

Temporal Variation of Drinking Water Quality Monitoring in Water Treatment Plant Using Chemometric Techniques

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Abstract

This research investigates the relationship between the physicochemical levels and the drinking water quality in Kuala Kubu Bharu, Selangor based on three different classes of drinking water. For this study the environmentric techniques such as the discriminant analysis (DA), the principal component analysis (PCA) and the factor analysis (FA) were applied to analyze the spatial variation of the most significant physicochemical parameters of the drinking water quality and to determine the source of pollution. Seven physicochemical variables were analyzed. The forward and backward stepwise DA managed to discriminate six and two variables, respectively from the original seven variables. PCA and FA (varimax functionality) were to identify the origin of each water quality variable based on the three different drinking water classes. Three PCs with 74.37% total variance were obtained for the raw water, settled water and clean water. Therefore this study shows that environmetric method is the ideal way in to provide meaningful information on the spatial variability of sophisticated drinking water quality data.

Keywords: Kuala Kubu Bharu, drinking water quality, physicochemical, discriminant analysis(DA), principal component analysis(PCA)

1.0 INTRODUCTION

A safe, palatable and aesthetically appealing supply of drinking water to the public is vital. Drinking water contamination has been an alerting issue. The pollution of water resources or aquatic environment due to urbanization and development could affect the quality of drinking water. Drinking water contains some trace elements that plays an important role in the human body. Excess of trace elements could affect the growth and cause death. The detrimental effect of metals are influenced by their solubility. On the other hand their solubility are dependent on pH and types of anions and other cations. Numerous physicochemical parameters detected in drinking water could cause adverse human health effects, influence the suitability of water and deteriorates the efficiency of water treatment. The major tribulations related with chemical elements of drinking water arises mainly due to their capability to cause undesirable health effects after lengthy duration of disclosure. Pollutants with increasing toxic properties, such as heavy metals and carcinogens, are given more attention (WHO, 2004). Therefore the quality of drinking water should be monitored from time to time. The National Standard for Drinking Water Quality (NSDWQ) under the Ministry of Health Malaysia is to maintain the quality of drinking water by setting the limits to constituents that may be present in water (National Standard for Drinking Water Quality, 2004). In order to ensure the quality of the drinking water few tests based on its physicochemical levels such as pH, turbidity, colour, iron (Fe), aluminium (Al), ammonia (NH₃) and manganese (Mn) was carried out.

The NSDWQ has set a benchmark values for the drinking water parameters. Firstly the benchmark value for pH is 6.5 to 9.0. Secondly the benchmark value for turbidity should be 5 NTU. The total suspended solids content is one of the most revealing properties of turbidity. Drinking water should not contain any settleable suspended solids. Next the benchmark value for colour is 15 TCU. Good drinking water should be colourless. The accepted benchmark values for iron (Fe), aluminium (Al), ammonia (NH₃) and manganese (Mn) are 0.3mg/l, 0.2 mg/l, 1.5mg/l and 0.1mg/l respectively. Contamination of atmosphere has resulted in the formation of acidic rains and leaching of some metals from soil to water (Vargova *et al.*, 2008). Problems associated with the adoption and application of recognized water quality standards are to some extent caused by failure to understand what purposes standards serve and how they should be used. Standards are too often allowed to substitute for common sense and judgment. If the drinking water parameters exceeds the benchmark values in the NSDWQ, this will lead to various water borne diseases. The inefficiency of the water treatment facility in maintaining the water quality level has been one of the major contributing factor.

This project is carried out in the Kuala Kubu Bharu Treatment Plant. The project was carried out in this area to study the quality of the drinking water by analyzing the secondary data of physicochemical levels of the drinking water quality. The secondary data comprises of the monthly observations from January 2011 until December 2011. The major aim of this study is to report on the assessment of the physicochemical parameters and the trace metals present in the drinking water sources earmarked for this study. It is hoped that the results would add to the existing

data. Besides that this project report could be a helpful source of information for other researchers in this area who intend to carry out the similar study.

