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A SHORT-TERM STUDY OF THE STATE OF SURFACE WATER ACIDIFICATION AT SEMENYIH DAM

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Abstract

A short-term study was done to analyze the state of acidification of surface water at Semenyih Dam, This study is part of a continuous monitoring programme for Malaysia as a participatory country of EANET (Acid Monitoring Network in East Asia). Surface water samples were taken at selected points of the dam from February to December 2005. Temperature, electrical conductivity, pH, alkalinity, acid neutralizing capacity (ANC) as well as concentration of specific ionic species were measured, determined and analysed in this study. Present available short-term study data indicates Semenyih Dam surface water is currently not undergoing acidification.

Abstrak

Satu kajian jangka pendek telah dijalankan untuk menentukan keasidan di Empangan Semenyih. Kajian ini adalah sebahagian aktiviti program pengawasan persekitaran akuatik dari Malaysia sebagai ahli EANET (Acid Monitoring Network in East Asia). Sampel permukaan air di ambil dari tempat tertentu di Empangan Semenyih dari bulan Februari ke Disember 2005. Parameter yang dianalisa termasuk suhu, kekonduksian elektrik, pH, kealkalian, kebolehan meneutralkan acid (ANC) serta kepekatan ion-ion terlarut. Data semasa kajian jangka pendek ini menunjukkan Empangan Semenyih tidak mengalami keasidan.

Introduction

Acidification is a process where emissions of acidifying substances affect living creatures and the environment. Acidification effects on the environment began to appear a long time ago, however, serious attention on the issue only started in the late 1960s [1]. In many parts of America and Europe, surface water acidification has been recognized as a major environmental problem and now there is growing concern that similar damage is occurring in recent industralised parts of East Asia [2].

Acidic pollutants can be deposited from the atmosphere to the earth's surface in wet and dry forms. The common term to describe this process is acid deposition. Lake acidification starts with acid deposition into the water bodies. There are two forms of acid deposition, wet deposition and dry deposition [3]. Wet deposition refers to acidic rain, fog and snow. When acidic water flows through and over the ground and falls into lakes, it affects a variety of plants and animals. Dry deposition refers to acidic gases and particles. About half of the acidity in the atmosphere falls back to earth through dry deposition.

Aquatic ecosystems in lakes and waterways are affected by acidification at all levels and this has a profound impact on both animal and plant communities. The influences on aquatic organisms are both directly, because of the resulting toxic conditions, and indirectly, because of the lack or loss of suitable, acid-sensitive prey for food.
In Northern Europe and North America, pH of lake waters decreased in the 1970's and damages from this decrease resulted in declining fish populations [2]. Currently, acidification damage to flora and fauna in lakes and waterways has been reported in Norway, Sweden, Finland and Scotland as well as parts of eastern North

America [1]. Studies conducted in these areas indicate inland water bodies having low alkalinity (below 0.05 meq/L) are prone to acidification by acidic deposition.

In East Asia, apparent acidification of lakes, streams and other waterways due to acid deposition has not been observed. [2]. This could be due to the fact that there are only few acidification studies done on aquatic environment compared to soil and vegetation studies [4]. A study done by Streets et al (2001) indicated a significant increase in SO_2 and NO_x emissions in Malaysia during a 7-year period from 1990 to 1997 [5]. This corresponds to an increase of 22% for SO_2 and 76% for NO_x. If this trend continues, it can be predicted that in the near future, emissions of SO_2 and NO_x in Asia will increase significantly. Therefore, it is necessary to continuously monitor the presence of acidifying species which may eventually affect the aquatic ecosystem. This study was done to quantify the major ions in the surface water of Semenyih Dam, which has been chosen as a background site. The overall objective is to detect any sign of inland aquatic acidification as a result of anthropogenic activities at the site, and henceforth make a short-term assessment of the state of acidification for Semenyih Dam. This study is part of a continuous monitoring programme, conducted by Universiti Teknologi MARA (UiTM) in collaboration with Ministry of Natural Resources and Environment (NRE) and Malaysian Metereological Services (MMS) to represent Malaysia as one of the 14 participatory countries of EANET (Acid Deposition Monitoring Network in East Asia). Semenyih Dam, categorised as a semi-urban area, was chosen as a background site due to its accessibility and suitability. This man-made dam was built to feed the Semenyih River to ensure there is sufficient water at a downstream intake point for a water treatment plant. This dam, located at Hulu Langat district, supplies a major portion of domestic water to Klang Valley which includes Federal Territory of Kuala Lumpur, and districts of Gombak, Petaling, Ulu Langat and Klang.

Experimental

Sampling site

The physical characteristics of the reservoir are shown in Table 1 below. The Semenyih Dam is located 25 km from Kajang town and 20 km from Bangi town. Beranang, Seremban, and Nilai are also located within 25 km from Semenyih Dam while Shah Alam is 80 km away. All these towns have industries, businesses and housing areas, which could contribute to anthropogenic pollution. There is also an agricultural area located on the west side of the reservoir and forest areas on the east side. Table 2 shows the industrial areas and the main type of industries located near the Semenyih Dam. According to Bhatia (2001). some of these industries dealing with automotives, packaging, paints, stainless steel and chemicals have potential to cause more acidic emissions than the rest [6]. Sulfate and nitrate were detected in dust samples by Matori et al (2004) in an air pollution study at Bangi [7]. This study is also in agreement with a terrestrial study done by M. Rozali et al (2001) which showed presence of SO_4^{2-} and NO_3^- in street dusts of Kajang, Nilai, Bangi and Seremban [8].

