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Table of Contents: Volume 9 Number 17, 16 September, 2014

ARTICLES

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Full Length Research Paper

Wet chemical synthesis of Tin Sulfide nanoparticles and its characterization

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Nanostructured materials have attracted much attention in various fields of science and technology. Tin sulfide (SnS) nanoparticles were successfully synthesized by wet chemical method. The as-prepared tin sulfide nanoparticles were characterized by X-ray diffraction, scanning electron microscopy (SEM), transmission electron microscopy (TEM) and dielectric studies. The SEM measurements show the aggregates of small nanoparticles. TEM images showed the presence of spherical tin sulfide nanoparticles of size in the range of 15 nm. The optical properties were obtained from UV-VIS absorption spectrum and the optical band gap was calculated. The dielectric constant calculated by varying the frequencies at different temperatures.

Key words: Preparation, SnS nanoparticles, scanning electron microscopy (SEM), transmission electron microscopy (TEM), optical property and dielectric constant.

INTRODUCTION

The consumption of fossil fuels has increased immensely in the recent years which made the role of renewable energy sources relevant. The other forms of energy such as coal, oil and gas are at the stage of extinction because of the extensive usage. Among the alternative energy sources, photovoltaics is known to be an almost maintenance free clean energy technology. In recent years, semiconductor nanostructures such as nanoparticles, nanorods, nanotubes, nanowires and nanobelts have attracted intensive interest due to their novel physiochemical properties that differ greatly from their bulk counterparts (Alivisatos et al., 1991). IV-VI semiconductor compounds such as PbSe, SnSe and SnS have been important role in different areas of materials science for several decades (Unger et al., 1986). Nanomaterials were widely studied due to their unique physical and chemical properties and also its potential applications in different areas (Simon et al., 1998). These properties and potential applications have stimulated the search for new synthetic techniques for these materials. In recent years, great resources were devoted to the preparation of nanocrystals using a wide variety of methods including electrodeposition (Natter et al., 1998), solvothermal route (Zhang et al., 2003), thermal decomposition (Nayral et al., 1999) and chemical reduction (Yang et al., 2000). These efforts have led to the successful synthesis of many nanocrystals including metals (Shafi et al., 1998) oxides (Liu et al., 2001; Haubold et al., 2001), as well as sulfides (Price et al., 2000) which have already been used as optoelectronic

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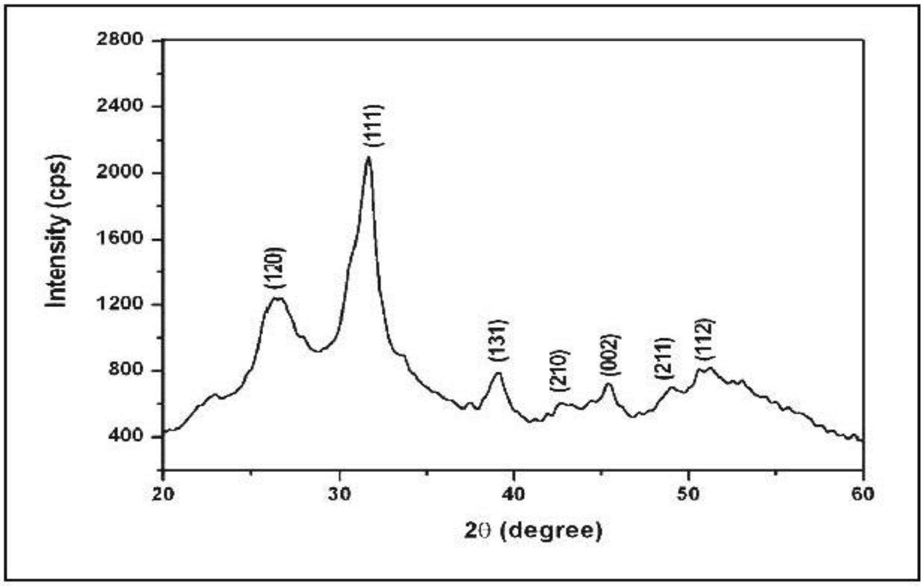

Figure 1. XRD pattern of tin sulfide nanoparticles.

materials in sensors, laser materials, solar cells and other devices. In this paper, we report a wet chemical method to prepare tin sulfide nanoparticles. Powder X-ray diffraction (XRD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) show the formation of tin sulfide nanoparticles possessing orthorhombic structure. The as-prepared tin sulfide nanoparticles display blue-UV emission, promising for applications in optical devices. Dielectric constant studies are carried out at different temperatures.

SYNTHESES OF TIN SULFIDE NANOPARTICLES

The tin sulfide nanoparticles were synthesized through wet chemical method. Tin (II) chloride ($SnCl_2$. $2H_2O$) and sodium sulfide (Na_2S) were taken as tin and sulfur sources respectively and deionized water was used as solvent. 1.2 g of tin (II) chloride and 1.72 g of sodium sulfide were dissolved in deionized water. Sodium sulfide solution was added drop wise into the solution. The colorless tin (II) chloride solution turns dark brown color with the addition of sodium sulfide solution. This indicates the formation of SnS nanoparticles. This reaction was carried out at room temperature for two hours. The precipitates were centrifuged and washed with deionized water and ethanol for several times and dried at room temperature.

RESULTS AND DISCUSSION

Structural studies

XRD is a non-destructive analytical method which identifies and determines various crystalline forms of materials. According to studies, the solution of nanoparticles obtained was purified by repeated centrifugation at 10, 000 rpm followed by re-dispersion of the pellet of nanoparticles into distilled water. After freeze drying of the purified particles, the structure and composition of nanoparticles were analyzed by XRD. As waves interact with a regular structure the diffraction occurs. Figure 1 shows the XRD pattern of tin sulfide nanoparticles. All the diffraction peaks are indexed to pure orthorhombic phase of tin sulfide. This is due to agglomeration of the particles in the powdered sample and hence, XRD was used for phase identification only. The strong and sharp diffraction peaks indicate that the product is well crystallized. Phase purity is confirmed from powder X-ray diffraction. No other impurity peaks are observed. The broadening of the peaks indicates the nanocrystalline nature of SnS. By Knowing the wavelength (λ) full width at half maximum (FWHM) of the peaks β and the diffracting angle θ, particle size (D) was calculated by using the Scherrer formula,

$$D = \frac{0.9\lambda}{\beta \cos\theta} \quad (1)$$

The average grain size of SnS is determined using Scherrer relation and it was found to be around 15 nm.

Optical studies

Optical absorption measurement was carried out on tin sulfide nanoparticles. Figure 2 shows the variation of the optical absorbance with the wavelength of the as-prepared tin sulfide nanoparticles. The optical absorption coefficient has been calculated in the wavelength range

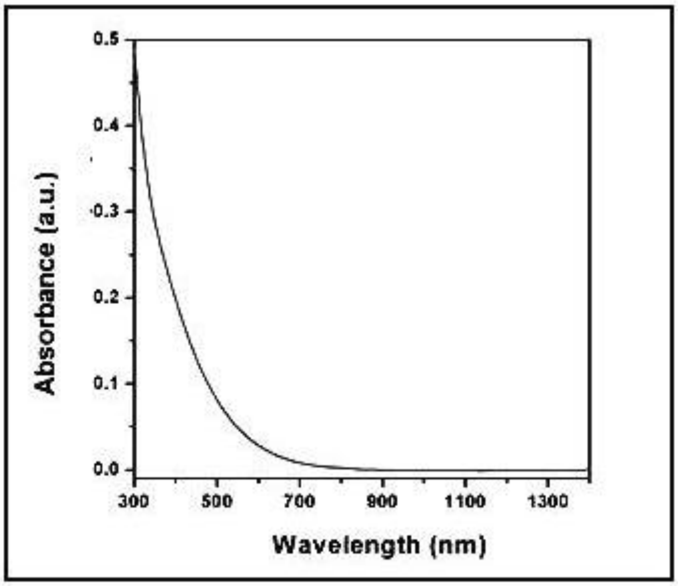

Figure 2. Optical absorption spectrum of SnS nanoparticles.

of 300 to 900 nm. It is clearly observed that the nanoparticles have a wide absorption range from the NIR to the UV, which means it is good for absorption of the sunlight. The absorption edge has been obtained at a shorter wavelength. The band gap energy gap was estimated from the Equation (1)

$$E_g=1.243\times10^3/\lambda_{max} \quad (2)$$

The band gap of tin sulfide nanoparticles was found to be 1.8 eV. In semiconductor nanoparticles, the band gap increases as the particle size decreases.