In this study the spatial analysis is conducted to identify the most significant parameters in the drinking water quality (Hafizan *et al.*, 2010). Since interpreting a large data is challenging therefore we have to use the proper method of data analysis (Dixon and Chiswell, 1996). A branch of chemistry is known as chemometrics. Chemometrics uses multivariate statistical modeling and data treatment. Chemometric techniques is widely used in investigative data treatment tool for categorization (Brodnjak-Voncina *et al.*, 2002; Kowalkowski *et al.*, 2006) of samples and the detection of cause of pollution (Massart *et al.*, 1997; Vega *et al.*, 1998; Shrestha and Kazama, 2007). Chemometrics helps to reveal and analyze multifaceted correlation in a broad range of environmental applications (Alberto *et al.*, 2001). One of the most common chemometric methods are cluster analysis (CA), discriminant analysis (DA) and principal component analysis (PCA) with factor analysis (FA) (Kennel *et al.*, 2007). This project has specific objectives. Firstly to analyze the physicochemical activities in the collected drinking water samples from the treatment plant. Secondly is to identify the source of variation for the significant parameters. The third objective is to compare the secondary data of drinking water from the water treatment plant with the Drinking Water Standards set by the Ministry of Health Malaysia. Lastly is to serve as a source of reference for the future projects in the same field.

2.0 METHODOLOGY

2.1 Study Area

This study was performed in Kuala Kubu Bharu. This place is situated in Hulu Selangor district of Selangor State in Malaysia. The geographical coordinates of this area are 3° 34' 0" North, 101° 39' 0" East and its original name (with diacritics) is Kuala Kubu Bharu. The population of Kuala Kubu Bharu is estimated 28,000 people.

2.2 Sampling Analysis

The research was done in Kuala Kubu Bharu Water Treatment Plant. The secondary data of physicochemical levels of the drinking water quality were analyzed. Water samples were collected daily from three sampling stations. The first station was the Geraci River and Kubu River followed by the sedimentation tank and the balancing reservoir respectively. In addition the data consist of three types of water samples such as raw water, settled water and clean water. The source of the raw water Geraci River and Kubu River. The raw water was pretreated in the water treatment plant before distributed to the consumers.

The settled water was collected from the sedimentation tank. Finally the clean water was collected from the balancing reservoir. Seven physico-chemical parameters were analysed such as pH, turbidity (Tur), colour, iron (Fe), aluminium (Al), ammonia (NH₃), and manganese (Mn). All the parameters were analysed using the Photometer (Palin Test 8000) except for colour and turbidity. Colour and turbidity were analysed using Nessleriser and Turbidimeter respectively. The Phenol Red and Bromo Purple tablets were used for the pH test. Iron LR tablet was used for Iron(Fe) test. Ammonia No 1 and Ammonia No 2 tablets were used for NH₃ testing. Aluminium No1 and Aluminium No 2 tablets were used for aluminum (Al) test. Next Manganese No 1 and Manganese No 2 were used for manganese (Mn) test.

2.3 Data Analysis

Two chemometric approaches such as discriminant analysis (DA) and principal component analysis (PCA) by using XLStat 2012 was applied for the justification of complex observing data matrices. These approaches presents an enhanced perceptive of water quality and technical competence of the considered systems, decides if crucial differences in water quality exist between diverse areas (Bierman *et al.*, 2009), permits detection of the potential factors that determines the water systems and provides an important device for dependable management of water resources as well as quick resolution to water quality or water treatment plant technology (Morales *et al.*, 1999; Reghunath *et al.*, 2002; Wunderline *et al.*, 2001)

2.3.1 Discriminant Analysis (DA)

DA was used to observe the significant differences between two or more naturally occurring groups. If discriminant analysis is effective for a set of data, the classification table of correct and incorrect estimates will yield a high correct percentage (Sangam *et al.*, 2008). DA works on raw data and constructs a discriminant function for each group (Johnson and Wichern, 1992; Wunderlin *et al.*, 2001) as in Eq.(1);

$$f(G_i) = k_i + \sum_{k=0}^n w_{ij} p_{ij}$$

where i represents the number of groups (G). Next k_i is the constant inherent to each group. The n is number of parameters used to classify a set of data into a given group and w_j is the weight coefficient, assigned by DA to a given selected parameter (p_j).

In this research DA helped to discriminate between three different classes of drinking water and the number of parameter analyzed is known as n . DA was applied to the secondary data by using standard, forward stepwise and backward stepwise modes to construct discriminant functions to evaluate the drinking water quality. The three classes of drinking water were known as the dependent variables and the parameters studied were the independent variables.