Table 1: Physical characteristics of Semenyih Reservoir

PARAMETER	CHARACTERISTICS
Altitude	30 m above sea level
Longitude	101^0 53.058 E
Latitude	3^o 04.574 N
Depth	40.6 m
Length	800 m
Catchment Area	3.6 km^2
Maximum water level	111 m above sea level

Sampling points

8 sampling points (Fig. 1) were selected. 4 sites (L, S, R and K) were located at the mouths of the 4 main rivers flowing into the dam. These rivers are the Lanjut, Semenyih, Rephen and Kesuma River. The other 4 sites (M1, M3, M5 and M8) are points along the middle of the dam. The geographical locations of these sampling points are shown in Table 3 and an aerial view is shown in Figure 1. The pH, EC and temperature were measured in situ while the samples were stored in polyethylene bottles at 4^0C and brought to the laboratory for further analysis.

Table 2: The industrial areas located near the Semenyih Dam

INDUSTRIAL AREAS	MAIN TYPE OF INDUSTRIES	DISTANCE
Beranang	Plastic, Electronic, Wood, Furniture, Garment, Concrete, Metal, Stainless Steel, Semiconductors, Food, Rubber and Latex, Packaging, Aluminium and others	15 km
Bangi	Petrochemical, Automotive Components Manufacturing, Steel Products, Food, Chemical, Diecasting, Plastic, Spray Painting , Printing, Plastic and others	20 km
Nilai	Metal, Food, , Concrete, Roofing, Furniture, Stainless Steel, Paint, Rubber, Piping, Motor, Plastic, Resin, Polyester, Automotive Parts Forging and others	20 km
Seremban	Roofing, Rubber and Plastics, Cement, Concrete, Food, Semiconductors, Furniture, Automotive Parts, Palm Products, Specialty Chemicals, Construction, Air-Conditioning and Electrical, Oil and Gas, Petrochemicals and others	25 km
Kajang	Food, Automotive Parts, Air Conditioning , Refrigeration and other related Equipment, Diecasting, Test Equpment and Machines and others	25 km
Shah Alam	Metal and Steel , Power cables & Conductor Wires , Rubber and Plastic , Automotive Parts, Audio and Electronic Products, Motor Assembly, Food and Beverage, Waste Treatment Plants, Plastics and others	80 km

Source: http;//search.yahoo.com/search? p=Bangi, p=Kajang, p= Nilai, p =Beranang, p = Seremban

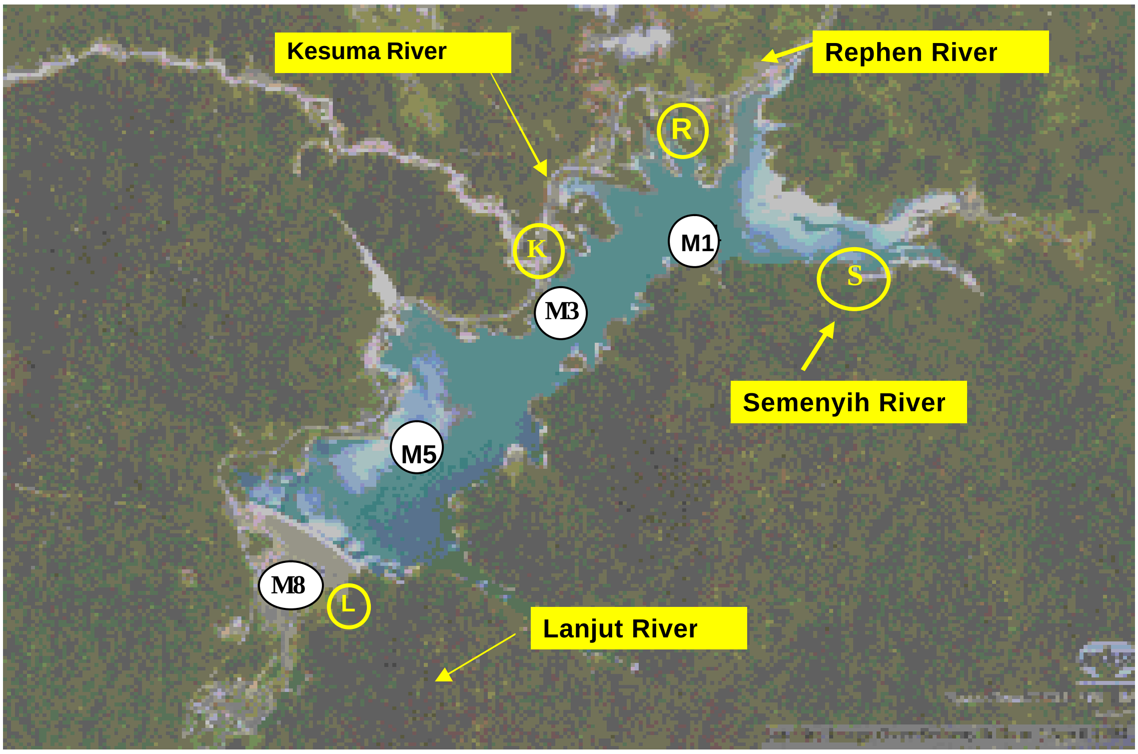


Fig 1: Location of the 8 sampling points on Semenyih Dam.