Scanning electron microscopy (SEM) analysis

External morphology, chemical composition, crystalline structure and orientation of materials making up the sample are revealed by SEM. Figure 3 shows the SEM image of tin sulfide nanoparticles. This SEM image reveals that the particles are in aggregation state due to their extremely small dimensions and high surface energy. It can be seen that the particles adopt irregular morphology with different sized particle. From the image it is clear that the particles were highly agglomerated in nature. This might be due to the fact that the agglomeration may be induced during the crystal growth itself because of the small size regime which is evident from the XRD analysis.

Transmission electron microscopy (TEM) analysis

TEM is commonly used for imaging and analytical characterization of the nanoparticles to assess the shape, size, and morphology. The particle size distribution was also measured from the bright-field TEM image shown in Figure 4. The detection and measurement of the nanoparticles (segmentation) on this type of samples is difficult because thickness changes locally and diffraction from different crystal orientations introduce large contrast variations. Size of tin sulfide nanoparticles measured from TEM image is 15 nm.

Dielectric constant studies

Dielectric studies show the effects of temperature and frequency on the conduction phenomenon in nanostructured materials. Dielectric behavior can effectively be used to study the electrical properties of the grain boundaries. The dielectric properties of materials are mainly due to contributions from the electronic, ionic, dipolar and space charge polarizations. Among these, the most important contribution to the polycrystalline materials in bulk form is from the electronic polarization, present in the optical range of frequencies. The next contribution is from ionic polarization, which arises due to the relative displacement of the positive and negative ions. Dipolar or orientation polarization arises from molecules having a permanent electric dipole moment that can change its orientation when an electric field is applied. Space charge polarization arises from molecules having a permanent electric dipole moment that can change its orientation when an electric field is applied. The dielectric parameters, like the dielectric constant (ε_r) is the basic electrical properties of the tin sulfide nanoparticles. The measurement of the dielectric

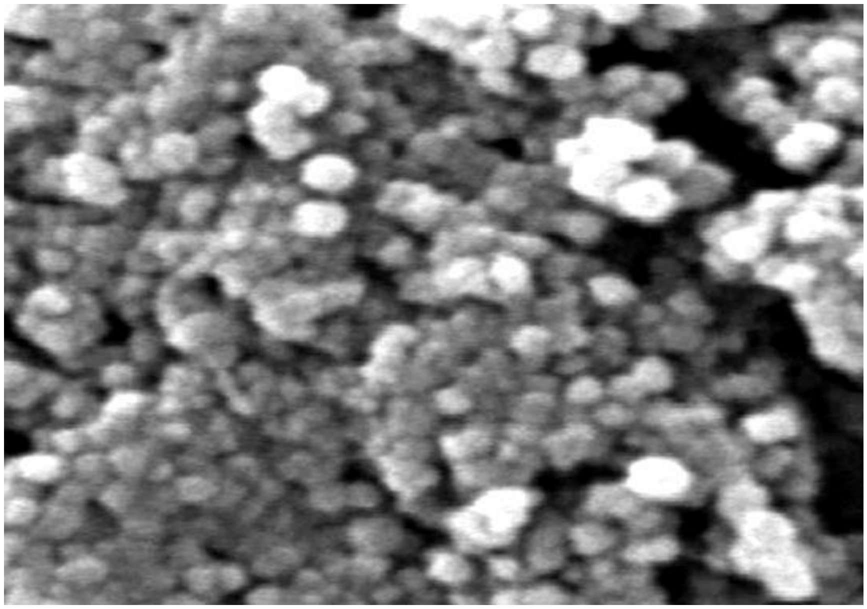

Figure 3. SEM image of tin sulfide nanoparticles.

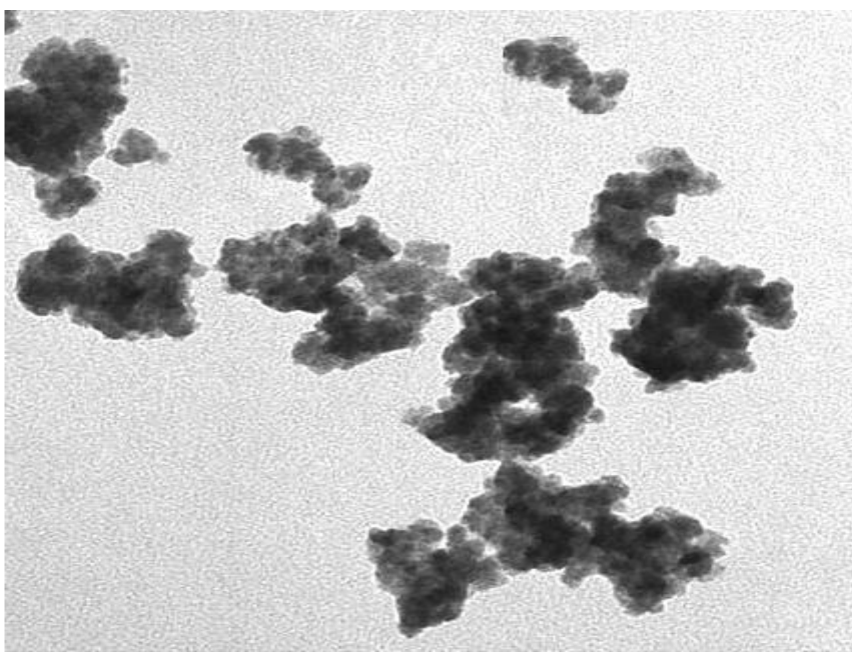

Figure 4. Typical TEM image of tin sulfide nanoparticles.

constant as a function of frequency and different temperatures reveals the electrical processes that take place in tin sulfide nanoparticles and these parameters have been measured. The variations of the dielectric constant of the tin sulfide nanoparticles at frequencies of 50Hz to 5 MHz and at different temperatures of 40, 50, 100 and120°C are displayed in Figure 5. The dielectric constant is evaluated using the relation:

$$\varepsilon_r = \frac{Cd}{\varepsilon_0 A} \quad (3)$$

Where d is the thickness of the sample and A, is the area of the sample. The results suggest that the dielectric constant strongly depend on the frequency of the a.c. signal and the different temperatures of the tin sulfide

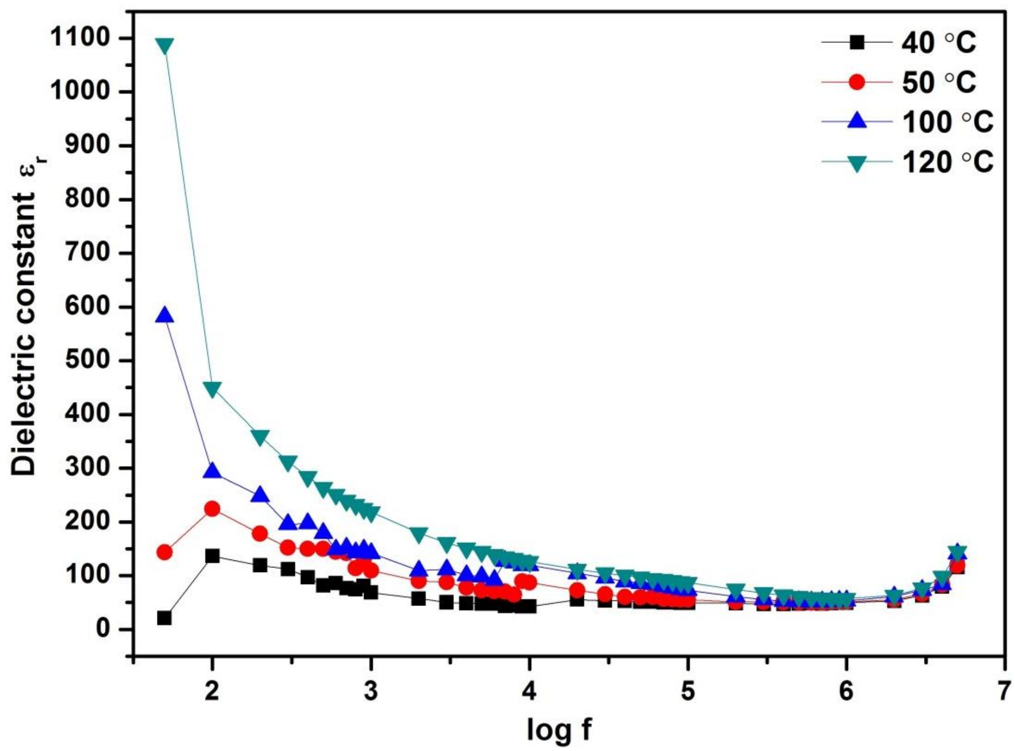

Figure 5. Variation of dielectric constant with log frequency.

nanoparticles. The dielectric constant has higher values in the lower-frequency (50 Hz) and then it decreases up to the high frequency (5 MHz). The dielectric constant of is high at lower frequencies due to the contribution of the electronic, ionic, dipolar and space charge polarizations, which depend on the frequencies (Xue et al., 2002). Space charge polarization is generally active at lower frequencies and indicates the purity and perfection of the nanoparticles. Its influence is strong at higher temperature and is noticeable in the low frequency range (Smyth et al., 1956).