2.3.2 Principal component analysis (PCA)

Analyzing one variable each time in a high number of variables limited gives an inadequate amount of data since the correlation between variables were not measured (Carrer *et al.*, 2006). Principal Component Analysis (PCA) is an influential pattern identification device that explains the variance of a huge data set of related variables with a minor set of independent parameters (Simeonov *et al.*, 2003). PCA is a familiar multivariate data presentation technique that permit to extort and envisage the information enclosed in a multivariate data set (Brereton., 2003). PCA was constructed to switch the original variables to latest and unconnected variables. The variables were known as principal components, which are linear combination of the original variables. A set of new orthogonal variables with linear arrangement of the original variables was generated by PCA. The new axes lie along the directions of highest variance (Shrestha and Kazama., 2007).

The PCA techniques extracts the eigenvalues and eigenvectors from the covariance matrix of original variables. PCA provides a good understanding about the relationship of a large number of variables with sufficient details. (Vega *et al.*, 1998; Alberto *et al.*, 2001). PC offers information on the important parameters that explains the total data set affording data reduction without losing the original sources (Vega *et al.*, 1998; Helena *et al.*, 2000). This is a prevailing procedure for trend detection which explains the significance of a big set of variables linked together and transforming into a less significant set of autonomous (uncorrelated) variables (principal components). The first PC is positive to the trend explaining the highest inconsistency. The second PC is positive to the trend, orthogonal to the first PC. Therefore usually a very small number of PC's is adequate to clarify the important details in the data set. The principal component (PC) can be expressed as

$$z_{ij} = a_{i1}x_{ij} + a_{i2}x_{2j} + \dots + a_{im}x_{mj} \quad (2)$$

where z is the component score, a is the component loading, x is the measured value of the variable, i is the component number, j is the sample number, and m is the total number of variables. The component loadings identifies the relative input of the parameters to each PC. The score plot provides information about the connectivity between samples. The loading plot portrays the correlation of the parameters. A combined analysis can be obtained from the score plot and loading plot which helps to us to know why there is differences among the samples or groups (Carrer *et al.*, 2006).

There were circumstances when the PCs generated by PCA were not available to be analyzed. Therefore the PCs were rotated by varimax rotation. Varimax rotations applied on the PCs with eigenvalues more than one were considered significant (Kim and Mueller., 1987). Through Varimax rotation new groups of variables called varimax factors (VFs) were obtained. The quantity of VFs attained by varimax rotations is the same as the numbers of variables in accordance with general features and may comprise unobservable, hypothetical, and latent variables (Vega *et al.*, 1998). The VF coefficients with a correlation superior than 0.75 are known as "strong", 0.75-0.50, as "moderate"; and 0.50-0.30, as "weak" significant factor loadings (Liu *et al.* 2003). For this case study, PCA was applied to the standardized data sets (7 variables) for three diverse classes.

3.0 RESULTS AND DISCUSSION

The physicochemical levels in water supply from the surface water intake in Kuala Kubu Bharu water treatment plant are within the standards set by the Ministry of Health Malaysia (MOH), Privatization Cum Concessionaire Agreement (PCCA) and Internal guidelines (PNSB) (NORTH TERRITORY WATER QUALITY STANDARD, 2011). Table 1 shows water quality standards set by the North Territory. The reference standards are Ministry of Health Malaysia (MOH) and Privatization Cum Concession Agreement (PCCA).

Table 1: Water Quality Standards set by the North Territory.

Class	Parameter	Unit	Standard	Reference
Raw Water	pH	no unit	5.5-9.0	MOH
	Turbidity	NTU	max. 1000	MOH
	Colour	HU	max. 300	MOH
	Ammonia (NH ₃)	mg/l	max. 1.5	MOH
	Iron (Fe)	mg/l	max. 1.0	MOH
	Manganese (Mn)	mg/l	max. 0.2	MOH
Settled Water	pH	no unit	NA	NA
	Turbidity	NTU	max.10	PCCA
	Colour	HU	max. 20	PCCA
	Aluminum (Al)	mg/l	NA	NA
	Iron(Fe)	mg/l	Na	NA
Clean Water	pH	no unit	6.5- 9.0	MOH
	Turbidity	NTU	max.5.0	MOH
	Colour	HU	max.15	MOH
	Aluminum (Al)	mg/l	max. 0.2	MOH
	Iron(Fe)	mg/l	max. 0.3	MOH
	Ammonia (NH ₃)	mg/l	max.1.5	MOH
	Manganese (Mn)	mg/l	max.1.0	MOH