Table 3: Geographical locations of sampling points at Semenyih Dam

Sampling Points	Altitude	Longitude	Sampling Points	Altitude N	Longitude E
M1	3^{0}05.800	101^{0}54.351	L	3^{0}04.552	101^{0}53.397
M3	3^{0}05.387	101^{0}53.864	S	3^{0}05.724	101^{0}54.634
M5	3^{0}05.288	101^{0}53.430	R	3^{0}06.089	101^{0}54.375
M8	3^{0}04.615	101^{0}53.092	K	3^{0}05.754	101^{0}53.969

Sampling Frequency

Surface water samples were collected at 1 foot depth using a grab sampler on bimonthly basis starting from Feb 12 to Dec 15, 2005. Two samples were taken at each sampling point. Sampling duration covered both rainy (late October to early March) and dry (early June to late September) seasons. A total of 112 samples were taken, 56 from the river mouths and 56 from the middle of the dam.

Chemical Analysis

Chemical analysis for anionic species and NH_4^+ was carried out using Metrohm 761 suppressed type ion chromatography. Major anions quantitatively determined were SO_4^{2-}, NO_3^- and Cl^-. The instrumental conditions for ion chromatography are shown in Table 4. At all stages in the course of analysis the conductivity of the ultra high quality (UHQ) water used in the analysis was not less than 18.2 mΩ cm, which was in compliance with the manufacturer's specifications. Analysis was done in duplicates. Quality check standard was run for every 10 samples. Cation analysis was carried out using inductively coupled plasma optical emission spectrometer (ICP-OES). The cations determined were K^+, Na^+, Ca^{2+}, and Mg^{2+}.

The ANC was calculated using formula by Skjelkvale et al (2000) as the difference between concentration of base cations and strong acid anions [9]. Alkalinity was determined by titration using 0.01M H_2SO_4 to endpoint 4.8 using a pH meter. The H^+ concentration was calculated from pH values taken in situ and again at the laboratory.

Table 4: Instrumental conditions using Metrohm 761 Ion Chromatography

	CATION	ANION
Analytical column	Metrostep Cation 1-2, 4.0 x 25 mm	Metrostep A Supp 5-10, 4.0 x 150 mm
Guard Column	Metrostep C2 Guard	Metrosep A Supp4 / 5Guard
Eluent	Tartaric acid / dipicolinic acid acid	Sodium carbonate/sodium hydrogen carbonate
Flow rate	1 ml min^{-1}	0.7 ml min^{-1}
Column temperature	Room temperature (~ 25°C)	Room temperature (~ 25°C)
Detector temperature	35°C	35°C
Suppressor	Not required	MSM Suppressor

Results and Discussion

Chemical characteristics of Semenyih Dam

The various measurements and analytical results for the 8 sampling points are presented in Table 5 and 6. Results of the monthly mean ionic species concentrations of Table 6 indicates HCO_3^- having the highest concentration among all the ionic species in the dam. HCO_3^- mean concentration range from 10.57 to 11.594 mg/L. The highest cation concentration was shown by Ca^{2+} concentration with an mean concentration range between 1.030 to 8.932 mg/L. The Na^+ had a mean concentration ranging between 0.953 to 3.374 mg/L, and K^+ mean concentration ranged between 0.797 to 3.243 mg/L. The Mg^{2+} mean concentration was less than Na^+ and K^+ average concentrations, with a range of 0.625 mg/L to 2.802 mg/L. The mean concentration of SO_4^{2-} anion was consistent throughout the study with a range between 1.260 to 1.508 mg/L. However, SO_4^{2-} mean concentration was much higher than NO_3^- which had a range of 0.03 to 0.917 mg/L. Cl^- had a higher but consistent mean concentration than NO_3- with a range of 0.663 to 0.941 mg/L. F^- had the lowest mean anion concentration which ranged from 0.066 to 0.277 mg/L. NH_4^+ had the lowest mean concentration of all the ionic species in the dam and it ranged from undetected to 0.173 mg/L. The overall results show that the mean concentrations of ionic species in Semenyih Dam followed the order: $HCO_3^- > Ca^{2+} > Na^+ > K^+ > Mg^{2+} > SO_4^{2-} > Cl^- > NO_3^- > F^- > NH_4^+$. The results show that the mean concentrations of the base cations (Ca^{2+}, K^+, Na^+ and Mg^{2+}) are higher than the concentrations of the strong acidic anions (NO_3^- and SO_4^{2-}).

Our previous short-term studies done on soils surrounding Semenyih Dam in 2005 indicated presence of Ca^{2+}, Mg^{2+}, K^+ and Na^+ ions while current on-going Semenyih Dam rainfall studies showed presence of Ca^{2+}, Mg^{2+}, K^+, Na^+ and NH_4^+ cations during this period of surface water study. Terrestrial studies done in Kajang, Nilai, Bangi and Seremban by M. Rozali et al (2001) showed presence of Ca^{2+}, Mg^{2+}, K^+ and Na^+ in street dusts. The Ca^{2+} concentration in surface water could have come from these sources as the dam itself is made of granite. The low and sometimes undetectable concentration of NH_4^+ indicates that agricultural activities associated with high ammonium-based waste products as well as contributions from the rainfall have not caused significant ammonium pollution to Semenyih Dam.

The presence of K^+ and Na^+ ions, normally associated with soil dust and biomass burning seem to be highest at the mouth of Semenyih River (Table 5). The Cl^- ion normally associated with sea salt spray and various anthropogenic activities had the highest mean concentration of 1.351 mg/L at the mouth of the Semenyih river (Table 5). According to M. Barzani Gasim et al (2002), anthropogenic activities due to rapid population growth, agricultural development, industrialization and urbanization after 1996 has deteriorated the water quality of Semenyih river [10]. However, the mean concentration level of Cl^- is still below the Malaysian Acceptable Value for Raw Water Quality of 250 mg/L.

