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The Impact of Anthropogenic Pollution and Urban Runoff Associated with Spatial and Seasonal Variation on the Water Quality in the Semenyih River, Malaysia

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Abstract: This study was carried out to investigate the anthropogenic and natural effects on the water quality of the Semenyih River using multivariate statistical techniques. The water samples were collected in the rainy (April) and dry (July) season, 2013. The water quality parameters were dissolved oxygen (DO), pH, conductivity, total dissolved solids (TDS), nitrate (NO_3), phosphate (PO_4), turbidity, ammonia-nitrogen (NH_3-N), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), oil and grease (OG), total hardness (TH), *E. coli* and total coliform (TC), whereas heavy metals were Fe, Zn, Cd, Mn, Cr, Ni, Pb and Cu. The results showed that turbidity, COD, OG, PO_4, *E. coli* and TC in rainy season as well as PO_4, *E. coli* and TC in dry season were exceeded the permissible threshold limits of NWQS of Malaysian rivers, therefore, the river was extremely contaminated by these parameters. Moreover, the mean concentrations of heavy metal were observed in the following sequences: Fe> Mn>Zn> Cu>Cr> Pb>Ni> Cd and Fe>Mn>Zn> Cr>Cu> Pb>Cd> Ni in the rainy and dry seasons, respectively. Cluster analysis classified 8 sampling stations into three clusters in the rainy season and two during dry season based on similarities of water quality characteristics, hence, it can reduce sampling stations and experimental analysis cost. Factor analysis of the water quality datasets generated four factors in both the rainy and dry seasons with total variance of 93.09% and 97.25%, respectively. Additionally, FA provided a significant data reduction and classification of variables which basically contribute to the spatial and seasonal variations of water quality. Overall, the anthropogenic pollution sources were the main reason of the water quality deterioration in the Semenyih River.

Key words: Semenyih River · Water quality · Anthropogenic pollution · Urban runoff · Multivariate statistical analysis

INTRODUCTION

Rivers are one of the most important water resources because they function as a resource for domestic water supply, fishing, agricultural and industrial purposes and recreation. Besides, rivers play a significant role in assimilating or conveying municipal and industrial wastewater and agricultural runoff. Generally, discharge from Municipal and industrial wastewater is a main source of pollution, whereas surface runoff is a seasonal phenomenon, significantly affected by climate within the basin [1].

Anthropogenic activities associated with urbanization and agricultural and industrial activities result in deterioration of water quality parameters [2]. In addition, the natural processes such as weathering processes, precipitation rate and soil erosion contribute to the degradation of surface water quality[3,4].Study by [5] reported that the values of heavy metals in surface water are affected by the industrial development and other anthropogenic activities. Generally, diversity and growth, fish survival, urban industrial supply, recreational activities, private water supply, waste disposal, irrigation and livestock watering and aesthetics value are all impacted by water quality status in watercourses[6]. Water quality evaluation and determination of pollution sources are very important to achieve the sustainable water management strategies [7]. Furthermore, river water quality assessment has become an essential aspect due to spatial and temporal variations which influence on the

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physical and chemical characteristics of the aquatic environment [8]. In general, most of the environmental problems occurring in the watershed are due to anthropogenic rather than natural causes. For example, water pollution is due to two main factors i.e. from development of the land and natural resources and the discharge of undesirable waste products and effluents into watercourses [9]. In addition, the composition of surface runoff in the drainage area is considered as the initial cause of the change in the quality of a river. In the natural situation, the changes can be detected by increasing concentrations of dissolved and suspended materials [10]. According to [11], human activities in particular livestock husbandry and agriculture play an important role in contributing contamination of river water among others pollutants. Wastewater of livestock farms contains high concentrations of ammonia-nitrogen, organic and inorganic nitrogen compound and pathogenic bacteria [12]. Furthermore, serious environmental damage as a result of animal waste have been well documented in rivers which receive runoff containing nutrient rich wastes caused oxygen depletion and increase the algae production [13].

According to [11] Semenyih River is one of the rivers in Malaysia in which human activities associated with urbanization, industrialization, agricultural and mining activities are extremely main sources of pollution. Moreover, the range of deterioration in water quality in the river varied depending on the percentage of change in land use. Therefore, the land use activities in the basin must be carefully planned and controlled on account of protecting the water resource and quality status. this study aimed to determine the water quality and heavy metals of the Semenyih river and to categorize them based on the National Water Quality Standard (NWQS) for Malaysia as well as to evaluate the impact of anthropogenic pollution and urban runoff on the water quality status of the river. Moreover, the multivariate statistical methods, namely cluster analysis and factor analysis were executed on the obtained datasets to recognize the water quality variables for seasonal changes in the water quality of river and to assess the differences among sampling stations of the Semenyih River basin.

MATERIALS AND METHODS

Study Area: The Semenyih River basin which has a total area of 266.60 km^2 consists of 36 sub-basins and 25 water catchment valleys with areas ranging from 1.37 to 35.57 km^2 (Fig.1). The basin includes seven different main land uses such as settlements, industry, rubber and oil palm plantations, forests, industry, water bodies and agricultural land. Semenyih Basin lies between longitude 101° 48'32.9 "E to 101° 52'30.5 "E and latitude 02° 54'14.9 "N to 03 ° 03'23.1 "N. The average annual rainfall of the area is about 3000 mm. Furthermore, the river originates from the hilly and forested areas in the western slope of Banjaran Titiwangsa, northeast of Hulu Langat [14]. In addition, it flows southwards toward the provinces of Sepang and Hulu Langat. Furthermore, the river has been negatively influenced by industrial and urban wastes since the early 1990. Currently, the ingestion of drinking water of more than 1 million people is from the Semenyih River. The major attain of river can be considered to start from the Semenyih Dam flowing south-southwest trend throughout the town of Semenyih, Bangi Lama and lastly amalgamation with a Langat River at about 4 km to the east of Bangi Lama town as well as Pajam and Beranang Rivers which are also the feeder rivers for Semenyih River [11]. Overall, it is one of the main rivers in the state of Selangor, Malaysia since the river is considered as a resource of cultivation and domestic water supply in Semenyih City, Bandar Tasek Kesuma and Bandar Rinching after the treatment [16]. Eventually, the climate of the study area is characterized by high rainfall, high average and homogeneous annual temperatures and high humidity. This climate has influenced the geomorphology and hydrology of the study area.

