	0.24	0.08	4.85	0.04	2.18	8.97	0.20	0.166	3.61	0.13	0.295	0.032	1.53	0.58
L8	Mean	31.29	5.71	23.00	6.14	12.33	42.03	1.24	0.76	22.00	0.35	0.931	0.221	18.70	0.33
	SD	0.18	0.09	3.62	0.10	2.08	7.48	0.09	0.15	4.84	0.08	0.089	0.010	4.04	0.58
L9	Mean	31.34	5.93	22.66	6.48	12.33	39.00	2.32	1.42	27.64	0.32	0.486	0.443	11.00	0.67
	SD	0.13	0.06	1.53	0.10	1.51	5.63	0.08	0.39	1.53	0.10	0.075	0.115	1.00	0.58
L10	Mean	31.24	6.00	80.33	6.02	40.00	35.33	2.03	0.73	27.61	0.07	0.573	0.223	5.33	0.33
	SD	0.13	0.07	17.56	0.09	14.45	3.90	0.25	0.11	4.73	0.01	0.098	0.035	0.89	0.58
T1	Mean	27.73	4.78	19.00	5.31	38.00	32.60	0.32	1.67	40.67	0.07	0.136	0.383	4.00	0.00
	SD	0.19	0.08	3.26	0.05	7.52	5.10	0.04	0.381	4.16	0.03	0.033	0.135	0.75	0.00
T2	Mean	25.27	4.72	22.00	4.08	14.00	33.63	0.11	1.28	34	0.04	0.268	1.487	9.33	3.67
	SD	0.13	0.07	1.34	0.10	3.11	4.50	0.02	0.423	2.65	0.01	0.024	0.895	1.58	6.35

*All parameters are in mgL^{-1} except temperature in ºC and pH in 0-14 scale and EC in µS cm^{-1}.

Table 3. Pearson correlation coefficient (r) among water quality parameters

	Temp	EC	TDS	pH	Turbidity	Depth	DO	BOD	Nitrate	AN	PO_4	COD	TSS	SO_4
Temp	1													
EC	0.196	1												
TDS	-0.189	0.670*	1											
pH	0.870**	0.161	-0.346	1										
Turbidity	0.333	-0.106	-0.306	0.385	1									
Depth	0.797**	0.123	-0.309	0.832**	0.139	1								
DO	0.809**	-0.071	-0.247	0.740**	0.324	0.637*	1							
BOD	-0.374	-0.615*	-0.079	-0.389	-0.121	-0.140	-0.202	1						
Nitrate	0.370	-0.199	-0.395	0.187	0.579*	0.178	0.099	-0.093	1					
AN	0.294	-0.036	-0.243	0.188	0.693*	0.051	0.128	-0.208	0.821**	1				
PO4	-0.518	-0.169	-0.129	-0.361	0.088	-0.369	-0.297	0.287	-0.418	-0.251	1			
COD	-0.630*	-0.260	0.379	-0.635*	-0.281	-0.418	-0.394	0.797**	-0.487	-0.385	0.474	1		
TSS	0.200	-0.273	-0.513	0.045	0.468	-0.112	0.137	-0.215	0.512	0.352	0.177	-0.435	1	
SO4	-0.426	-0.152	-0.323	-0.191	-0.244	-0.067	-0.192	-0.109	-0.406	-0.274	0.557	0.088	-0.087	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