The mean of the pH obtained for raw water, settled water, and clean water were 6.79, 6.64 and 7.37 respectively. The mean of colour for raw water, settled water, and clean water was 26.52 HU, 6.81 HU and 5.03 HU. The mean of turbidity for raw water, settled water, and clean water were 13.78 NTU, 3.57 NTU and 2.18 NTU respectively. The mean of Iron (Fe) for raw water, settled water, and clean water were 0.035 mg/l, 0.082 mg/l and 0.017 mg/l respectively. The mean of aluminium (Al) for raw water, settled water, and clean water was 0.017 mg/l, 0.00 mg/l, and 0.00 mg/l respectively. The mean of ammonia (NH₃) for raw water, settled water, and clean water was 0.0096 mg/l, 0.00 mg/l and 0.0035 mg/l respectively. The mean of manganese (Mn) for raw water, settled water, and clean water were 0.046 mg/l, 0.00 mg/l and 0.019 mg/l respectively. As a conclusion the aim of national and international standards by examined water quality was achieved (Astel *et al.*, 2006). The water-quality data were then proceed with a variety of chemometric methods to discover their spatial and temporal trends.

3.1 Spatial Variation of Physico-Chemical Parameters

DA was analyzed on the secondary data to study the spatial variation between the different classes of drinking water such as raw water, settled water and cleaned water. The drinking water classes were known as dependent variables. The physicochemical parameters were known as the independent variables. DA was performed on three modes such as standard, forward stepwise, and backward stepwise modes respectively. The accuracy of spatial classification using standard mode DA were 91.87% (seven discriminant variables). Using the forward stepwise discriminant, the accuracy of spatial classification were 91.87% (six discriminant variables). Next the accuracy of spatial classification using the backward stepwise discriminant analysis were 91.87% (two discriminant variables). This shows that the classification matrix accuracy was excellent. The confusion matrix for DA in standard, forward stepwise and backward stepwise mode were presented in Table 2.

Table 2: Confusion matrix of discriminant analysis for standard, forward stepwise and backward stepwise mode

Sampling regions	% Correct	Regions assigned by DA		
		Clean Water	Raw Water	Settled Water
Standard DA mode (7 variables)				
Clean Water	100.00%	365	0	0
Raw Water	86.30%	1	315	49
Settled Water	89.32%	0	39	326

Forward stepwise mode (6 variables)

Clean Water	100.00%	365	0	0
Raw Water	86.30%	1	315	49
Settled Water	89.32%	0	39	326

Backward stepwise mode (2 variables)

Clean Water	100.00	365	0	0
Raw Water	86.30	1	315	49
Settled Water	89.32	0	39	326

The six discriminant variables in the forward stepwise discriminant analysis were found to be pH, iron (Fe), manganese (Mn), aluminium (Al), ammonia (NH₄), and turbidity. They have elevated distinction in their spatial distribution. The two discriminant variables in the backward stepwise discriminant analysis were found to be iron (Fe) and colour. The observation between three different classes of drinking water were shown in Figure 1. Box and whisker plots of the variation of the physicochemical parameters in the drinking water were shown in Figure 2. The settled water has the highest level of pH and iron (Fe). The raw water has the highest loading of turbidity, ammonia (NH₃) and manganese (Mn). The clean water has the highest level of aluminium (Al). The backward stepwise mode was proven to be a useful means for identification of the discriminant variables in spatial variations of physicochemical distribution in drinking water.

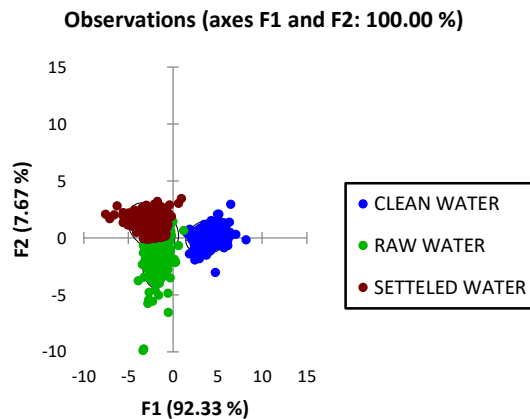
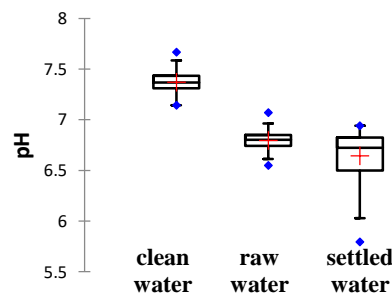