The Figure 5 shows the variation of dielectric constant as function of frequency and temperatures. It is clear from Figure 5 that dielectric constant increases with the increase in temperature. This increase in dielectric constant as a result of increase in temperature can be explained on the basis of phenomenon that as the temperature increases, the dipoles relatively become free and they respond to the applied electric filed. Consequently the polarization increased and hence dielectric constant also increases with the increase in temperature. The variation of dielectric constant with frequency may be explained on the basis of space-charge polarization phenomenon (Rezlescu et al., 1974). According to this, dielectric material has well conducting grains separated by highly resistive grain boundaries. On the application of electric field, space charge accumulates at the grain boundaries and voltage drops mainly at grain boundaries (Gul et al., 2010).

Most of the atoms in the nanocrystalline materials reside in the grain boundaries, which become electrically active as a result of charge trapping. The dipole moment can easily follow the changes in the electric field, especially at low frequencies. Hence, the contributions to the dielectric constant increase through space charge and rotation polarizations, which occur mainly in the interfaces. Therefore, the dielectric constant of nanostructured materials should be larger than that of the conventional materials. One of the reasons for the large dielectric constant of nanocrystalline materials at sufficiently high temperature is the increased space charge polarization due to the structure of their grain boundary interfaces. As the temperature increases, the space charge and ion jump polarization decrease, resulting in a decrease in the dielectric constant.

CONCLUSION

The tin sulfide nanoparticles were synthesized through wet chemical method. The XRD pattern revealed the orthorhombic structure of tin sulfide nanoparticles. SEM micrograph shows the aggregation state of tin sulfide nanoparticles. TEM images showed the presence of spherical tin sulfide nanoparticles of size in the range of 15 nm. In UV-VIS absorption spectrum shows that the nanoparticles have a wide absorption range and 1.8 eV direct allowed transition energy gap. The as-prepared tin sulfide nanoparticles have good crystalline and show strong blue-UV emission, promising for applications in optical devices. The dielectric property studied at different temperatures.

Conflict of Interest

The authors have not declared any conflict of interest.

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International Journal of Physical Sciences

Full Length Research Paper

Effects of land use on river water quality of Awat-Awat Lawas Mangrove Forest Limbang Sarawak Malaysia

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Water quality and trace elements of river water of Awat-Awat, Sundar and Trusan river from Awat-Awat Lawas Mangrove Forest Limbang (AALMFL) Sarawak, Malaysia were investigated in the current research. This study used the application of Water Quality Index (WQI) and National Water Quality Standards (NWQS) provided by Department of Environment (DOE) Malaysia in evaluating the quality of the river. Fifty two different sampling points were selected from upstream, middle stream and downstream of river. Monitoring, sampling and water analysis was conducted from November 2012 until May 2014. The analysis of water samples were performed according to Standard Methods for the Examination of Water and Wastewater APHA 2005. Based on Malaysian Water Quality Index (WQI) by DOE Malaysia, overall water quality status at the study area was found categorized under Class III which represents moderate water quality status. The main concern of water quality in this river is high level of suspended solids and turbidity. The present data of the physico-chemical analysis of river water is very useful for assessment of the mangrove forest ecosystem. It's also important as a baseline data and a reference for government, NGO and other sector or institution in maintaining and preserving the water resources at the area. The results finding in this present research suggest proper water management, conservation and preservation to restore the water quality of this river and its tributary for a productive ecosystem and aquatic resources.

Key words: Water quality index (WQI), water quality parameters, mangrove forest, Sarawak, Malaysia.

INTRODUCTION

River water includes freshwater of mangrove forest facing tremendous challenges in facing development and exploitation especially in this century. River water quality monitoring is very important for rivers affected in urban area. To improve water management, a study on water quality is very important and necessary for evaluation and management of rivers ecosystem and it's practicable in many countries worldwide.

Water quality is the suitability of water for various uses, purposes, and processes. The chemical, biological, microbial and physical characteristic of water is component of water quality. Any of the biological, chemical or physical aspects that influence the use of water is a water quality variable (Boyde, 2000). The water condition that relate to variety of species (biotic) requirements and human needs is measured according

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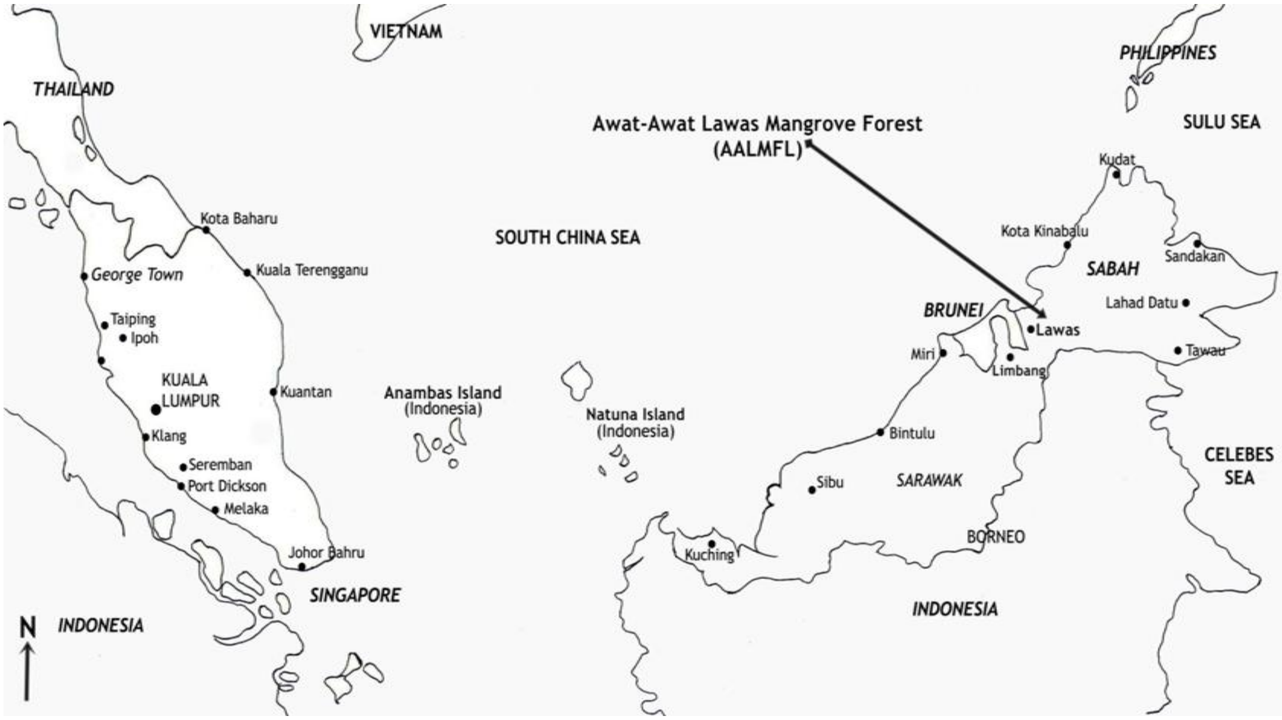

Figure 1. Location of research area of AALMFL in Sarawak, Malaysia.

to all of the aforementioned characteristics (Diersing and Nancy, 2009).

The standards for surface water quality vary because of different environment condition, ecosystem, human uses and activities. Natural process and the human activities affect the surface water (Melina et al., 2005; Singh et al., 2005; Stark et al., 2000). Sources of the water pollutants can be recognized by their natural process on earth, concentration of natural substances and by man-made (Gupta, 2004). The natural entry of pollutants into water bodies getting via rain, weathering process, precipitation rate and sediment transport (Yayýntas et al., 2007; Yilmaz et al., 2005).