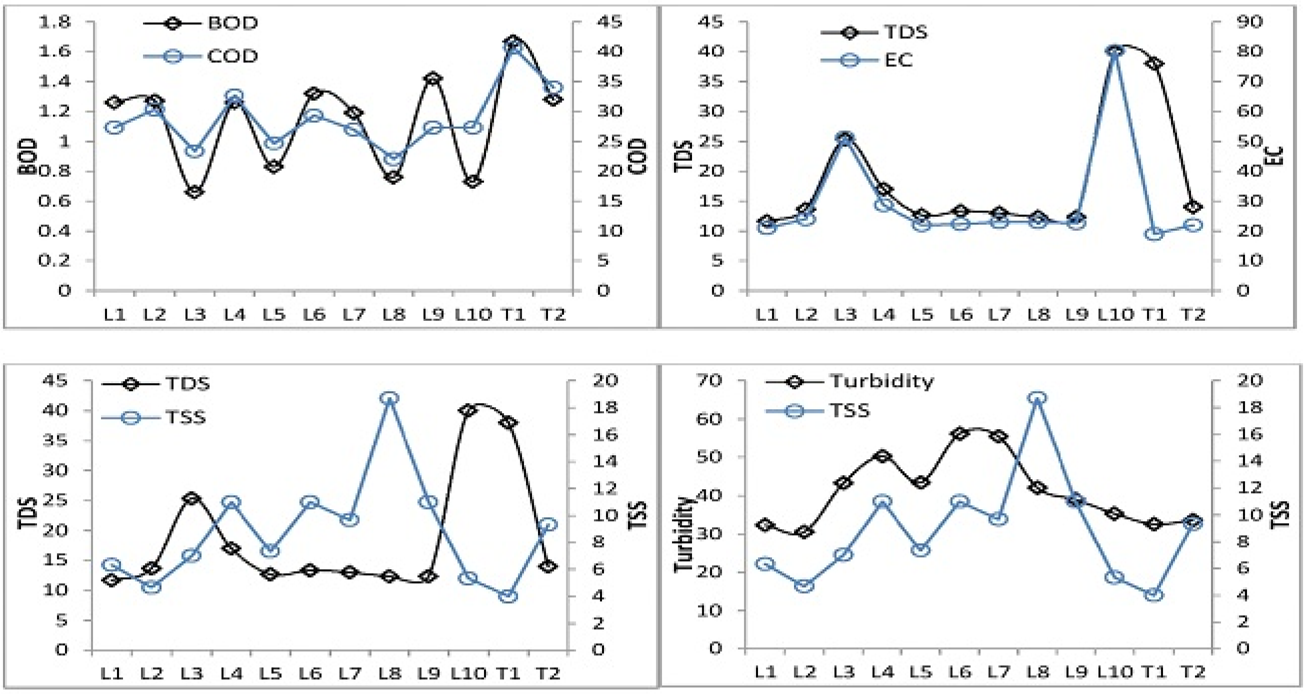

Figure 2. Physico-chemical parameters at different sampling stations

Correlation showed that DO has strong positive significance (r=0.74) with pH. This indicates that, the main contributing factor for DO was photosynthesis activities in the lake water (Sujaul et al. 2012).

Oxygen concentration monitoring in an aquatic system is an important aspect (Galal-Gorchev et al. 1993), as all three physical, chemical and biological processes are involved in changing its concentration along the local characteristics (Kazi et al. 2009). COD value was recorded higher at site T1 and the lowest at site L8. COD is used widely as an index of waste concentration of pollution as swage, agricultural and industrial waste. Simultaneously BOD and COD was detected maximum at station T1 due to active mining pollution and sedimentation. These two variables have strong positive correlation (Table 2) with a similar trend of distribution shown in Figure 2.

The mean nitrate (NO_3-N) content in the study area was 0.19±0.148 mg L^{-1} (range from 0.04 to 0.52 mg L^{-1}). The Lake is badly polluted with AN (NH_3-N) with a wide variation (0.14-2.33 mg L^{-1}) over the stations. The AN concentration was beyond threshold level under class III (EQR 2006). A huge amount of nitrate and AN incorporated during this month with the backflow of Pahang River through the only connecting channel Chini River into this lake. Owing to this, station L7 which is the end point to Chini River, is polluted by these two nutrients (Figure 3). Among other nutrients, sulphate (SO_4) and phosphate (PO_4) were most prominently detected in the settlement and agricultural areas. Sulphate contaminates the fresh water usually leaching from agricultural areas as the residual effect of fertilizer. Moreover waste discharge, combustion of fuel and mining are potential sources of sulphate accumulation in the reservoir (Wetzel 2001 and Hem 2002). Raw sanitary waste and detergent significantly increase phosphate content in the lake though other phosphate sources are also similar as sulphate. EPA (1976) study recommends that excess amount of phosphate concentration (>0.025 mg L^{-1}) might accelerate algal bloom and aquatic plants, that can cause nuisance to the reservoir. But we found manifold higher concentration of phosphate (0.48 mg L^{-1})- more than double the national standard (EQR 2006).