The highest mean SO_4^{2-} concentration of 2.391 g/L was detected at the mouth of Rephen river, however it is well below the Malaysian Acceptable Value for Raw Water Quality of 400 mg/L. The mouth of Kesuma river showed the highest mean concentration NO_3^- of 1.924 mg/L which is still within the permissible level of the Malaysian Acceptable Value for Raw Water Quality of 10 mg/L.

Alkalinity of water is a measure of its capacity to neutralize acids. Alkalinity of many surface waters is taken as a function of bicarbonates, carbonates and hydroxide content with bicarbonates (HCO_3^-) representing the major form of alkalinity (90%). HCO_3^- therefore provides the natural buffering systems in the lakes. HCO_3^- is usually released by the weathering of land minerals and decomposition of organic matter. The concentration of the HCO_3^- ions represents the largest ionic species present in Semenyih Dam. Its concentration is more than ten times the concentration of the strong anions, SO_4^{2-} and NO_3^-. Alkalinity values for Semenyih show a mean range of 0.22 to 0.40 meq of HCO_3^- per litre. Lakes with zero or insignificant alkalinity (less than 0.02 meq of HCO_3^- per litre) are classified as acidic [1]. This indicates Semenyih Dam has relatively high acid buffering capacity and therefore will not be considered an acid sensitive lake. This is also supported by the high ANC value shown in Table 7. High ANC values (above 0.1 meq/L) indicates that particular body of water is currently insensitive to acidic deposition or not acid deposition impacted as the sum of the concentration of the strong acid anions (SO_4^{2-}, NO_3^- and Cl^-) are small compared to the basic cations (K^+, Ca^{2+}, Mg^{2+} and Na^+).

Physical characteristics of Semenyih Dam

The pH, electrical conductivity and temperature were taken both in situ and in the lab. The monthly mean readings of pH are given in Figure 2. The mean pH readings at Semenyih Dam varied from pH 6.42 to 8.12. All these values show an overall mean above a neutral pH of 7.00. The maximum pH recorded was taken in the middle of the Semenyih Dam. The lowest pH of 6.25 was detected in Sept, taken at the mouth of Lanjut River, however, this did not significantly affect the overall basic pH of the Semenyih Dam. Natural waters usually have pH values in the range of 4 to 9, and most are slightly basic because of the presence of bicarbonates and carbonates of the alkali and alkaline earth elements. Lakes that have pH levels lower than 5.6 are usually classified as very acidic [1]. A pH of more than 7.00 indicates the presence of high levels of bicarbonates and or carbonates and this corresponds to high alkalinity. High alkalinity implies that Semenyih Dam has high acid buffering capacity and thus is not under the threat of acidification.

Temperature affects most chemical reactions that occur in water and it also affects the solubility of gases in water as well as the electrical conductivity readings of water. Figure 3 shows that the mean temperature readings at Semenyih Dam range from 24.04 to 31.19^{0}C with the highest temperature recorded at Kesuma River in the month of February and December 2005.

Electrical conductivity in water is affected by the presence of inorganic dissolved solids such as chlorides, nitrates (anions) and cations such as sodium, magnesium and calcium. Normally EC readings are used in quality control activities to compare between calculated EC (using concentration of main cations and anions in water) and measured EC. Average EC readings for Semenyih Dam range from 19.00 to 29.99 µS/cm (Fig 4). The highest EC readings was detected in the middle of the dam during the month of December while the lowest EC reading found in the month of May, was also detected in the middle of the dam.