Since ancient times, rivers, lakes, sea, swamps and estuaries commonly become the location to dispose wastes for a decade (James et al., 2001; Jamie and Richard, 1996; Keizrul and Jusoh, 1996). Water often deteriorates in quality as a result of its use by humans for various purposes such as plantation, intensive aquaculture, intensive deforestation, industrial factory and urban development which are discharged into water bodies (WRMHD, 2009; Yayýntas et al., 2007; Ardebili et al., 2006; Gammons et al., 2005; Seidel et al., 2005; Boyde, 2000).

Exploitation of forest areas by human activities causes destruction to forest ecosystem. Illegal encroachment and other on-going anthropogenic activities in the forest areas remained a threat to the mangroves forest and cause various problems such as soil loss and serious threat to the water resources. Without proper planning, the continuous exploitation, conversion and development of forest area will cause long-term negative impact to the environment include its water quality. The objectives of this study were to evaluate water quality and trace elements in river water of AALMFL Sarawak Malaysia for better understanding of the effective water conservation and management.

MATERIALS AND METHODS

Study area

Field work was carried out at river water of AALMFL Sarawak, Malaysia which lies between latitude 4º56´N and longitude 115º14´E (Figure 1). Lawas is the main town of the Lawas District in Limbang Division in North of Sarawak. The area experiences an annual rainfall more than 4000 mm during year. The study area was divided into three rivers, namely Awat-Awat, river, Sundar river and Trusan river. The altitude of AALMFL is about 120 m above sea level. AALMFL is a mangrove forest reserve dominated with mangrove species such as *Avicennia* sp, *Bruguiera parviflora*, *B. sexangula*, *Lumnitzera racemosa*, *L. littorea*, *Nypa fruticans*, *Rhizophora apiculata*, *R. mucronata*, *Sonneratia alba*, *S. caseolaris* and *Xylocarpus granatum*.

Water collection and preservation

The water sample was collected from 52 stations specifically, taken from upstream, middle stream and downstream of river. The samples were taken during dry season and wet season from November 2012 until May 2014. The wet season was between November and February; during peak rainfall December and

Table 1. DOE Malaysia water quality index classification.

Parameter	Unit	I	II	III	IV	V
NH_3-N	mg/L	< 0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
BOD	mg/L	< 1	1 - 3	3 - 6	6 - 12	> 12
COD	mg/L	< 10	10 - 25	25 - 50	50 - 100	> 100
DO	mg/L	> 7	5 - 7	3 - 5	1 - 3	< 1
pH	-	> 7	6 - 7	5 - 6	< 5	> 5
TSS	mg/L	< 25	25 - 50	50 - 150	150 - 300	> 300
WQI		> 92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	< 31.0
Status		Very clean	Clean	Moderate	Slightly polluted	Severely polluted

January and during dry season from March to October. Four replicates of water samples were taken from each station of rivers. Samples were taken by using a boat. Water samples were collected below 10 cm from surface water by using HDPE bottles (in 500 ml) size and dark BOD bottles (in 300 ml) size. The water sample for physico-chemical analysis were kept in ice box during the data collection and then was immediately transferred into refrigerator at a temperature below 4ºC for further analyses in laboratory. The water sampling, preservation, transporting and storage were performed according to International Standard ISO 5667-3, while the water samples analysis were implemented according to Standard Methods for the Examination of Water and Wastewater by APHA (2005).

Water quality measurement

The data collected for water quality measurement include water temperature (Water Temp), pH, dissolved oxygen (DO), electrical conductivity (EC), salinity (SAL), total dissolved solids (TDS) and turbidity were analysed in field (*in situ* analysis) using Troll Multiparameter (Model 9500). Meanwhile, ammoniacal nitrogen (NH_3-N), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solid (TSS) and trace elements (ex situ analysis) was measured and analysed in analytical and water quality laboratory. To ensure the high accuracy of the results, *ex situ* analysis was conducted immediately as the samples were transferred into laboratory. Five Standard Methods of water quality measurement was used in this study including (i) APHA 5210-B to measure dissolved oxygen, (ii) APHA 5220-B to measure COD concentration using COD Reactor Model HACH, (iii) APHA 2540-D to measure the suspended solids level, (iv) APHA 4500-NH_3-BC to examine the content of ammoniacal nitrogen (NH_3-N) using HACH model DR/5000 Spectrometer, and (v) APHA 3110 measure metals (trace elements) includes macro elements such as potassium (K), calcium (Ca), sodium (Na) and magnesium (Mg), and micronutrients such as manganese (Mn), iron (Fe), zinc (Zn) and copper (Cu) by using advanced instrumental analysis of Atomic Absorption Spectrophotometer (AAS). The Standard Method APHA methods are truly standards and internationally accepted procedures recommendations by specialist and expertise for evaluation of water quality. All analyses were tested four times. Unit for all parameters tested were in milligram/litre (mg/l), except for pH, electrical conductivity (µS/cm), turbidity (NTU), salinity (ppt) and water temperature (°C).

Data analysis

The results were compared with WQI and NWQS by the DOE Malaysia to classify the status of the river water of AALMFL. WQI measured by calculated the mean values including of DO, BOD, COD, NH_3N, TSS and pH into a WQI formula to classify the status of the river water using the following formula:

WQI = [0.22 × SIDO] + [0.19 × SIBOD] + [0.16 × SICOD]+[0.15 × SIAN]+[0.16 × SISS] + [0.12 × SI pH]

RESULTS AND DISCUSSION

WQI classification by DOE Malaysia showed in Table 1. Statistical summary of all parameters analysed is presented in Table 2 (Awat-Awat river), Table 3 (Sundar river) and Table 4 (Trusan river). Mean of six water quality (DO, BOD, COD, AN, SS, pH) and sub-indexes for water quality calculation (SIDO, SIBOD, SICOD, SIAN, SISS, SI, pH) were presented in Table 5 and trace elements examined from the samples results were presented in Table 6.

The water temperature (Water Temp) recorded between 28.43 and 30.39°C (Tables 2 to 4). The temperature was relatively high. High temperature was a normal condition for mangrove forest water. Water temperature represents the heat concentration in the water bodies. Water temperature is important in aquatic environment because its influence the solubility and dissolved oxygen content in water (UNEP, 2006). Warm water that affect by hot climate and temperature also contribute to low DO level.

The pH values ranged from 6.91 to 7.51(Tables 2 to 4). pH from 6.5-8.5 indicate good status of water quality condition. pH range 6.5-8.5 is typical for most of the country in world. Suitable and optimum pH for fish health and growth was range from 6-9. Fish mortality reported if pH was outside this range. Unpolluted river water generally shows near neutral, neutral and slightly alkaline pH. Water pH with too high and too low pH values is very harmful to variety of an aquatic life. Neutral pH (6.91-7.51) indicated good and healthy water condition for fish and aquatic life as found in this study.

Electrical conductivity (EC) values ranged from 2.72-3.70 µS/cm (Tables 2 to 4). The EC shown an ability of water to carry an electrical current and corresponds together with the dissolved ions in water (Ugwu and

Table 2. Mean values and rangedofwater quality parameters at Awat-Awat river.