Dissolved Metals in the Lake

The mean concentration of selected trace elements in water samples is shown in Table 4. Water quality of the lake was found safe from toxic metals wih reference to the national standards (EQR 2006). Only iron concentration was significantly higher all over the lake, especially around Jemberau and Melai catchment due to open space bauxite mining in the catchment. Station T1 carried maximum Fe with Mn as it flows in between the mining hills. Trace metals concentration was found in a decreasing order of Fe >Ba >Mn >Pb.

Table 4. Trace elements concentration in surface water of the study area (ppb)

S. N.	Mn	Fe	Ba	Pb
L1	52.023	548.7	6.08	0.172
L2	0.583	314.4	17.55	0.028
L3	1.997	272.2	14.38	0.094
L4	0.269	433.8	20.17	0.144
L5	0.252	424.5	18.52	4.118
L6	0.138	36.2	11.93	0.021
L7	0.180	182.3	10.99	0.067
L8	0.330	402.8	6.93	5.978
L9	0.419	420.5	8.81	0.006
L10	0.492	182.3	10.99	0.019
T11	77.93	1103	8.43	0.010
T12	0.397	153.4	8.96	0.030

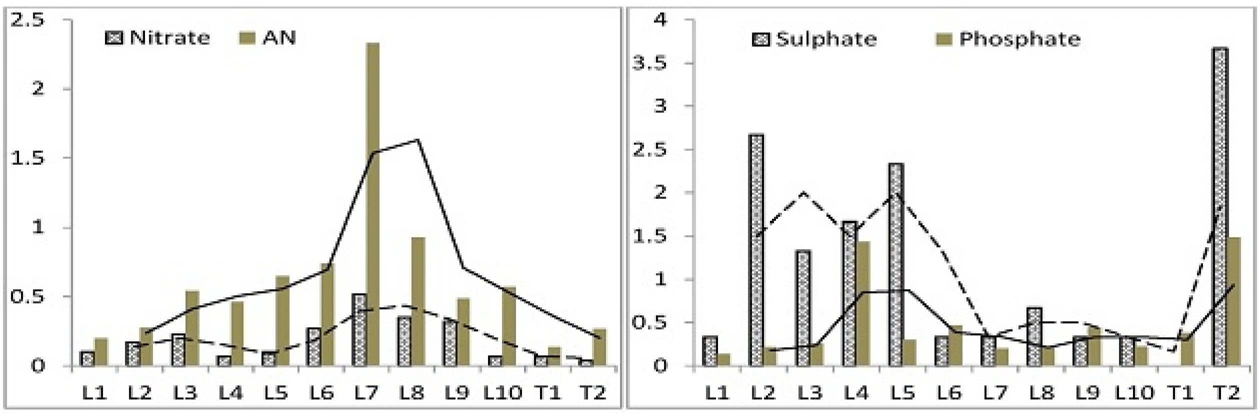

Figure 3. Distribution of nutrients over different sampling stations at the lake area

Water Quality Index (WQI)

Water quality is generally classified and compared with a local standard index as a technique to understand the present status easily and quickly from a vast analysis. Department of the environment (DOE) Malaysia induced water quality index for fresh water reservoirs, that distinguished the study area into particular classes and corresponding pollution level in Table 5. However, the basin water quality was moderate and classified as class II (WQI=82.00) which is consistent to the results of Sharip et al. (2014). Whereas, station T2 had poorest water quality (70) of class III and station L1 and L5 simultaneously showed maximum values of 87.00 (class II). The station 12 was the only station identified water quality status under class III and the value was 70.