Sampling Stations: In this study, eight sampling stations were selected along the river from the upstream to downstream as well as the selection criteria of the sampling locations were based on the characteristic of water condition, land use and human activities along the river. Stations 1 and 2 were located in the upstream and represent clear water. Furthermore, station 3 was located in the area where mining activity and deforestation occurred, so the water was turbid. Station 4 was more turbid due to runoff from human activities including random settlements. Station 5 was situated in the Semenyih City in which pollution was contributed by the urban activity as well as domestic and industrial effluents. In addition, stations 6 and 7 was located after livestock farms and agricultural activities that adversely impact on the water quality in those stations. The last station was located after Bangi City in Jenderam Hilir and characterized by turbid and contaminated water as a result of accumulated pollutants from previous stations and water treatment plant as well as erosion and human activities (Fig. 1).

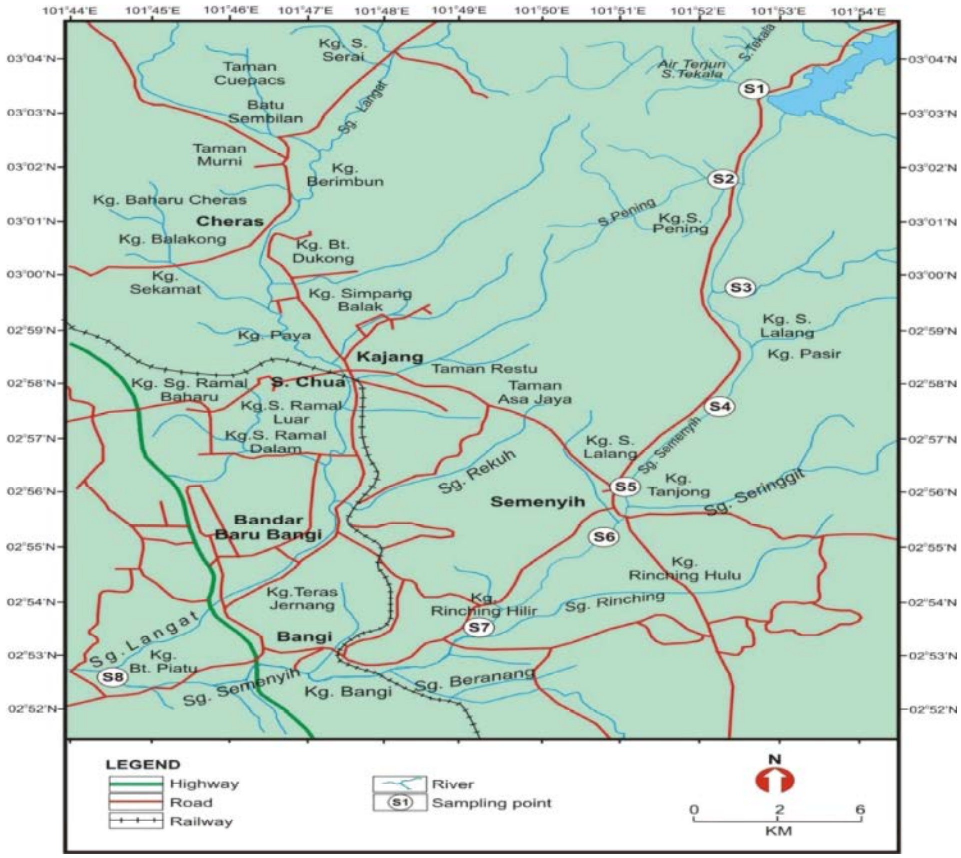

Fig. 1: Study area and sampling stations along the Semenyih River

Sampling Methods and Analytical Procedures: Water sampling has been carried out in rainy (April) and dry (July) seasons, 2013. Three water samples were collected from each station close to the right and left banks and in the middle of the river with triplicate. Water samples were collected in specific bottles according to the [15]. Samples were collected in sterile glass flasks (bacteriology) and acid-washed plastic bottles (chemistry), cooled, transported to the laboratory and processed within 6 h of collection. Dissolved oxygen (DO), conductivity, total dissolved solids (TDS) and pH were measured in situ using Multisensor probe YSI model 449D, while biochemical oxygen demands (BOD_5), chemical oxygen demands (COD), Total suspended solids (TSS), oil and grease (OG), turbidity, phosphate (PO_4), nitrate (NO_3), ammonia nitrogen (NH_3-N), total hardness (TH), E. coli and total coliform (TC) were analyzed in the laboratory. BOD_5 was analyzed as described by 5-day test as well as COD was assayed using the open reflux method [17]. Additionally, TSS and O&G were determined by total solids dried at 103-105°C and liquid-liquid, partition-gravimetric methods respectively [16]. Moreover, turbidity, PO_4, NO_3 and NH3-N were assayed by absorptometric, acid ascorbic, diazotization and Nessler methods respectively [16, 17]. Furthermore, total hardness was determined by the convenient Inductive Coupled Plasma-Mass Spectrometry (ICP-MS). In addition, dissolved heavy metals (Fe, Zn, Cd, Mn, Cr, Ni, Pb and Cu) were measured by convenient Inductive Coupled Plasma-Mass Spectrometry (ICP-MS). Eventually, E. coli and TC were determined based on the membrane filter technique [16]. All the used equipments were calibrated before use based on the manufacturer's directions.

Statistical Analysis: Statistical analysis of data was fulfilled using SPSS version 20. Cluster analysis (CA) was executed by means of squared Euclidean distances and the Ward's method to sort the variables of sampling stations and water quality indicators, respectively [2]. Additionally, Principal component analysis (PCA) /factor analysis (FA) was used to identify pollution factors influenced water quality. Otherwise, Bartlett's sphericity and Kaiser-Meyer-Olkin (KMO) tests were applied to a suitability examination of the data for FA. Nevertheless, all analyzed data were standardized by scale transformation to ensure normal distributions for CA and FA [19].