Station	W.Temp °C	pH	EC µS/cm	DO mg/L	TDS mg/L	TURB NTU	SAL ppt	BOD mg/L	NH_3N mg/L	COD mg/L	TSS mg/L
S1	32.9	7.63	3.24	8.3	32.76	55.26	33.32	0.75	0.11	15.3	49
	32.7-33	7.59-7.68	3.24-3.25	8.28-8.33	32.6-32.9	39.4-71	30.9-33.21	0.15-1.61	0.09-0.12	8-15.5	43-58
S2	30.4	7.18	2.73	4.52	27	43.86	33.20	0.65	0.22	14.66	49
	30.3-30.5	7.07-7.37	2.72-2.75	4.17-4.8	26.6-27.4	13.7-44.1	27.1-33.2	0.36-1.01	0.2-0.27	7-15	23-98
S3	29.43	6.96	2.65	2.74	25.73	43.89	33.32	0.7	0.13	15.67	47
	29.4-29.5	6.94-6.98	2.64-2.66	2.74-2.75	25.4-25.9	13.7-44.1	31.4-32.6	0.2-1.87	0.03-0.22	8-15.77	23-49
S4	31	6.47	1.01	4.03	9.73	78.2	33.33	0.9	0.13	11.66	87
	30.8-31.3	6.38-6.59	0.7-1.18	3.98-4.12	3.4-10.5	75-82.6	26.8-33.4	0.15-1.61	0.07-0.19	9-14	74-131
S5	29.76	6.74	1.33	4.28	11.93	66.6	33.33	0.78	0.12	13.4	56
	29.6-29.9	6.39-7.41	1.18-1.44	4.11-4.51	10.1-12.9	58.4-78.2	26.3-33.7	0.72-0.84	0.1-0.15	8-13.05	53-58
S6	28.26	6.47	1.74	4.3	12.03	48.16	33.33	0.78	0.12	14.33	71
	28.2-28.4	6.44-6.54	1.7-1.79	3.71-5.08	10-15.8	48-48.4	32-33.7	0.82-0.84	0.1-0.15	8-14.6	45-167
S7	30.06	6.56	5.33	5.33	18.63	45.83	33.31	0.81	0.1	13.74	48
	29.7-30.4	6.48-6.66	4.51-6.98	4.51-6.98	13.2-21.7	37.9-51.8	29.4-34.8	0.73-0.75	0.08-0.15	10-14	4-108
S8	31.5	6.81	2.03	4.57	28	40.03	33.32	0.78	0.17	14.30	51
	31.4-31.6	6.8-6.82	1.61-2.85	4.26-5.11	27.8-28.1	28.4-41	28-34.1	0.33-0.49	0.11-0.3	9-14.5	14-83
S9	30.13	6.95	2.91	5.01	28.76	40.5	33.32	0.79	0.1	14.98	77
	30.1-30.2	6.91-7.02	2.90-2.91	4.33-5.78	28.7-28.8	29.5-41.9	28.4-33.5	0.1-0.89	0.03-0.01	9-14.99	68-93
S10	30	7.09	3.27	5.36	29	47.36	33.32	0.51	0.12	12.66	57
	30-30.1	6.99-7	3.26-3.28	3.17-8.46	20.9-33.1	43.6-52.6	28.4-33.5	0.13-0.66	0.1-0.15	8-12.99	33-56
S11	30.83	7.05	3.07	4.1	28.16	40.16	33.32	0.65	0.13	14	77
	30.8-30.9	6.99-7.11	2.61-3.3	3.42-4.81	17.9-33.4	35.9-43.5	28.6-33.1	0.36-1.01	0.07-0.19	9-14.8	68-93
S12	30.43	7.11	3.41	2.95	32	63.33	33.32	0.51	0.10	14.67	46
	30.3-30.6	7.06-7.29	3.41-3.42	2.4-3.88	26.2-34.9	39.5-79.9	28.6-33.1	0.13-0.75	0.08-0.1	9-14	33-58

Table 3. Mean values and ranged of water quality parameters at Sundar river.

Station	W.Temp °C	pH	EC µS/cm	DO mg/L	TDS mg/L	TURB NTU	SAL ppt	BOD mg/L	NH_3N mg/L	COD mg/L	TSS mg/L
S1	**30.2**	**7.15**	**3.59**	**4.48**	**37**	**1.9**	**23.3**	**0.86**	**0.12**	**0.09**	**0.0954**
	29-30.3	7-7.16	3-4.2	4.33.5.1	30-38	1.2-2.1	21-23.6	0.1-0.9	0.09-0.13	0.07-0.1	0.0876-0.0986
S2	**30.3**	**7.12**	**3.54**	**5.49**	**36.4**	**2.1**	**23**	**0.79**	**0.09**	**0.1**	**0.0039**
	30-31	7-7.22	3-5.1	4.5-5.6	30-36.7	1.8-2.4	22.1-24	0.93-1.6	0.07-0.1	0.09-0.2	0.0032-0.0048

Table 3. Contd.

S3	**30**	**7.09**	**3.5**	**5.46**	**36.6**	**2.7**	**23.1**	**0.87**	**0.09**	**0.08**	**0.0042**
	29.9-31	7.01-7.10	3.2-4.1	5.1-5.7	31-37.1	1.9-2.9	22.1-24.5	0.99 -1.3	0.08-0.11	0.07-0.2	0.0040-0.0063
S4	**30.3**	**6.99**	**3.53**	**5.37**	**36**	**2.1**	**22.7**	**0.9**	**0.1**	**0.08**	**0.0033**
	30-31	6.87-7.01	3-4.2	5.1-5.9	33-36.7	1.7-2.3	20.1-23.5	1.0 -1.15	0.09-0.2	0.07-0.3	0.0021-0.0047
S5	**30.2**	**7.15**	**3.56**	**5.2**	**37.1**	**3.6**	**23.2**	**0.99**	**0.11**	**0.08**	**0.0047**
	29-30.4	7-7.17	3-5.1	5.2-6.28	35.2-37.6	3.2-3.7	21.1-24.5	0.98-1.3	0.09-0.13	0.06-0.09	0.0041-0.0059
S6	**30**	**7.84**	**3.7**	**5.05**	**26.7**	**6.7**	**24**	**0.97**	**0.08**	**0.09**	**0.0039**
	29-30.2	7.2-7.9	3.1-4.3	4.2-5.09	25.5-27.8	5.4-6.9	21.3-24.6	0.8-1.02	0.07-0.1	0.06-0.2	0.0024-0.0042
S7	**29.9**	**7.79**	**3.68**	**4.45**	**30**	**10**	**23.8**	**0.76**	**0.09**	**0.08**	**0.0037**
	28-29.9	7.1-7.88	3-4.2	4.1-5.6	26.6-31.4	7.5-10.4	21.1-24.8	0.7-1.3	0.08-0.2	0.06-0.2	0.0031-0.0045
S8	**30**	**7.78**	**3.66**	**5.03**	**37.8**	**7.2**	**23.7**	**0.65**	**0.08**	**0.09**	**0.092**
	29-30	7.2-7.90	3.1-4.2	4.88-5.2	34.5-39.5	6.7-7.6	21-26.8	0.71-0.8	0.06-0.09	0.07-0.3	0.089-0.098
S9	**30.2**	**7.7**	**3.58**	**4.48**	**37**	**6.8**	**23.3**	**0.99**	**0.08**	**0.1**	**0.0029**
	29-30.3	7.1-7.8	3.1-4.4	4-4.7	33.4-37.2	5.9-6.9	22-25.9	0.8-0.1	0.07-0.09	0.08-0.4	0.0027-0.0035
S10	**30**	**7.56**	**3.72**	**4.09**	**38.3**	**7.9**	**24.1**	**0.75**	**0.1**	**0.2**	**0.0048**
	29-29.99	7-7.7	3.5-4.2	4-4.8	36.8-39.2	6.5-8.5	21.3-26.5	0.6-0.87	0.09-0.3	0.1-0.45	0.0046-0.0053
S11	**30.3**	**7.49**	**3.56**	**4.72**	**26.5**	**3.9**	**22.9**	**0.95**	**0.12**	**0.1**	**0.0949**
	29-30.1	7-7.5	3.1-4.6	4-4.9	25.9-27.4	3.2-4.1	21.3-24.6	0.76-0.98	0.9-0.13	0.09-0.35	0.0947-0.0962
S12	**30.5**	**7.25**	**3.47**	**4.74**	**35.5**	**3.8**	**22.4**	**0.94**	**0.1**	**0.1**	**0.0038**
	28-29.4	7.1-7.3	3.2-4.3	3.1-3.9	34-36.7	2.9-3.9	20.4-23.9	0.84-0.2	0.9-0.3	0.09-0.34	0.0036-0.0046
S13	**30.3**	**7.56**	**3.75**	**4.81**	**38.7**	**5.6**	**24.4**	**0.96**	**0.11**	**0.08**	**0.0076**
	30-31	7.2-7.6	3.4-3.8	3-4.2	37.6-39.2	4.9-5.8	21.3-25.4	0.7-0.2	0.08-0.13	0.06-0.09	0.0064-0.0087
S14	**30.4**	**7.3**	**3.51**	**4.16**	**36**	**2.4**	**22.7**	**0.97**	**0.12**	**0.09**	**0.0036**
	30-30.2	7-7.4	3.1-4.7	4-4.7	35.9-37.2	1.99-2.8	20.1-24.9	0.76-0.21	0.11-0.12	0.07-0.2	0.0028-0.0045
S15	**30.3**	**7.11**	**3.54**	**4.75**	**36.3**	**2**	**22.8**	**0.61**	**0.1**	**0.09**	**0.0914**
	29-30.3	7.3-7.14	3.1-5.2	4.1-4.8	35.6-38.2	1.87-2.3	20.7-23.5	0.59-0.64	0.1-0.4	0.06-0.3	0.0902-0.0918
S16	**29.7**	**7.95**	**4.1**	**7.29**	**43.4**	**7.9**	**27**	**0.86**	**0.11**	**0.08**	**0.0036**
	28-29.9	7.3-7.9	4-5.1	6.99-7.6	39-44.2	9.8-7.4	20.4-27.8	0.81-0.95	0.9-0.34	0.07-0.2	0.0033-0.0048
S17	**29.6**	**7.88**	**4**	**7.01**	**42.4**	**46.9**	**26.3**	**0.72**	**0.1**	**0.08**	**0.0063**
	28-29.8	7-7.88	3.9-4.2	6.88-7.5	41-43.6	44.6-47	25.4-27.4	0.54-0.91	0.9-0.3	0.06-0.4	0.0056-0.0068
S18	**29.5**	**7.89**	**3.98**	**6.8**	**42**	**32.1**	**26.1**	**0.9**	**0.12**	**0.08**	**0.07676**
	28.7-29	7.2-7.9	3.92-4.3	6.1-7.5	39-43.1	30.1-33	25.8-27.6	0.7-0.22	0.1-0.13	0.05-0.31	0.07590-0.7274
S19	**29.6**	**7.85**	**4.04**	**6.36**	**42.5**	**26.7**	**26.6**	**0.98**	**0.09**	**0.09**	**0.0924**
	28-29.4	7.2-7.9	4.1-4.7	6.2-7.2	39.8-43.2	24.8-28	25.7-28.3	0.95-0.99	0.07-0.1	0.07-0.4	0.0920-0.0938
S20	**29.6**	**7.91**	**4.05**	**5.7**	**31.6**	**23.9**	**26.6**	**0.92**	**0.09**	**0.08**	**0.0042**
	28.2-29	7.10-7.92	4.01-4.33	5.1-6.4	29.8-32.7	21-24.5	23.2-27.2	0.78-0.96	0.06-0.1	0.07-0.4	0.0039-0.0054