Table 5: Mean concentrations of ionic species in mg/L for each sampling point

Na^+	**M1**	**M3**	**M5**	**M8**	**L**	**S**	**R**	**K**	F^-	**M1**	**M3**	**M5**	**M8**	**L**	**S**	**R**	**K**
Feb	1.866	2.716	2.041	2.675	2.004	1.939	1.881	2.590	**Feb**	0.064	0.064	0.085	0.087	0.063	0.080	0.078	0.082
Mac	3.054	2.732	2.856	2.671	2.604	2.591	2.663	2.691	**Mac**	0.082	0.081	0.068	0.085	0.082	0.086	0.082	0.081
May	2.822	2.849	2.797	2.781	2.591	2.604	2.578	2.628	**May**	0.074	0.082	0.081	0.080	0.089	0.087	0.085	0.086
July	3.476	2.297	3.389	3.399	3.620	3.620	2.628	3.436	**July**	0.067	0.070	0.054	0.073	0.065	0.067	0.065	0.069
Sept	2.171	2.139	2.204	2.144	2.157	2.253	2.204	2.117	**Sept**	0.099	0.091	0.086	0.078	0.076	0.078	0.083	0.098
Oct	2.198	2.136	2.150	2.229	2.238	2.226	2.224	2.166	**Oct**	0.088	0.091	0.090	0.087	0.085	0.071	0.099	0.087
Dec	1.933	1.878	2.038	2.032	1.977	1.963	1.914	1.889	**Dec**	0.090	0.086	0.090	0.084	0.088	0.043	0.143	1.590
K^+	**M1**	**M3**	**M5**	**M8**	**L**	**S**	**R**	**K**	Cl^-	**M1**	**M2**	**M5**	**M8**	**L**	**S**	**R**	**K**
Feb	1.538	2.233	1.826	2.473	1.902	1.827	1.607	2.148	**Feb**	0.735	0.679	0.669	0.675	0.726	0.706	0.632	0.645
Mac	2.140	2.126	2.268	2.158	2.221	2.191	2.357	2.28	**Mac**	0.666	0.771	0.717	0.665	0.666	0.664	0.676	0.802
May	2.127	2.135	2.323	2.314	1.993	2.052	2.357	2.035	**May**	0.689	0.649	0.649	0.661	0.688	0.651	0.666	0.656
July	3.198	2.297	3.318	3.129	3.375	3.765	3.638	3.223	**July**	0.762	0.794	0.621	0.739	0.868	0.762	0.953	0.799
Sept	1.789	1.746	1.912	1.890	1.831	1.813	1.839	1.881	**Sept**	0.807	0.838	0.798	0.807	0.832	0.768	0.783	0.852
Oct	1.738	1.828	1.943	1.835	1.909	1.947	1.965	1.836	**Oct**	0.854	0.851	0.939	0.849	0.977	1.351	0.860	0.845
Dec	1.766	1.803	1.812	1.746	1.781	1.835	1.834	1.796	**Dec**	0.657	0.666	0.637	0.672	0.650	0.690	0.669	0.668
Ca^{2+}	**M1**	**M3**	**M5**	**M8**	**L**	**S**	**R**	**K**	NO_3^-	**M1**	**M3**	**M5**	**M8**	**L**	**S**	**R**	**K**
Feb	6.752	7.998	7.339	8.327	7.543	6.494	7.513	18.317	**Feb**	0.262	0.264	0.273	0.252	0.289	0.271	0.239	0.195
Mac	2.323	7.024	10.648	9.373	7.244	9.436	10.745	2.583	**Mac***	15.003	9.735	4.623	3.471	3.098	3.997	8.230	34.689
May	8.76	9.207	8.717	8.979	9.856	8.798	8.497	8.639	**May**	0.233	0.225	0.375	0.443	0.033	0.638	0.255	nd
July	5.039	2.297	4.858	4.041	4.775	4.841	4.467	4.535	**July**	0.054	nd	0.382	0	0.050	0.054	0.308	0.067
Sept	2.407	2.554	2.212	2.076	2.260	2.686	2.352	2.191	**Sept**	0.031	0.033	0.030	0.024	0.032	0.013	0.017	0.037
Oct	1.990	2.059	2.068	2.196	2.022	2.220	2.126	1.988	**Oct**	0.695	1.084	0.772	0.961	0.576	0.358	0.964	1.924
Dec	1.859	1.826	2.176	2.023	1.898	1.854	2.035	1.844	**Dec**	0.247	0.217	0.242	0.302	0.337	0.385	0.268	0.475

* sample suspected contaminated
nd : not detected

Table 5: Mean concentrations of ionic species in mg/L for each sampling point (cont.)

Mg^{2+}	**M1**	**M3**	**M5**	**M8**	**L**	**S**	**R**	**K**	**SO_4^{2-}**	**M1**	**M3**	**M5**	**M8**	**L**	**S**	**R**	**K**
Feb	1.482	1.788	1.500	1.846	1.623	1.462	1.623	1.246	**Feb**	1.275	1.290	1.324	1.265	1.294	1.306	1.23	1.337
Mac	0.726	1.966	2.067	2.003	1.702	2.072	1.961	0.823	**Mac**	1.388	1.533	1.532	1.572	1.375	1.33	1.352	1.418
May	1.721	1.958	1.961	1.959	1.67	1.694	1.695	1.764	**May**	2.048	1.444	1.714	1.863	1.169	1.377	1.420	nd
July	2.930	2.297	2.916	2.647	2.902	3.252	2.730	2.742	**July**	1.441	1.420	1.199	1.405	1.383	1.376	2.391	1.449
Sept	0.481	0.698	0.643	0.695	0.686	0.711	0.662	0.661	**Sept**	1.549	1.380	1.338	1.347	1.353	1.331	1.407	1.368
Oct	0.638	0.632	0.672	0.634	0.624	0.629	0.719	0.693	**Oct**	1.350	1.402	1.384	1.398	1.405	1.539	1.391	1.456
Dec	0.616	0.635	0.660	0.682	0.574	0.613	0.577	0.640	**Dec**	1.245	1.244	1.262	1.255	1.253	1.235	1.282	1.302
NH_4^+	**M1**	**M3**	**M5**	**M8**	**L**	**S**	**R**	**K**	**HCO_3^-**	**M1**	**M3**	**M5**	**M8**	**L**	**S**	**R**	**K**
Feb	0.058	nd	0.119	0.034	0.029	0.032	0.084	0.062	**Feb**	10.343	10.676	9.342	10.676	10.343	9.675	11.344	20.352
Mac	0.049	0.096	nd	0.063	0.437	0.028	0.033	0.070	**Mac**	10.009	10.343	10.343	9.675	11.344	10.343	10.009	20.018
May	0.134	0.131	0.022	nd	0.049	0.210	0.064	0.099	**May**	10.009	11.677	10.343	9.675	10.343	9.342	11.010	18.683
July	nd	nd	0.188	nd	nd	nd	0.135	0.071	**July**	10.009	11.344	10.676	10.343	10.343	10.676	9.342	19.351
Sept	nd	nd	nd	nd	nd	nd	nd	nd	**Sept**	10.010	9.010	11.010	10.010	9.810	12.010	10.810	11.910
Oct	nd	nd	nd	nd	nd	0.072	nd	nd	**Oct**	13.010	11.010	12.010	10.010	10.910	11.010	10.710	11.010
Dec	0.135	0.149	0.165	0.181	0.182	0.169	0.161	0.244	**Dec**	10.010	12.010	11.010	10.010	12.010	12.010	10.710	11.710

Table 6: Overall mean and standard deviation for physical and chemical compositions of surface water for Semenyih Reservoir (based on all sampling points)