RESULT AND DISCUSSION

Water Quality Parameters: The results obtained for the eight sampling stations during the rainy season for the fifteen water quality parameters are shown in Table 1A and 1B, while the results of the dry season were represented in Table 2A and 2B. Dissolved oxygen is a significant variable in ecological water health due to its role in determining the seasonal and spatial variations in the Semenyih River. DO values were higher in the rainy season than in the dry season. The maximum value of the DO (7.10 mg/L) was observed at station 2, whereas the minimum (4.20 mg/L) at station 8 during the rainy season. The low DO values in the dry season were probably attributed to high water temperature and microorganism activities, which consume dissolved oxygen in river water in the decay of organic matters. The pH value is an important factor for aquatic ecosystems, including toxicity to the aquatic life [16]. The pH values in all the stations in Semenyih River showed slightly acidic in the rainy season, while showing slightly alkaline during dry season. In addition, river water was slightly alkaline at all stations but station 1 recorded lower alkaline than the other stations in the dry season due to its situation in the upstream. On the contrary, the acidic rain as well as the decomposition of organic materials can cause acidification and lower pH values [20], as observed during rainy season at all stations. The conductivity values were ranged from 33 μS/cm recorded at station 2 to 90.33 μS/cm at station 8 during the rainy season. On the other hand, the conductivity values ranged from 36 μS/cm at station 1 to 99 μS/cm at station 8 in the dry season. The conductivity values during the rainy season were lower compared to the dry season except for Station 6 and 7. The levels of conductivity recorded in this study were lower than those reported for the same basin (range 46.5-187) by [12]. The ability of the aquatic system to transmit electric current as a result of the dissolved ions in a body of water is referred to as conductivity. The high conductivity of water is an indication of the high levels of dissolved salts in the water [21]. Total dissolved solids (TDS) values were ranged from 21.22 mg/L at station 1 and 2 to 56 mg/L at station 8 during the rainy season. In comparison with the dry season, the TDS values ranged from 23 mg/L at station 1 to 65.33 mg/L at station 8. Generally, the TDS concentrations in the river are essentially influenced by extreme anthropogenic activities and runoff with high suspended matter [22]. In the case of nitrate (NO_3), spatial variations were found in the rainy and dry seasons. In the rainy season, there is a high spatial variability, the highest value of NO_3 was recorded at station 8 (12.33 mg/L), while the lowest at station 1 (0.87 mg/L. in contrast to the dry season, the NO_3 levels were decreased, with a maximum value at station 8 (6.57 mg/L) and minimum value at station 1 (0.83 mg/L). The increasing concentration of nitrates in the rainy season ascribed to pollution sources from the agricultural activities (stations 2 and 6) and water treatment plant (station 8). Furthermore, the discharge of industrial and domestic wastewater of Semenyih and Bangi cities affected on NO_3 content at stations 5 and 7, respectively [10]. In the rainy season, there is an increase in the phosphate (PO_4) concentrations at station 2 (1.07 mg/L), station 6 (2.05 mg/L) and station 8 (1.94 mg/L), whereas the values were less than 1 mg/L in the other stations. In the dry season, the concentrations of PO_4 ranged from 0.34 mg/L at station 1 to 1.81 mg/L at Station7. Furthermore, the high concentrations of phosphate which was observed in the Semenyih river water is indication the pollution by effluents contained detergents and fertilizers [16]. Turbidity values ranged between minimum 15.33 NTU at station 1 to maximum 185.67 NTU at station 6 during the rainy season. In the dry season, turbidity values ranged from 3.33 NTU to 68.67 NTU, the low turbidity was recorded at station 1, while the high value was at station 8. The turbid water generally ascribed to the high amount of sediments, stream flow, surface runoff, erosion and overland flow [23]. In regards ammonia nitrogen (NH_3-N), the highest value was recorded at station 8 (1.96 mg/L), while the lowest value was recorded at station 1 (0.07 mg/L) during the rainy season. In the dry season, the values of NH_3-N were higher than the rainy season with the maximum in station 8 (2.09 mg/L) and the minimum in station 1 (0.06 mg/L). The high concentrations of ammonium are probably an indicator of the discharge of untreated domestic wastewater from rural and urban areas particularly from Semenyih and Bangi cities as well as effluents of water treatment plant [1], which affected on stations 6, 7 and 8. For total suspended solids (TSS), the high values of TSS indicate pollution of a water body [24]. In both rainy and dry seasons, TSS values were increased along the river stream. Downstream stations were heavily polluted with very high content of TSS, which were 96,83 mg/L, 88.50 mg/L and 92.38 mg/L at stations 6,7 and 8 during rainy season as well as 58.33 mg/L, 73 mg/L and