Table 5. Water quality classification of the study area by DOE-WQI

Station	DOE-WQI	WQ Class	WQI Status
L1	87	II	SP
L2	85	II	C
L3	82	II	C
L4	84	II	C
L5	87	II	C
L6	82	II	C
L7	77	II	SP
L8	82	II	C
L9	84	II	C
L10	84	II	C
T1	77	II	SP
T2	70	III	SP

CONCLUSION

Tasik Chini ecosystem is susceptible and responds to the anthropogenic activities from its surrounding. This study revealed that pollution relates to anthropogenic activities and natural calamities. Admittedly water quality changes with sampling locations. Station around Chini River was significantly affected by the flood water especially with nutrients nitrates, AN, turbidity and TSS content. Agricultural activities and sedimentation from upper hill area contributing heavy metals and eutrophication in the corresponding catchment of the lake water downstream. Stations are significantly responding at iron mining, sedimentation from changing the land pattern and flood and sewage discharge from the locality. Malaysian DOE-WQI standards classify the overall water quality under class II, which is suggested safe for body contact and allowed to use further with conventional treatment.

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REFERENCES

Abas, A.; Islam, M.S. and Chek, T.C. 2008. Water quality of several feeder rivers between two seasons in Tasik Chini, Pahang. Sains Malaysiana 37(4): 313-321.

Ahmad, A. and Shuhaimi-Othman, M. 2010. Heavy Metal Concen-trations in Sediments and Fishes from Lake Chini, Pahang, Malaysia. Journal of Biological Sciences 10(2): 93-100.

AOAC. 1984. Official Methods of Analysis. Pages 338-383, In: Sidney, W. (Editor) Association of Official Analytical Chemists, volume 2. Virginia, Salem.

APHA. 2012. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, American Water Works Association, Water Environment Federation, Washington, DC.

Bartram, J. and Ballance, R. (Editors). 1996. Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programmes. CRC Press, Boca Raton, FL, USA.

DOE. 2014. Department of Environment, Malaysia; Ministry of Natural Resources and Environment. (https://enviro.doe.gov.my/view.php?id=15791), 2013.

Ebrahimpour, M. and Mushrifah, I. 2010. Seasonal variation of cadmium, copper, and lead concen-trations in fish from a freshwater lake. Biological Trace Element Research 138(1-3): 190-201.

Ebrahimpour, M. and Mushrifah, I. 2008. Heavy metal concentrations in water and sediments in Tasik Chini, a freshwater lake, Malaysia. Environmental Monitoring and Assessment 141(1-3): 297-307.

EQR. 2016. Environmental Quality Report 2015: Department of Environment. Ministry of Natural Resources and Environment. Malaysia. (https://enviro.doe.gov.my/ekmc/digital-content/environmental-quality-report-2015/)

Galal-Gorchev, H.; Ozolins, G. and Bonnefoy, X. 1993. Revision of the WHO guidelines for drinking water quality. Annali dell'Istituto Superiore di Sanità 29: 335–345.

Geng, L.; Alexander, B.; Cole-Dai, J.; Steig, E.J.; Savarino, J.; Sofen, E. D. and Schauer, A. J. 2014. Nitrogen isotopes in ice core nitrate linked to anthropogenic atmospheric acidity change. Proceedings of the National Academy of Sciences 111(16): 5808-5812.

HACH. 2010. Data Sheet DR 500 UV-Vis Laboratory Spectophotometer. Colorado, USA,

Hanif, N.M.; Latif, M.T.; Ali, M. M. and Othman, M.R. 2009. Atmospheric surfactants around lake ecosystems. European Journal of Scientific Research 32(3): 268-276.