Table 4. Mean values and ranged of water quality parameters at Trusan river.

Station	W.Temp °C	pH	EC µS/cm	DO mg/L	TDS mg/L	TURB NTU	SAL ppt	BOD mg/L	NH_3N mg/L	COD mg/L	TSS mg/L
S1	**29.7**	**7.95**	**4.1**	**7.03**	**43.4**	**73.9**	**27**	**1.5**	**0.13**	**13.4**	**62**
	28-29.8	7-7.97	3-4.3	6-7.5	41-45.9	70-74.5	25-28.7	1.21-1.53	0.1-0.13	11-13.7	49-63.2
S2	**29.6**	**7.88**	**4**	**7.01**	**42.4**	**46.9**	**26.3**	**0.87**	**0.14**	**14.67**	**59**
	29-29.7	6.67-8	3.9-4	6-7.02	40-44.5	45-47.7	25.4-27.6	0.8-1.9	0.12-0.14	13.2-15.1	57-62.3
S3	**29.5**	**7.89**	**3.98**	**6.8**	**42**	**42.1**	**26.1**	**1.17**	**0.12**	**14.3**	**61**
	28-29.6	7.9-8	3.3-4	6.7-7	39-43.6	41.7-43	25-28.7	1.2-1.8	0.11-0.13	13.5-14.9	57-64.1
S4	**29.6**	**7.85**	**4.04**	**6.36**	**42.5**	**46.7**	**26.6**	**1.2**	**0.13**	**13.2**	**59**
	29-29.8	7.8-8	3-4.5	6-6.6	41-43.2	44-48.7	25.4-27	1.11-1.25	0.12-0.14	11.97-14	56-62.8
S5	**29.6**	**7.91**	**4.05**	**5.7**	**31.6**	**43.9**	**26.6**	**1.13**	**0.12**	**14.3**	**57**
	26-29.8	7.6-8	3-4.8	5-6	30-34.5	41-44.8	25-27.5	1-2.1.4	0.11-0.14	11.78-15	55.6-59.2
S6	**26.6**	**6.07**	**1**	**4.76**	**0**	**760.1**	**0**	**1.5**	**0.13**	**14.33**	**75**
	26-26.7	6-6.15	1-2.2	4-5.1	0-0	703-765	0-0	1.11-1.67	0.11-0.15	12.35-15	69-76.7
S7	**26.9**	**6.06**	**1.9**	**5.03**	**0**	**410.3**	**0**	**1.07**	**0.14**	**13.15**	**58**
	26-27	6-6.12	1.1-2	4.33-5.2	0-0	409-413	0-0	1.3-1.08	0.11-0.13	12-14.1	49-64
S8	**26.66**	**6.47**	**1.9**	**5.7**	**0**	**470.3**	**0**	**0.45**	**0.13**	**13.2**	**76**
	26-27	6-6.30	1.4-1.9	4.99-6	0-0	465-472	0-0	0.46-0.5	0.12-0.13	11.44-14	71-79
S9	**26.7**	**5.92**	**1.9**	**4.97**	**0**	**435.7**	**0**	**1.5**	**0.11**	**14.1**	**62**
	28-29.8	5.3-6	1.1-1.8	4.5-6	0-0	432-439	0-0	1.2-1.6	0.09-0.12	13.9-14.2	59-65.2
S10	**27.4**	**6.57**	**1.9**	**4.63**	**0**	**499**	**0**	**1.21**	**0.16**	**14.3**	**68**
	29-29.9	6-6.12	1.2-1.8	4-5.1	0-0	470-501	0-0	1.1-1.42	0.14-0.15	13-15.4	61-71.2
S11	**27**	**6.08**	**1.8**	**5.18**	**0**	**470**	**0**	**1.4**	**0.11**	**13.6**	**65**
	28-29.8	6-6.7	1.2-2	5-6.4	0-0	465-482	0-0	1.1-1.49	0.1-0.11	12.9-14.9	59-67
S12	**26.4**	**6.44**	**1.8**	**5.28**	**0**	**360**	**0**	**1.2**	**0.29**	**14.5**	**58**
	26-31		1-2.1	4.3-6	0-0	343-366	0-0	1.2-1.29	0.15-0.27	13.4-15.4	50-64
S13	**27.81**	6-5.9-	**1.8**	**4.58**	**0**	**322.8**	**0**	**1.1**	**0.15**	**14.3**	**65**
	26-27.9	6.8	1-2.4	4.2-5	0-0	310-333	0-0	1.08-1.23	0.12-0.15	12-15.4	48-67
S14	**27.87**	**6.88**	**2.63**	**5.63**	**0**	**302.4**	**0**	**1.2**	**0.17**	**14.37**	**53**
	26-28.5	6.1-7	2-2.8	5-6.2	0-0	300-309	0-0	1.1-1.22	0.14-0.16	12-15.1	46-54
S15	**29.6**	**6.85**	**2.62**	**5.61**	**0**	**303.2**	**0**	**1.1**	**0.16**	**14.33**	**64.5**
	28-29.7	6.1-7	1.9-3	4.9-6	0-0	301-305	0-0	1.09-1.15	0.12-0.15	13-15.4	61.2-66.7
S16	**29.8**	**7.87**	**4.05**	**5.03**	**42.7**	**22**	**26.5**	**1.01**	**0.08**	**14.56**	**60.5**
	28.7-29	7-7.9	3.9-4.7	4.9-6	41-44.3	21-25.6	22-27.1	1-1.2	0.2-0.3	14.11-15.6	57.3-61.2
S17	**29.8**	**7.78**	**4.0**	**5.06**	**42.6**	**25.2**	**26.4**	**1.1**	**0.23**	**13.9**	**60.2**
	27-29.1	7-8	3.99-4	4.89-6	40-44.5	23-26	23-27.5	1.01-.1.31	0.2-0.4	13.4-14.5	57.6-65.5
S18	**30.5**	**7.76**	**4.01**	**5.7**	**42.3**	**25.3**	**26.3**	**1.05**	**0.15**	**14.9**	**50.1**

Table 4. Contd.

	29-30.2	6.7-8	4-4.2	5-5.9	40-43.5	22-26	24-27.5	1.02-1.14	0.13-0.16	13.1-15	47.60-1.3
S19	**29.7**	**7.94**	**4.02**	**5.13**	**42.4**	**30.5**	**26.3**	**1.1**	**0.1**	**13.87**	**51.2**
	28-9.87	7.2-8	3.99-4	4-6	41-44.3	30-32	25-27.3	0.8-1.3	0.1-0.3	13-15.6	46.8-54.2
S20	**29.6**	**7.8**	**4.01**	**4.96**	**42.3**	**33.1**	**26.3**	**1.4**	**0.07**	**13.43**	**65.6**
	28-29.5	6.9-8	3.67-4	4.88-6	40.1-45	30-35	25-27.8	1.13-1.5	0.07-0.09	13-15.3	63.2-66.7

Table 5. WQI parameters results and class of water quality of AALMFL Sarawak, Malaysia.