	Month	EC (25^{0}C) µS/cm	pH	T (^{0}C)	F^- mg/L	Cl^- mg/L	NO_3^- mg/L	SO_4^{2-} mg/L	HCO_3^- mg/L	Na^+ mg/L	K^+ mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	NH_4^+ mg/L
Mean	Feb	23.31	8.12	31.19	0.075	0.683	0.255	1.290	11.594	2.214	1.944	7.424	1.571	0.06
Sdev		0.33	0.08	0.31	0.010	0.037	0.029	0.034	3.592	0.376	0.319	0.644	0.192	0.03
Mean	March	19.52	7.34	24.04	0.081	0.703	5.525	1.437	11.510	2.765	2.218	7.422	1.665	0.125
Sdev		2.32	0.13	2.20	0.006	0.055	2.767	0.094	3.472	0.147	0.080	3.358	0.562	0.154
Mean	May	19.00	7.39	25.14	0.083	0.663	0.315	1.572	11.385	2.704	2.167	8.932	1.803	0.101
Sdev		1.64	0.14	1.79	0.005	0.016	0.178	0.286	3.039	0.118	0.144	0.431	0.132	0.063
Mean	July	23.15	7.62	25.14	0.066	0.787	0.114	1.508	11.510	3.374	3.243	4.356	2.802	0.150
Sdev		1.95	0.18	1.79	0.006	0.096	0.146	0.365	3.220	0.453	0.441	0.887	0.275	0.054
Mean	Sept	24.32	6.42	28.3	0.090	0.810	0.030	1.380	10.570	2.170	1.840	2.340	0.650	0
Sdev		1.87	0.11	2.31	0.009	0.028	0.008	0.071	1.050	0.044	0.056	0.202	0.074	0
Mean	Oct	19.52	7.34	24.04	0.087	0.941	0.917	1.416	11.210	2.196	1.875	2.084	0.655	0.066
Sdev		2.32	0.13	2.20	0.008	0.173	0.470	0.057	0.910	0.040	0.079	0.089	0.035	0.008
Mean	Dec	29.99	7.49	30.21	0.277	0.664	0.309	1.260	11.190	0.953	0.797	1.939	0.625	0.173
Sdev		1.48	0.19	0.97	0.531	0.016	0.087	0.022	0.870	0.061	0.031	0.125	0.038	0.033

Table 7 : Acid Neutralizing Capacity (ANC) values (in meqL^{-1}) for Semenyih River from Feb to Dec 2005

Month	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}	[BC]	[SAA]	**ANC**
Feb	0.019	0.0041	0.027	0.096	0.050	0.370	0.129	0.645	0.050	**0.6**
Mac	0.020	0.089	0.030	0.120	0.057	0.370	0.137	0.684	0.139	**0.5**
May	0.019	0.0051	0.033	0.118	0.055	0.446	0.149	0.768	0.057	**0.7**
July	0.022	0.0018	0.031	0.147	0.083	0.217	0.230	0.677	0.055	**0.6**
Sept	0.023	0.0048	0.029	0.094	0.047	0.117	0.053	0.312	0.052	**0.3**
Oct	0.027	0.015	0.030	0.095	0.048	0.104	0.054	0.301	0.071	**0.2**
Dec	0.019	0.0050	0.026	0.041	0.021	0.097	0.051	0.210	0.050	**0.2**

Table 8: Monthly rainfall amount in mm for Semenyih Dam from Feb to Dec 2005

Month	Jan	Feb	Mac	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Rainfall amount	7.7	119.5	224.8	177.1	139.1	52.0	239.1	127.2	68.0	207.8	244.8	218.4