76.33 mg/L in dry season of the same stations. However, TSS values were decreased in upstream stations, which indicated that the polluting process of the river was largely acting on the river. In addition, TSS values are greater compared to the values (ranged from 28-107.14 mg/L) reported by [15]. BOD is a significant factor to assess the water quality regarding organic matter. In the rainy season, the highest BOD_5 value was observed in station 8 (3.69 mg/L), whereas the lowest value in station 1 (0.37 mg/L). In addition, the values of BOD_5 were ranged from 0.35 mg/L at station 1 to 4.42 mg/L at station 6 during the rainy season. The high BOD5 values in the downstream stations attributed to domestic wastewater, discharge of livestock farms and surface runoff which contains high concentrations of organic matter [20]. The BOD concentration continuously increases because of natural plant decaying process and other contributors that increase the total nutrient in water bodies such as fertilizer, construction effluent, animal farm and septic system [25]. The chemical oxygen demand (COD) values were fluctuating between minimum 8.34 mg/L at station 1 and maximum 97.64 mg/L at station 8 in the rainy season, whereas in dry season, the minimum value (9.41 mg/L) was recorded at station 1 and the maximum (63.21 mg/L) at station 6. Generally, the wide usage of chemical and organic fertilizer and release of sewage has an effect on COD level [25]. Oil and grease (O&G) are main specific chemical pollutants in the river. The O&G values were various from a station to another in rainy season due to the surface runoff and domestic wastewater, whereas in dry season, O& G values were gradually increased from the upstream station to the downstream station. The lowest O&G value was observed at the station 1 (0.33 mg/L) and the highest value was in the station 8 (2.63 mg/L) during the rainy season. Furthermore, the minimum O&G value was observed at the station 1 (0.24 mg/L) and the maximum value was in the station 8 (2.92 mg/L) during the dry season. For the total hardness (TH), the values ranged from 4.28 mg/L at station 2 to 12.76 mg/L at station 8 during the rainy season, whereas in dry season, the minimum value was 4.22 mg/L at station 2 and maximum value was 15.99 mg/L at station 8. Generally, the total hardness is depending on the geology of the area with which the surface water is associated [27]. E. coli and total coliform (TC) were detected and measured in the river. The highest values of E. coli and TC were observed in the station 6 (103000 count/100 mL and 144333.33 count/100mL), whereas the lowest were recorded at Station1 (330 count/100 mL and 920 count/100 mL) in the rainy season. In addition, the highest and lowest values of E. coli and TC were recorded at the same stations during dry season. Commonly, coliform bacteria amounts were increased with the concentration of nitrogen and biodegradable organic materials [28]. The microbial loading was discharge from point sources, such as storage facilities and livestock farms and from nonpoint sources, such as agriculture activities and urban runoff [11]. Moreover, nutrients are main factors which influence microbial survival in the aquatic environments as well as light, pH, temperature and salinity [14]. In the rainy season, the mean values of conductivity, TDS and TH were categorized as class I, while DO, pH, BOD_5 were classified as class II based on the NWQS, Malaysia [28]. Therefore, these parameters were in the normal range. In addition, the mean values of NO_3, NH_3-N and TSS were categorized under class III and reached to the threshold limit. Similarly, the mean values of turbidity, COD and O&G were classified as class IV, whereas PO_4, E.coli and TC were classified as class V and exceeded the permissible threshold levels of NWQS [29]. On the other hand, during the dry season the mean values of water quality parameters during dry season were classified as the following; pH, conductivity, TDS and TH were categorized as class I, while DO and turbidity were categorized under class II, hence, these parameters were in the normal range. Furthermore, NO_3, NH_3-N, TSS, O&G, BOD and COD were categorized as class III and reached the allowable threshold limit. Likewise, PO_4, E. coli and TC were categorized as class V and exceeded the allowable threshold limits of NWQS [29]. Therefore, the river was extremely contaminated with turbidity, COD, O&G, PO_4, E. coli and TC in the rainy season, whereas in the dry season, it was extremely polluted with PO_4, E. coli and TC.

Heavy Metals: The results of heavy metals variables are given in Table 3 and Table 4 for a rainy and dry season, respectively. In the case of Fe, values ranged between minimum 283.81 µg/L at station 5 and maximum 1200.87 µg/L at station 8 during the rainy season. In addition, Fe values were ranged between minimum 204.89 µg/L at station 1 and maximum 589.60 µg/L at station 6 during the dry season. In the rainy season, the urban runoff and wastewater from Semenyih and Bangi cities and industrial effluents were principally contributed to the high Fe concentrations in the river [16]. For Zn, the Maximum value was presented in station 1 (27.13 µg/L), while the minimum value was at station 5 (1.14 µg/L) in the rainy season, while in the dry season, the highest concentration was detected in station 8 (44.42 µg/L), whereas the lowest was detected at station 1 (18.74 µg/L). The rainy season

Table 1: A- Mean values of water quality parameters in the rainy season (Stations 1, 2, 3 and 4).

Station No.	Station1		Station2		Station3		Station4	
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DO mg/L	6.22	0.01	7.10	0.01	6.95	0.01	6.74	0.03
pH	6.37	0.03	5.88	0.02	6.13	0.02	6.20	0.01
Cond µS/cm	35.00	0.00	33.00	0.00	36.00	0.00	51.00	0.00
TDS mg/L	21.00	0.00	21.00	0.00	22.33	0.58	32.00	0.00
NO_3 mg/L	0.87	0.06	2.57	0.06	4.63	0.06	3.23	0.15
PO_4 mg/L	0.27	0.01	1.07	0.03	0.66	0.02	0.55	0.01
Tur NTU	15.33	0.58	74.33	0.58	102.00	2.00	140.00	3.00
NH_3-N mg/L	0.07	0.01	0.46	0.01	0.54	0.01	1.02	0.01
TSS mg/L	6.00	1.32	58.00	1.80	66.33	2.36	76.00	1.32
BOD mg/L	0.37	0.13	0.96	0.12	2.22	0.04	1.73	0.10
COD mg/L	8.34	0.93	29.36	2.89	43.45	4.88	55.31	2.78
O&G mg/L	0.33	0.12	1.17	0.25	0.87	0.31	1.93	0.12
TH mg/L	6.49	0.32	4.28	0.07	4.77	0.54	6.60	0.11
E.coli count/100mL	360	26.46	11333.33	3055.05	50666.67	2516.61	82000	14177.45
TC count/100mL	2200	500	36000	12529.9	91000	6082.76	119000	10440.3

Table 1: B- Mean values of water quality parameters in the rainy season (Stations 5, 6,7 and 8).