Locations	Unit	Awat-Awat river		Sundar river		Trusan river	
		Mean± (SD)	**SI**	**Mean± (SD)**	**SI**	**Mean± (SD)**	**SI**
DO	mg/L	4.62±0.02	0	5.27±0.63	0	5.50±0.75	0
BOD	mg/L	0.71±0.11	97	0.71±0.11	97	1.163±0.24	95
COD	mg/L	14.11±1.13	80	0.09±0.02	99	14.03±0.53	80
AN	mg/L	0.12±0.03	88	0.1±0.01	90	0.14±0.04	86
TSS	mg/L	59.58±14.40	68	0.03±0.04	97	61.50±6.70	67
pH	-	6.91±0.25	99	7.51±0.33	97	7.12±0.79	99
WQI			67		75		67
Class		III		III		III	

*SI, Sub Index; SD, standard deviation.

Table 6. Values of selected trace elements parameters analysed from AALMFL Sarawak, Malaysia.

Location	Potassium(mg/L)	Calcium(mg/L)	Sodium(mg/L)	Magnesium(mg/L)	Manganese(mg/L)	Iron(mg/L)	Copper(mg/L)	Zinc(mg/L)
Awat-Awat river	20.12±0.46	20.50 ±0.08	113.30 ±0.22	12.71 ±0.91	0.02±0.02	0.3±0.01	0.05±0.013	0.03±0.006
Sundar river	588.48±6.91	575.61±39.39	198.21±42.97	289.31±8.98	0.03±0.02	0.2±0.31	0.01±0.01	0.001±0.002
Trusan river	5.36±2.54	18.53±2.48	233.92±101.07	28.66±0.84	0.03±0.03	0.09±0.03	0.03±0.005	0.001±0.002

Wakawa, 2012; Alexander et al., 2011; PEARL, 2009). Low level of EC proves the absence and low level of dissolved salts in the water bodies as found in this study. The river water at mangrove forest generally has low electrical conductivity because discharges by high content of organic matter include both of dissolved and suspended material. The dissolved organic material in form of liquid in water is not an electrolyte type and this is the reason it does not conduct electricity. The conductivity in freshwater was range between 0.1 and 10 μS/cm (Ugwu and Wakawa, 2012) or 60 and 130 μS/cm (Alexander et al., 2011) were in a normal condition.

Dissolved oxygen (DO) concentration ranged from 4.62 to 5.50 mg/L (Tables 2 to 4). DO is total of oxygen that dissolved in water bodies (Brönmark and Hansson, 2005). DO utilized in the process of respiration, degradation, and decomposition and only slightly soluble in water. It was the most important parameter for respiration of aerobic microorganism and other life forms in water. High number or overpopulation of microorganism includes bacteria and varieties of aquatic life make them using great amounts of dissolved oxygen in water bodies. The aquatic plants also affects DO level by release the oxygen into water during the photosynthesis process. According to Weiner and Matthews (2003) the saturation of DO decreases with high water temperature. The colder the water, the more oxygen it can hold and vice versa (WWF, 2011; Said et al., 2004). The amount and saturation of DO in water bodies is directly an interaction to the water temperature. As temperature increases, the amount of dissolved oxygen also decrease because the water gets warmer make it holds less of oxygen. Similar situation found by researches in evaluation of river water at Murray River Australia. High and warm water temperatures (28-43-30.39°C) reduce the amount of oxygen (4.62-5.50 mg/L) of water as found in this study.

Medium level of DO indicated that the river water in the area still can support fish and an aquatic life in the river. Medium level of DO is also probably because the river water was discharge by various types of nutrient and an organic matter near and along the river which increases respiration during decomposition and degradation. This is normal condition for river water at mangrove forest because mangrove was a place which is highly source of much type of organic matters. Discharge of organic matter content that eventually caused lack of oxygen in the water. An organic and inorganic input with less and limitation of mixing may also reduce the existing and availability of oxygen (Mcneil and Closs, 2007; Singh et al., 2005) in an aquatic system. Oxygen dissolved easily into water with low level of dissolved solids as found in this study. According to DOE and NWQS Malaysia, 5-7 mg/L of DO is required for optimum fish health.

Total dissolved solids (TDS) level found ranged from 20.71 to 36.39 mg/L (Tables 2 to 4). The TDS values are still under permissible limit by World Health Organization (WHO, 2004). TDS showed the present of dissolved materials in water bodies such as detergents, solvents and fuel which cannot remove by general and conventional filtration (Avvannavar and Shrihari, 2007). The TDS concentration is directly related to conductivity result. River water at AALMFL found having low concentration of dissolved solids in water bodies as its conductivity was also low.

The turbidity (TURB) of water samples found ranged from 13.61 to 233.67 NTU (Tables 2 to Table 4). The turbidity level in this study was considered high at Awat-Awat river (51.09 NTU) and Trusan river (233.67 NTU). According to International Standards and DOE Malaysia, the acceptability of water for domestic use ranges from 5 to 25 NTU. Turbidity is water clarity and refers to the declining ability of water to transmit and pass light causing by suspended particles that could be origin from dissolved organic material (Boyde, 2000). Turbidity generally because of soil erosion, excess of nutrients and various wastes and pollutants disposed into water bodies. Turbid waters have been known for their harmful effects on fish.

The suspended material whether originated from the soil particles effects by the soil erosion or it could cause by the alga cells that suspended in water bodies. Such particles absorb heat in the sunlight, thus raising water temperature which will decrease the dissolved oxygen levels in water bodies as found in this study. High concentrations of turbidity are very dangerous because it’s harmful to variety of aquatic organism’s life in river. Medium level of turbidity at Awat-Awat river (51.09 NTU) and high levels of turbidity at Trusan river (233.67 NTU) indicate that there is some erosion and pollution taken place near river water at the area. Through study and observation, there is logging and sand reclamation activities carried out in the vicinity of the Trusan river which certainly contributed to high level of its turbidity.

The water salinity (SAL) concentration found from 13.22-33.31 ppt (Tables 2 to 4). Salinity indicates the concentration of dissolved salts in water bodies. The concentration of salinity is important to aquatic life because only certain species can survive in high salinity concentration (Friedl et al., 2004). Despite some of species can survive in saline environment, many species cannot live and survive in high salinity level.

The biochemical oxygen demand (BOD) level ranged from 0.867 to 1.163 mg/L (Tables 2 to 4). Detection limit and minimum oxygen depletion for BOD is 2 mg/L as specifies by APHA.BOD measure the amount of oxygen demanded by aerobic microorganism for organic matter decomposition. BOD measure an organic pollution at surface water and waste water (Metcalf and Eddy, 2004). BOD increases with high content of organic material and other contributors such as total nutrient which was origin from fertilizer, animal farm and sewage. The oxygen demand, BOD and COD was in normal condition for freshwater which ranging from 0.867 to 1.163 mg/L mg/L for BOD and 0.09 to 14.11 mg/L for COD as found in this study. Low BOD level was probably because of there is some of total nutrient discharged and disposed into the river.

The ammoniacal nitrogen (NH_3N) concentration found ranged from 0.1-0.14 mg/L (Tables 2 to 4). Ammonia is an indication of excessive usage and improper management of ammonia whether from agricultural (fertilizers, herbicides, pesticides), household or industrial chemicals. Organic materials mainly debris also contribute to produce ammonia in water. Ammonia is toxic to all aquatic organisms even in low concentration. Ammonia becomes more toxic with high water temperature, acidic pH and low level of dissolved oxygen in water. Low concentration of NH_3N (0.1 mg/L) found at Sundar river and these are considered safe concentration levels. While moderately high level of NH_3Nat Awat-Awat (0.12 mg/L) and Trusan River (0.14 mg/L) indicated there is some pollution at both of the river.