Source : Malaysian Meteorological Department

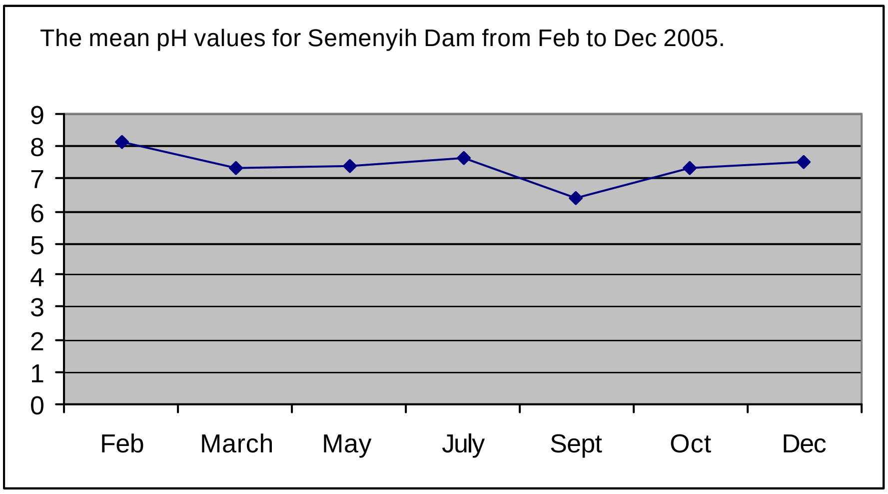


Fig 2: The mean pH values for Semenyih Dam for Feb to Dec 2005

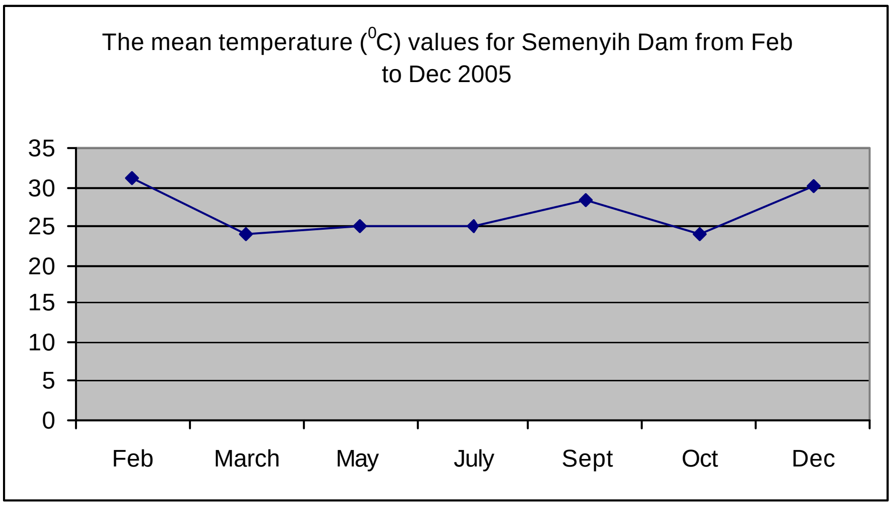


Fig 3: The mean temperature values for Semenyih Dam for Feb to Dec 2005

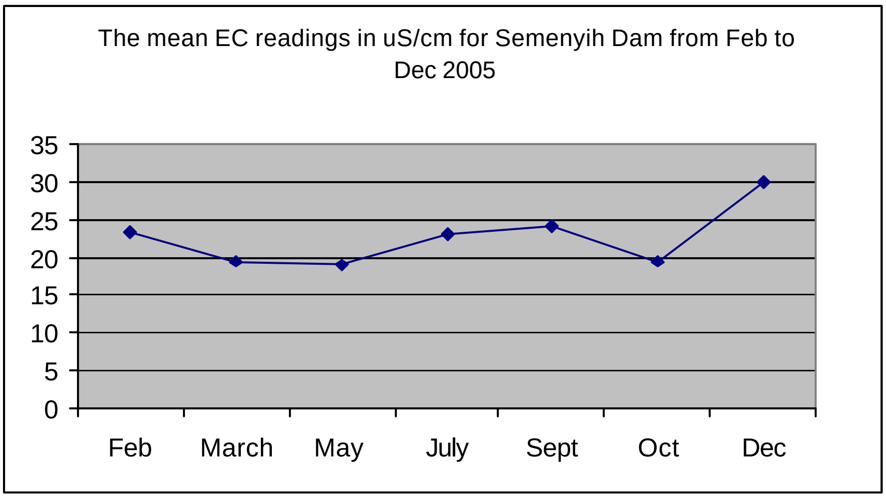


Fig 4: The mean EC readings for Semenyih Dam for Feb to Dec 2005

Temporal variation of chemical parameters

The highest mean concentration of NO_3^- (1.924 mg/L) was detected in October (Fig 5), at the mouth of Kesuma River, while for SO_4^{2-}, the highest mean concentration (2.391 mg/L) was found in July, at the mouth of Rephen River. The higher mean concentration for SO_4^{2} compared with NO_3^- indicates the more predominant role of SO_4^{2-} than NO_3^- in acidic species contribution. The SO_4^{2-} concentrations do not show much variation between sampling points (1.23 - 2.39 mg/L) with one instance showing the absence or non-detectable SO_4^{2-} . This finding is probably due to the absence of single major contributor from the river mouth where the samples were taken. Another explanation could be the waters are well-mixed at those points.

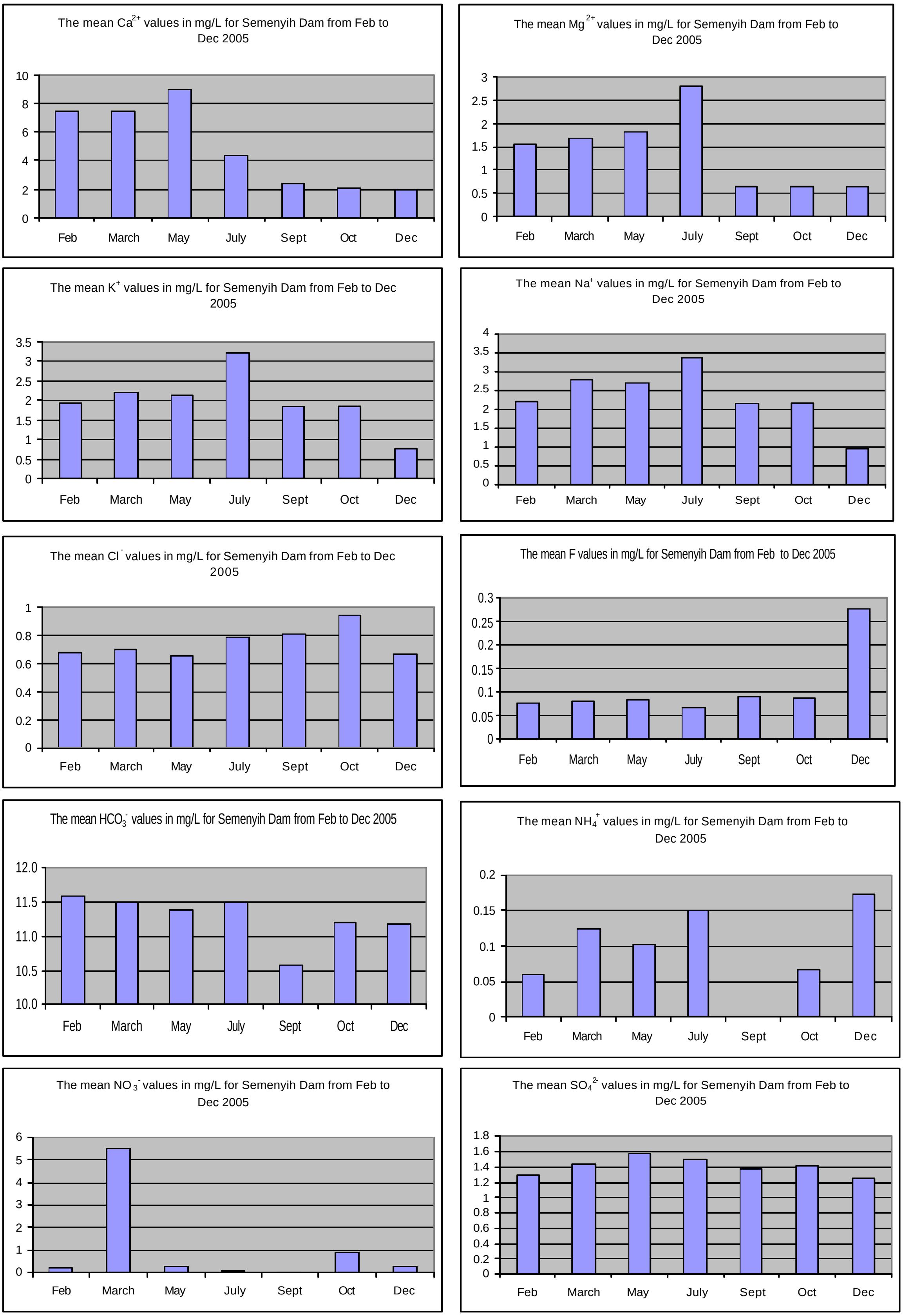
The effect of rainfall on the concentrations of acidic species NO_3^- can be seen from the rainfall data for May, September, October and December 2005 (refer to Table 8 for rainfall data). The NO_3^- mean concentration is lowest at 0.03 mg/L when the rainfall is lowest at 68.0 mm and is the highest at 0.917mg/L when the rainfall is the high at 207.8 mm for the month of October. However, this trend is not seen with the NO_3^- concentration in the months of May and December. In the month of May, when rainfall was 139.1 mm, the mean NO_3^- concentration was 0.315 mg/L while it was only 0.309 mg/L when rainfall in December was 218.4 mm. This probably indicates that rainfall is not the only NO_3^- contributor to the surface water.