Station No.	Station5		Station6		Station7		Station8	
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DO mg/L	6.60	0.01	6.64	0.01	5.47	0.01	4.20	0.03
pH	6.17	0.01	6.33	0.01	6.40	0.01	6.52	0.01
Cond µS/cm	65.00	0.00	87.00	0.00	73.67	0.58	90.33	0.58
TDS mg/L	40.00	0.00	54.00	0.00	45.00	0.00	56.00	0.00
NO_3 mg/L	3.43	0.06	4.70	0.10	4.93	0.12	12.33	0.21
PO_4 mg/L	0.63	0.01	2.05	0.02	0.81	0.03	1.94	0.02
Tur NTU	138.00	3.00	185.67	2.52	157.67	3.51	167.00	2.00
NH_3-N mg/L	0.83	0.02	1.24	0.01	0.86	0.03	1.96	0.01
TSS mg/L	76.00	2.50	96.83	1.53	88.50	3.97	92.83	1.15
BOD mg/L	2.64	0.32	3.30	0.29	2.33	0.23	3.69	0.08
COD mg/L	75.33	6.35	93.60	3.00	68.64	4.12	97.64	1.31
O&G mg/L	2.50	0.10	2.07	0.15	1.93	0.15	2.63	0.15
TH mg/L	8.51	0.19	11.86	0.23	10.29	0.68	12.76	0.27
E.coli count/100mL	107666.67	14047.54	173000	9000	113333.33	11150.49	204333.33	9609.02
TC count/100mL	176000	18681.54	261333.33	10503.97	216666.67	15821.93	286000	11000

Table 2: A- Mean values of water quality parameters in the dry season (Stations 1, 2, 3 and 4).

Station No.	Station1		Station2		Station3		Station4	
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DO mg/L	6.45	0.01	6.34	0.02	6.35	0.01	5.79	0.01
pH	7.36	0.04	7.52	0.04	7.40	0.03	7.28	0.02
Cond µS/cm	36.00	0.00	38.00	0.00	42.00	0.00	61.67	0.58
TDS mg/L	23.00	0.00	25.00	0.00	28.00	0.00	40.67	0.58
NO_3 mg/L	0.83	0.15	1.33	0.12	2.27	0.06	2.63	0.15
PO_4 mg/L	0.34	0.03	0.94	0.02	0.83	0.02	0.84	0.03
Tur NTU	3.33	0.58	28.00	1.00	31.67	1.15	25.00	3.00
NH_3-N mg/L	0.06	0.04	0.26	0.02	0.36	0.01	0.71	0.03
TSS mg/L	9.67	1.04	42.17	2.52	53.83	2.25	43.83	1.04
BOD mg/L	0.35	0.03	1.77	0.09	2.67	0.04	3.26	0.06
COD mg/L	9.41	0.94	18.45	0.55	28.07	0.15	31.91	1.71
O&G mg/L	0.24	0.04	0.98	0.05	1.75	0.04	1.95	0.01
TH mg/L	4.54	0.08	4.22	0.07	4.42	0.02	6.97	0.03
E.coli count/100mL	483.33	32.15	3800.00	400.00	52000.00	3605.55	71666.67	4041.45
TC count/100mL	1326.67	66.58	6800.00	700.00	87000.00	4000.00	97333.33	4041.45

Table 2: B- Mean values of water quality parameters in the dry season (Stations 5, 6,7 and 8)

Station No.	Station5		Station6		Station7		Station8	
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DO mg/L	5.70	0.03	5.14	0.01	5.65	0.01	5.09	0.01
pH	7.13	0.02	7.06	0.02	7.15	0.03	7.23	0.02
Cond µS/cm	65.67	0.58	75.33	0.58	71.00	1.00	99.00	1.73
TDS mg/L	43.00	0.00	47.33	0.58	47.00	1.00	65.33	0.58
NO_3 mg/L	3.27	0.06	4.47	0.35	5.20	0.20	6.57	0.21
PO_4 mg/L	1.15	0.03	1.52	0.01	1.81	0.05	1.68	0.05
Tur NTU	34.33	1.53	47.00	4.00	61.67	0.58	68.67	2.52
NH_3-N mg/L	0.92	0.01	1.27	0.04	1.56	0.04	2.09	0.11
TSS mg/L	51.50	2.65	58.33	2.75	73.00	1.80	76.33	3.82
BOD mg/L	3.63	0.05	4.42	0.05	4.23	0.04	4.27	0.05
COD mg/L	62.68	1.69	63.21	0.31	60.51	0.65	61.83	0.80
O&G mg/L	2.86	0.07	2.68	0.05	2.82	0.06	2.92	0.04
TH mg/L	8.87	0.06	8.81	0.10	9.59	0.05	15.99	0.08
E.coli count/100mL	113666.67	6658.33	206333.33	9712.53	127000	3605.55	194666.67	7094.60
TC count/100mL	168333.33	5033.22	278333.33	2516.61	183000	4000	257666.67	6506.41

Table 3: Mean values of heavy metals in the rainy season of the Semenyih River.

Heavy metals µg/L	Station1	Station2	Station3	Station4	Station5	Station6	Station7	Station8
Fe	288.92	390.01	351.77	500.51	283.81	567.44	962.88	1200.87
Zn	27.13	18.32	9.87	7.39	8.56	14.10	11.09	15.66
Cd	0.58	0.68	0.31	0.36	0.36	0.39	0.84	0.87
Mn	15.89	20.76	13.97	17.85	13.05	20.18	41.33	18.57
Pb	0.91	1.25	1.25	2.23	1.14	3.28	2.99	5.69
Cu	3.78	2.57	1.65	2.12	2.32	2.36	2.39	8.98
Ni	0.60	1.49	0.49	0.86	0.71	1.44	1.38	1.54
Cr	6.78	3.87	0.78	1.67	2.61	1.40	1.18	1.55

Table 4: Mean values of heavy metals in the dry season of the Semenyih River.