Hem, J.D. 2002. Study and Interpretation of the Chemical Characteristics of natural water (3rd edition). United States Geological survey, Washington. DC.

Ho S. C. 1994. Status of limnological research training in Malaysia. Pages 129-145, In: Dudgeon, D. and Lam, P.K.S. (Editors) Inland Waters of Tropical Asia and Australia: Conservation and Management, Mitteilungen der Internationale Vereiningung der Limnologie 24. E. Schweizerbart'sche, Stuttgart.

ISO. 1986. Water Quality Determination of Nitrate. Part 1: 2,6-Dimethylphenol Spectrometric Method. International Organization for Standardization, Geneva.

Kazi, T.G.; Arain, M.B.; Jamali, M.K.; Jalbani, N.; Afridi, H. I.; Sarfraz, R.A.; Baig, J.A. and Shah, A.Q. 2009. Assessment of water quality of polluted lake using multivariate statistical techniques: A case study. Ecotoxicology and Environmental Safety 72(2): 301-309.

Latif, M. T.; Ngah, S. A.; Dominick, D.; Razak, I. S.; Guo, X.; Srithawirat, T. and Mushrifah, I. 2015. Composition and source apportionment of dust fall around a natural lake. Journal of Environmental Sciences 33: 143-155.

Maznah, W. W. and Makhlough, A. 2015. Water quality of tropical reservoir based on spatio-temporal variation in phytoplankton composition and physico-chemical analysis. International Journal of Environmental Science and Technology 12(7): 2221-2232.

Mir, S.I.; Ismail, B.S. and Tayeb, M.A. 2016. Hydrology and sediment loading in a degrading natural lake system in Malaysia. Environmental Earth Sciences 75(3): 1-7.

Mir, S.I.; Sahid, I.; Gasim, M.B.; Rahim, S.A. and Toriman, M.E. 2015. Prediction of soil and nutrient losses from the lake Chini watershed, Pahang, Malaysia. Journal of Physical Science 26(1): 53.

Molisani, M. M.; de Sousa Barroso, H.; Becker, H.; Moreira, M. O. P.; Hijo, C. A. G.; do Monte, T. M. and Vasconcellos, G. H. 2010. Trophic state, phytoplankton assemblages and limnological diagnosis of the Castanhão Reservoir, CE, Brazil. Acta Limnologica Brasiliensia 22(1): 1-12.

Sharip, Z.; Zaki, A. T.; Shapai, M.; Suratman, S. and Shaaban, A. J. 2014. Lakes of Malaysia: Water quality, eutrophication and management. Lakes & Reservoirs: Research & Management 19(2): 130-141.

Shuhaimi-Othman, M.; Lim, E. C. and Mushrifah, I. 2007. Water quality changes in Chini Lake, Pahang, West Malaysia. Environmental monitoring and assessment 131(1-3): 279-292.

Sujaul, I.M.; Ismail, B.S.; Muhammad Barzani, G.; Sahibin, A.R. and Mohd Ekhwan, T. 2013. Hydrological assessment and suspended sediment loading of the Chini Lake catchment, Pahang, Malaysia. International Journal of Water Resources 5(6): 303-309.

Sujaul Islam, M.; Ismail, B. S.; Muhammad Barzani, G.; Sahibin, A.R. and Mohd Ekhwan, T. 2012. Hydrological assessment and water quality characteristics of Chini Lake, Pahang, Malaysia. American-Eurasian Journal of Agricultural & Environmental Sciences 12(6): 737-749.

Sujaul, I. M.; Sobahan, M. A.; Edriyana, A. A.; Yahaya, F.M. and Yunus, R.M. 2015. Adverse impacts of poor wastewater management practices on water quality in Gebeng Industrial Area, Pahang, Malaysia. World Academy of Science, Engineering and Technology, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering 9(5): 491-494.

Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems. 3rd Edition, Academic Press, San Diego, CA. 1006 pages.

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