Similiarly the mean SO_4^{2-} concentration seem to increase with increasing rainfall as can be seen with rainfall data from Sept and October. In the month of October with rainfall of 207.8 mm, there was 1.416 mg/L of SO_4^{2-} while SO_4^{2-} was 1.380 mg/L when rainfall was 68.0 mm in September. Again this pattern was not followed in the months of May and December. May with rainfall of 139.1 mm had the highest mean SO_4^{2-} concentration while December with the highest rainfall of 218.4 mm had the lowest mean SO_4^{2}- concentration of 1.260 mg/L. Like NO_3^-, other contributing factors besides rainfall (wet deposition) influence SO_4^{2-} concentration in surface waters. It is a well a known fact that atmospheric deposition by which fine particulates and dusts is deposited onto the ground occur mainly through wet and dry deposition. Therefore in the absence of rainfall, dry deposition also influences the amount of atmospheric particulates containing NO_3, SO_4^{2-}, Ca^{2+} and other materials which may be deposited and washed into inland waters. Besides, contribution from inflowing rivers should also be considered.

The concentrations of Ca^{2+}, K^+, Mg^{2+} and Na^+ did not show much variation between the sampling points and the monthly collections. Both Cl^- and F^- concentrations depicted the same trend as Ca^{2+}, K^+, Mg^{2+} and Na^+ concentrations (refer to Fig 5).

Conclusion

The overall results show that the mean concentrations of ionic species in Semenyih Dam followed the order: $HCO_3^- > Ca^{2+} > Na^+ > K^+ > Mg^{2+} > SO_4^{2-} > Cl^- > NO_3^- > F^- > NH_4^+$. The results show that the mean concentrations of the base cations (Ca^{2+}, K^+, Na^+ and Mg^{2+}) are more dominant in concentration than the strong acidic anions (NO_3^- and SO_4^{2-}). This situation thus favours a high ANC value. The high concentration of HCO_3^- promotes high alkalinity. The presence of high ANC values, high alkalinity readings together with basic pH measurements indicate Semenyih Dam has relatively high buffering capacity. Presently this dam has the capacity to neutralize any form of acidification mainly due to anthropogenic activities. Since Semenyih Dam is currently not experiencing acidification, it is not classified as an acid sensitive lake. However any change in the present state of acidification would indicate possible pollution contribution that would pose a potential threat to the inland aquatic system.



The mean Ca^{2+} values in mg/L for Semenyih Dam from Feb to Dec 2005

The mean Mg^{2+} values in mg/L for Semenyih Dam from Feb to Dec 2005

The mean K^{+} values in mg/L for Semenyih Dam from Feb to Dec 2005

The mean Na^{+} values in mg/L for Semenyih Dam from Feb to Dec 2005

The mean Cl^{-} values in mg/L for Semenyih Dam from Feb to Dec 2005

The mean F values in mg/L for Semenyih Dam from Feb to Dec 2005

The mean HCO$_3^-$ values in mg/L for Semenyih Dam from Feb to Dec 2005

The mean NH$_4^+$ values in mg/L for Semenyih Dam from Feb to Dec 2005

The mean NO$_3^-$ values in mg/L for Semenyih Dam from Feb to Dec 2005

The mean SO$_4^{2-}$ values in mg/L for Semenyih Dam from Feb to Dec 2005

Fig 5 : Temporal variation of chemical parameters for Semenyih Dam.

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