Heavy metals µg/L	Station1	Station2	Station3	Station4	Station5	Station6	Station7	Station8
Fe	204.89	311.54	316.06	443.28	551.17	589.60	336.91	550.90
Zn	18.74	23.51	24.73	29.38	31.49	32.48	40.85	44.42
Cd	0.19	0.15	0.36	0.79	0.21	0.21	0.21	0.82
Mn	16.98	19.33	21.99	25.93	32.55	52.04	62.84	94.22
Pb	0.33	0.64	0.82	0.84	0.90	1.08	1.20	1.64
Cu	1.42	0.39	0.45	0.92	1.13	1.44	1.42	1.78
Ni	0.00	0.03	0.15	0.35	0.41	0.37	0.25	0.35
Cr	3.30	1.08	2.66	1.88	2.23	3.31	2.76	7.44

is characterized by a decreasing trend of Zn concentrations compared to the dry season. Principally, Zn content had been shown as an example of the evolution of toxic metals related to mining pollution [29]. In regards Cd, the highest value was detected in the rainy season at station 8 (0.87 µg/L), while the lowest value was detected at station 3 (0.31 µg/L). In the dry season, the maximum value was recorded at station 8 (0.83µg/L) and the minimum at station 2 (0.15 µg/L). For Mn, it ranged from 13.97 µg/L at station 3 to 41.33 µg/L at station 7 during rainy season. In the dry season, Mn values were ranging between 16.98 µg/L and 94.22 µg/L, with a minimum value at station 1 and maximum value at station 8. For the rainy season, the highest value of Pb was observed at station 8 (5.69 µg/L), while the lowest value was at station 1 (0.91 µg/L). In the dry season, the high value was determined in station 8 (1.64 µg/L), whereas the low was recorded at station 1 (0.33 µg/L). Generally, there is a temporal decreasing trend in Pb concentrations in the water of all sampling stations from rainy season to dry season. The high concentrations of Pb are basically ascribed to anthropogenic sources and natural weathering [31].In the rainy season, The Cu values ranged from 0.91 µg/L at station 1 to 8.98 µg/L at station 8, compared to Cu between minimum 0.39 µg/L at station 2 to maximum 1.78 µg/L at station 8 during dry season. The Ni values were ranging from 0.60 µg/L at station 1 to 1.54 µg/L at station 8, compared to 0.00 µg/L at station 1 and 0.41 µg/L at

Table 5: Comparison between NWQS to Malaysia and the mean valus of this study.

Heavy metal	Mean of rainy season µg/L	Mean of dry season µg/L	NWQS, Class II (µg/L)
Fe	568.28	413.042	1000
Zn	14.02	30.701	5000
Cd	0.55	0.367	10
Mn	20.20	40.733	100
Pb	2.34	0.930	50
Cu	3.27	1.117	10
Ni	1.07	0.239	50
Cr	2.48	3.084	50

station 5 in the dry season. Generally, the Ni sources are chemical industries and mining [16]. In the case of Cr values, the maximum value (6.78 µg/L) in the rainy season was appeared at station 1 and the minimum value (0.78 µg/L) was recorded at station 3. In the dry season, the maximum value was occurred at station 8 (7.44 µg/L) and minimum value at station 2 (1.09 µg/L). The order of heavy metal concentrations in water samples during the rainy season was Fe> Mn>Zn> Cu>Cr> Pb>Ni> Cd. On the other hand, the order of heavy metal concentrations in the dry season was Fe> Mn>Zn> Cr>Cu> Pb>Cd> Ni. The mean values of heavy metals during rainy and dry season were low if compared to NWQS to Malaysian rivers(Table 5) [29]. The accumulation of heavy metals along the Semenyih River may depend largely on common sources of pollution, which are identified as industrial discharges and domestic sewage [32].

Cluster Analysis: Cluster Analysis (CA) was used to determine the similarities between the sampling stations using Ward's method with Euclidean distances [33- 35]. It grouped the eight sampling stations into three (rainy season) and two (dry season) statistically significant clusters at $(D_{link}/D_{max}) * 25 < 10$ in which rendered a dendrogram (Fig.2 and Fig.3). Based on 23 water quality variables, CA classified the eight sampling stations into three clusters during rainy season (Fig.2). Cluster 1 consisted of stations 3, 4 and 5 and cluster 2 comprised stations 1 and 2. In addition, stations 6, 7 and 8 formed cluster 3. In the rainy season the CA was affected by precipitation which caused dilution of the river water as a result of surface runoff [1]. In cluster 1, the sampling stations had similar characteristic which was impacted by parallel pollution sources in consequence of the land use changed of forest to agriculture and unplanned settlements [11]. Furthermore, the stations of cluster 1 were located in the middle of the river and influenced by urban runoff and anthropogenic activities. Stations 3 and 4 receive pollution from mining, domestic effluents of