The chemical oxygen demand COD found ranged from 0.09 to 14.11 mg/L (Tables 2 to Table 4). The COD level results found having low concentration (0.09 mg/L) at Sundar river and moderately high at Awat-Awat (14.11 mg/L) and Trusan river (14.03 mg/L). COD determines the amount of oxygen need and required for the oxidation of both organic and inorganic material in water bodies (Otukune and Biukwu, 2005). Deterioration of water quality can be known with high concentration of COD and low concentration indicates the water is still in good condition. The COD level which is considered unpolluted and good water condition is generally less than 25 mg/L (DOE, 2009; APHA, 2005) as found in this study. This indicated no heavy organic and inorganic pollutants in water.

Total suspended solids (TSS) level ranged from 0.03 to 61.50 mg/L (Tables 2 to 4). TSS is suspended solid materials that include an organic material (algae, bacteria, plankton, and plant fiber) and inorganic material (clay, silt) that is suspended in the water bodies. TSS including an organic particles and the mineral those is consist in water bodies. These particles come from natural process and anthropogenic activities which are originated from soil erosion from agricultural, forestry, construction, industrial activities and urban development discharges into water bodies (UNEP, 2006; US EPA, 2005).

High concentrations of suspended solids decrease the quality of water to absorbing light from the sunlight. These cause aquatic plants receive less light which blocking the sunlight from reached aquatic plant (submerged vegetation). Photosynthesis process decline and less oxygen will produce. Warm water condition, less light and less oxygen makes it impossible for aquatic life to survive in water bodies (NDDH, 2005).

Natural events such as torrential or heavy rainfall lead to excessive erosion which will increase the content of suspended material in rivers, stream or lakes. These also cause storm water runoffs that give numerous water impacts such as flooding, pollution and ecosystem degradation (Jiri et al., 2001). Many of these pollutants can be attached to TSS which given bad impact to an aquatic life and their habitat. National Water Quality Standard (NWQS) Malaysia recommends the maximum concentration of TSS for surface water ranging from 25 to 50 mg/L (Sujaul et al., 2012). High level (59-58 mg/L) of TSS at Awat-Awat and Trusan river (61.50 mg/L) indicates there is a land erosion and pollution occurred at the study sites.

Macroelements (K, Ca, Na, Mg)

The potassium ranged from 5.36 to 588.48 mg/L (Table 6). K is essential element in plant and human nutrition. Concentration of K is generally less than 20 mg/L in freshwater and as high as 400 mg/L in seawater (APHA, 2005; Jamie and Richard, 2005). K concentration found in this study was in natural levels for fresh water that is mixing with the seawater.

The calcium ranged from 18.53-575.61 mg/L (Table 6). K. Calcium mainly by leaching of rocks over limestone, dolomite and other calcium that containing variety of rocks and minerals. Most calcium in surface waters comes from river that flow over the rocks (APHA, 2005; Jamie and Richard, 2005). Calcium is essential elements in plant and animal nutrition, but will contribute hardness to water if the concentration is high.

The sodium ranged from 113.30 to 233.92 mg/L (Table 6). Concentrations of sodium were varying from freshwater, seawater and brackish water. High sodium concentration may affect human health and also the plants. High sodium concentration is because the river's located near the sea where seawater normally has high concentration of sodium.

The magnesium ranged from 12.71 to 289.31 mg/L (Table 6). Magnesium is an abundant element in the earth and a common constituent of natural water which gives hardness to water. Magnesium commonly used in alloys production and fertilizers ingredients (APHA, 2005). Magnesium essential for plant and human but high concentration gives bad implications to health.

MICRONUTRIENTS (Mn, Fe, Zn, Cu)

The manganese ranged from 0.02 to 0.03 mg/L (Table 6). Manganese is a metallic pollutant and other pollutant cause by mining, drainage and excessive decayed of organic matter. Soils and rocks usually contain manganese. Manganese is essential trace elements for animals and plants but will be toxic and corrosive if the concentration is too high. The concentration of manganese in natural waters was about 0.02 mg/L or less (Van der Perk, 2006; APHA, 2005). Low concentration of manganese (0.02-0.03 mg/L) found in this study which is probably origin from soil, rocks and some decayed organic matter in the water bodies. This is a normal condition for natural waters and the concentration considered safe.

The iron ranged from 0.09 to 0.3 mg/L (Table 6). Iron is a metallic pollutant which is origin mainly from contact with soil and rocks in water. Effluents from industries such as steel mills and metal plants are sources of iron pollution (APHA, 2005; P.K. Goel., 2001). High concentration of iron can leach out from soil by run-off especially in acidic water condition. Generally, 0.7 mg/L of iron concentration found in natural stream water. Low concentration (0.09-0.3 mg/L) of iron found in this study area which is probably naturally origin from soil and rocks in the stream and the level considered safe.

The copper ranged from 0.01 to 0.05 mg/L (Table 6). Copper is an essential element and deficiencies of copper lead to disorders in animals and plants but high concentration of copper will be toxic and gives serious degradation to water quality. Mining effluents, smelting, fungicides, chemical industries and other industrials such as metal is anthropogenic sources (Van der Perk, 2006; APHA, 2005; P.K. Goel, 2001) of copper pollution. Low concentration (0.01-0.05 mg/L) of copper as found in this study naturally derived from mineral in water bodies and this value considered safe.

The zinc ranged from 0.001 to 0.03 mg/L (Table 6). Zinc is an essential element but high concentrations will cause phytotoxicity to animals and humans. Mining, smelting, waste and sewage disposals are anthropogenic sources of zinc pollution (Alaa and Werner, 2010; Van der Perk, 2006; APHA, 2005). FAO recommend level for zinc in irrigation waters is about 2 mg/L and standard for drinking water by U.S. EPA is 5 mg/L. Low concentration of zinc (0.03 mg/L) found at the study and this considered safe.

Based on results obtained from this study indicate that the mean concentration of the following parameters: pH, EC, DO, TDS, BOD, COD and NH_3-N are still under permissible limit for river water by DOE Malaysia,WHO and other guidelines and standards from another country respectively.

Overall, the main concern of water quality parameter in this river is high level of suspended solids and turbidity. This is probably cause by natural process and anthropogenic activities which are originated from soil erosion from agricultural, forestry activity, logging, urban runoff, sand reclamation, settlements activity from residential area, wastewater discharges into water bodies and land use activities which are carried out near the river especially at Awat-Awat and Trusan river was identified as the evidence contribute to high level of its suspended solids and turbidity.

Suspended solids indicated soil erosion in the river and also relate to transport by river include the nutrients, metals and chemicals use in agricultural activities. There are a lot of agricultural and plantation activities run near the river, which certainly contributes to the pollution. Turbidity resulted in the presence of suspended particles such as clay, silt or an organic matter. The suspended matter could be the soil particles as a result of soil erosion, suspended sediments or surface run-off in natural waters which increase the turbidity levels in river water. High level of turbidity at Awat-Awat and Trusan river suggests heavy erosion took place at and near the river that caused its high concentration

Sediment exists naturally in river, but if the level is too high, it can cause disturbance to ecosystem and give a significant impacts on water quality. High turbidity can cause decline in oxygen level in water as found in this study. Turbid waters reduce water clarity and availability of food source in water bodies which will eventually decrease the ability of fish to find food. High level of suspended solids and turbidity is very harmful to variety of aquatic organisms' and fish habitat thereby decreases the population and productivity of aquatic life.

Previous studies by Neves Fernando et al. (2014), Martin et al. (2010), Harvey et al. (2009), Robertson et al. (2006) and Henley et al. (2000) proves that sedimentation and turbidity cause declines in populations of fish and variety of aquatic organisms and degrade aquatic habitat. Collings et al. (2006) also found that turbidity reduced productivity of sea grasses from the Adelaide metropolitan coastline. Similar conditions were found by Ahmad-Kamil et al. (2013); where they found that seagrass percentage covers in Lawas river decline cause by high level of turbidity in September and November 2009.

Conclusion

The water quality analysis of the river water at Awat-Awat, Sundar, and Trusan river from AALMFL Sarawak Malaysia were categorized under Class III which are considered moderate water quality status. The main concern of water quality in this river is high level of suspended solids and turbidity. Poor water quality can be the result of natural processes (normal condition) of river water but it is more as a result of human activity (anthropogenic activities). The present data of the water quality and trace elements analysis of river water is very useful for assessment of the mangrove forest ecosystem and also important as a baseline data for government and other sectors for conservation and maintaining the water resources at the area. The results study suggest this mangrove forest should be maintain and manage properly to prevent the deterioration of its water quality. Greater attention should be focused on conserving the biodiversity and water resources especially in mangrove area in order to achieve sustainable development and better understanding of the effective water conservation and management.

Conflict of Interest

The authors have not declared any conflict of interest.

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