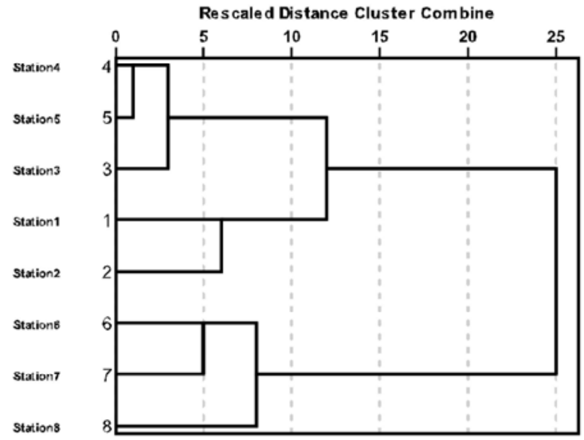

Fig. 2: Dendrogram showing clustering of sampling stations in the rainy season

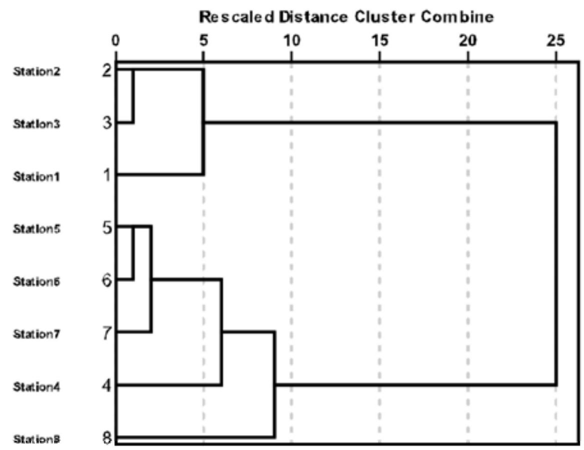

Fig. 3: Dendrogram showing clustering of sampling stations in the dry season

unsewered areas and agricultural activities, whereas station 5 was impacted by industrial activities, surface runoff and wastewater from the Semenyih city [14]. In cluster 2, station 1 was located in the upstream which was surrounded by extended forest covering. Generally, the upstream area of rivers is covered with intensely forest covering and in general affected by surface runoff [36]. In addition, anthropogenic activities at this station were limited except some recreational activities in upstream. Besides, station 2 was located near to station 1 and influenced by pollution sources from deforested areas. In cluster 3, station 6 appeared to be principally influenced by the livestock farms and leaches from small dumps situated on the banks of course, therefore, water quality was found to be extremely contaminated by livestock farming activities [11,13,15]. Moreover, stations 7 and 8 were located in the downstream and affected by increasing flow rate, deforestation, palm plantation, agricultural runoff, urban runoff, erosion and discharge of vehicles washing and workshops. Overall, the anthropogenic activities in this area were comprised industries and settlements, which covered Bangi, Rinching, Beranang and Broga which cause deterioration of water quality [16]. On the other hand, the eight sampling stations during dry season were classified into three distinctive clusters at (Fig.3). Cluster 1 contained stations 1, 2 and 3 that corresponded to relatively moderate pollution. Station 1 was relatively unpolluted due to its location in the upstream. Additionally, Cluster 2 comprised stations 4, 5, 6, 7 and 8 which their contamination may be attributed to the strong impact of anthropogenic factors [11]. In addition, this cluster can be subdivided into 2 sub clusters, the first one includes station 8 in which pollution level was high and basically associated with wastewater of water treatment plant and domestic effluent of Bangi City. Likewise, stations 4, 5, 6 and 7 can be formed the second subcluster of cluster 2, which located as mentioned above but during the dry season it was not negatively affected by the high precipitation rate. These results showed that the deterioration in water quality, particularly in the midstream and downstream stations was impacted by untreated domestic effluents, wastewater of livestock husbandry farms, agriculture and urban runoff and industrial activities, besides discharge from Bangi and Semenyih cities that includes more than half the population around Semenyih basin [1, 15]. Eventually, the result indicates that the cluster analysis is a positive multivariate technique to evaluate and classify surface water in the Semenyih river basin. At the same time, it is a significant technique to build an optimal strategy to reduce sampling stations and experimental analysis cost.

Principal Component Analysis (PCA) or Factor Analysis (FA): Principal component analysis (PCA) executed on the standardized datasets for the eight sampling stations in the rainy and dry seasons separately, as represented by cluster analysis. Factor analysis or PCA is a significant multivariate technique to classify and evaluate the factors affecting on water quality [37, 38]. Factor analysis of the datasets of rainy and dry seasons generated four factors in both the rainy and dry seasons, with total variance 93.09% and 97.25%, respectively. In this study, the factor loading was classified to strong (>0.75-1), moderate (0.50-0.75) and weak (0.30-0.50) based on loading values [39, 40]. In the rainy season, the datasets of 23 water quality variables consisted of four factors (Table 6). Factor 1 comprised 40.79% of the total variance, has strong positive factor loading on turbidity, TSS, BOD, COD, OG, E. coli and TC, while conductivity, TDS, NH3-N and TH indicated moderate positive loadings as well as weak loading on NO3, PO4, Fe and Pb. These variables ascribed to industrial, mining, anthropogenic and land use activities. This was mostly expected because the domestic and industrial effluent of Bangi and Semenyih cities that discharge their wastewater directly into the Semenyih river. In addition, the moderate positive loading of conductivity, TDS, NH3-N and TH are attributed to the lithologic sources (rocks and sediments) and urban runoff. Furthermore, the strong loading of turbidity, TSS, BOD, COD, OG, E. coli and TC are due to surface runoff, domestic wastewater and fertilizer (animal waste) used in agricultural activities as well as discharge from urban areas involving the erosion of road edges due to surface runoff, clearing of lands and agricultural runoff [41]. According to [42], the transport of coliform is primarily through the soil or direct input by a warm blooded animal (e.g. livestock). Factor 2 contained 28.56 % of the total variance and has strongly significant loading of pH and

Table 6: Factor loadings of the 23 parameters on varimax rotation in the rainy season.

	Rotated Component matrix			
Parameters	Factor1	Factor 2	Factor 3	Factor 4
DO	-0.10	-0.89	-0.27	-0.26
pH	0.15	0.94	-0.13	0.14
Cond	0.70	0.61	0.25	0.13
TDS	0.71	0.59	0.27	0.12
NO3	0.45	0.62	0.50	-0.01
PO4	0.49	0.29	0.74	-0.06
TUR	0.95	0.21	0.17	0.14
NH3N	0.68	0.52	0.46	-0.05
TSS	0.94	0.06	0.28	0.18
BOD	0.84	0.42	0.24	-0.11
COD	0.87	0.40	0.26	-0.01
OG	0.81	0.32	0.23	0.02
TH	0.54	0.74	0.22	0.14
E.coli	0.77	0.57	0.29	-0.01
TC	0.81	0.51	0.24	0.12
Fe	0.36	0.65	0.41	0.47
Zn	-0.85	0.27	0.27	-0.02
Cd	-0.23	0.49	0.49	0.65
Mn	0.16	0.10	-0.01	0.98
Pb	0.46	0.67	0.51	0.16
Cu	-0.08	0.78	0.54	-0.11
Ni	0.28	0.14	0.79	0.48
Cr	-0.90	0.05	-0.04	-0.13
Variance%	40.79	28.56	14.60	9.13
Cumulative%	40.79	69.35	83.96	93.09

Table 7: Factor loadings of the 23 parameters on varimax rotation in the dry season.

	Rotated Component matrix			
Parameters	Factor 1	Factor 2	Factor 3	Factor 4
DO	-0.48	-0.70	-0.46	-0.18
pH	-0.22	-0.84	-0.38	0.22
Cond	0.57	0.56	0.52	0.31
TDS	0.59	0.53	0.50	0.34
NO3	0.75	0.43	0.48	0.17
PO4	0.86	0.41	0.26	-0.08
TUR	0.91	0.29	0.29	0.10
NH3N	0.72	0.43	0.51	0.19
TSS	0.92	0.34	0.05	0.16
BOD	0.69	0.70	0.08	0.13
COD	0.61	0.73	0.27	-0.07
OG	0.67	0.71	0.11	0.10
TH	0.57	0.38	0.62	0.34
E.coli	0.53	0.69	0.43	0.08
TC	0.55	0.71	0.40	0.05
Fe	0.28	0.86	0.15	0.27
Zn	0.79	0.38	0.40	0.20
Cd	0.14	0.12	0.21	0.94
Mn	0.71	0.24	0.63	0.21
Pb	0.79	0.37	0.37	0.32
Cu	0.12	0.33	0.92	-0.04
Ni	0.30	0.90	0.09	0.28
Cr	0.32	0.03	0.81	0.40
Variance%	37.72	31.14	20.02	8.37
Cumulative%	37.72	68.86	88.88	97.25

Cu, while having moderate loading of conductivity, TDS, NO3, NH3-N, TH, *E. coli*, TC, Fe and Pb. The Strong loading of Cu and pH pointed to pollution from anthropogenic sources due to the discharge of domestic sewage as well as industrial effluents that cause Cu pollution in receiving water. On the other hand, the moderate positive loadings are strongly associated with municipal sewage and wastewater treatment plants as well as the metal group originating from industrial effluents [44]. Factor 3 showed about 14.60 % of total variance. It has only one parameter with strong positive loadings (Ni) and has moderate loading on NO_3, PO_4, Pb and Cu Furthermore, NH_3-N, Fe and showed weak positive loading. The strong and moderate positive loading is ascribed to anthropogenic sources including wastewater, mining and discharge from industrial facilities or as leachate from landfills and soil [44]. Factor 4 encompassed 9.13% of the total variance, has a strong positive loading on Mn and moderate positive loading on Cd as well as positive weak loading on Fe and Ni. In contrast, the datasets of the dry season of the 23 water quality parameters comprised three loading factors (Table 7). Factor 1 was the most important with 37.72% of the total variance with strong significant loading of NO_3, PO_4, turbidity, TSS, Zn and Pb as well as moderate loading on conductivity, TDS, NH_3-N, BOD, COD, OG, TH, E. coli, TC and Mn, which stranded for organic and inorganic contamination from domestic effluent besides point and nonpoint source contamination. Factor 2 showed 31.14% of total variance. It has two parameters with strong positive loading namely, Fe and Ni. Furthermore, conductivity, TDS, BOD, COD, OG E. coli and TC showed moderate positive loading. Additionally, NO_3, PO_4, NH_3-N, TSS, TH, Zn and Cu indicated weak positive loading, while DO and pH represented strong negative loading. Therefore, the strong and moderate positive loadings are attributed to products from anthropogenic activities with extremely urban impacts. Moreover, the strong positive loading of Fe is associated with iron in rocks and clay soils and argillaceous limestone as well as industrial wastes and mine drainage [32]. Factor 3 showed 20.02% of the total variance and has only two parameters with strong significant loadings which were Cu and Cr. The presence of Cu and Cr ascribed to anthropogenic sources such as industrial effluents derived from the production of corrosion inhibitors and pigments [1, 15], which then becomes a pollutant of aquatic ecosystems and harmful to aquatic organisms [16]. In addition, the moderate positive loadings of conductivity, TDS, NH3-N, TH and Mn are attributed to pollution from industrial activities and lithologic sources. Factor 4 stranded for 8.37% of the total variance, with strong positive loading on Cd which ascribed to the high fluxes from industrial and urban wastes including the immense urban runoff [16]. This study represented the most influenced parameters on water quality in both rainy and dry seasons. Based on the strong loading, the twenty-three parameters were reduced to 11 parameters during both rainy and dry season; therefore, these parameters were the most influence on the water quality of the Semenyih River. Consequently, factor analysis was used as a valuable technique to provide a significant data reduction and to classify parameters which basically contribute to the spatial and seasonal variations in the water quality.

CONCLUSIONS

The water quality of the Semenyih River varies based on the seasons and locations of the sampling stations. In the rainy season, the mean values of conductivity, TDS and TH were categorized as class I, while DO, pH, BOD_5 were classified as class II based on the NWQS for Malaysian rivers,. In addition, the mean values of NO_3, NH_3-N and TSS were categorized under class III. Similarly, the mean values of turbidity, COD and O&G were classified as class IV, whereas PO_4, E. coli and TC were classified as class V. On the other hand, the mean values of water quality variables during dry season were classified as the following; pH, conductivity, TDS and TH were categorized as class I, while DO and turbidity categorized under class II. Furthermore, NO_3, NH_3-N, TSS, O&G, BOD and COD were categorized as class III. Likewise, PO_4, E. coli and TC were categorized as class V and exceeded the permissible threshold limits of NWQS. Therefore, the river was extremely contaminated with turbidity, COD, O&G, PO_4, E. coli and TC in the rainy season and PO_4, E. coli and TC during dry season, because these variables exceeded the tolerable threshold levels of NWQS. The order of heavy metal concentrations during the rainy season was Fe> Mn>Zn> Cu>Cr> Pb>Ni> Cd, while was Fe> Mn>Zn> Cr>Cu> Pb>Cd> Ni in the dry season. Cluster analysis classified 8 sampling stations into three and two clusters during dry and rainy season based on the similar water quality characteristics. Hence, it can reduce sampling stations and experimental analysis cost. Furthermore, factor analysis (FA) of the water quality datasets generated four factors in both the rainy and dry seasons with total variance of 93.09% and 97.25%, respectively. Additionally, FA provided a significant data reduction and classification of variables which basically contribute to the spatial and seasonal variations of water quality. Overall, the anthropogenic pollution sources were the main reason of the water quality deterioration in the Semenyih River. Yet, the river water needs excessive treatment before using it as a resource for domestic purposes.

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