Figure 1: The observation between three different classes of drinking water



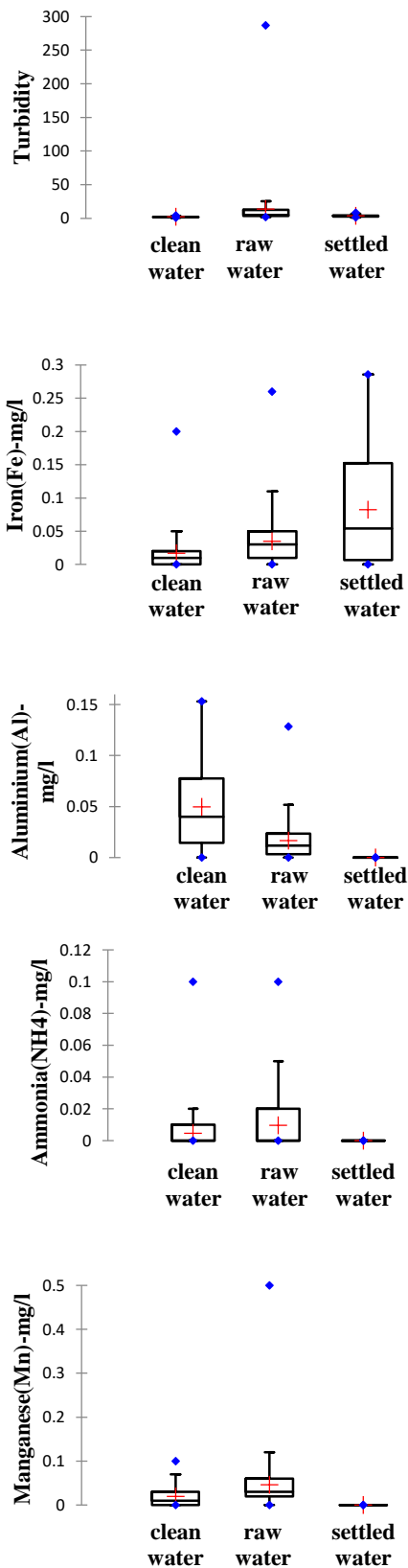
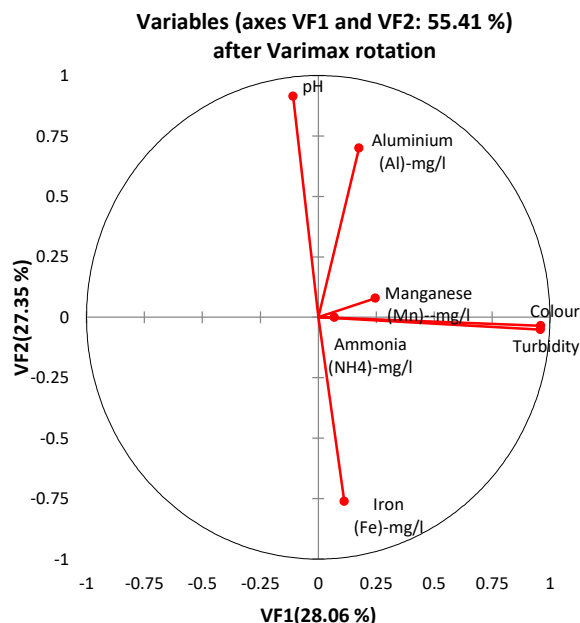


Figure 2: Box and whisker plots of the variation of physicochemical parameters for each classes of drinking water

3.2 Source identification of the monitoring area

PCA was applied for data reduction or to normalize log-transformed data set and also for interpretation by identifying the latent factors that influence each classes (Raw Water, Settled Water, and Cleaned Water). Besides that, the data was made consistent in order to be treated with corresponding values. Before applying PCA, correlation analysis was performed to discover an interior formation and aid in the detection of contamination sources. The PCs are only crucial if the eigenvalues > 1 . Table 3 summarized the PCA results consisting the variables loading factor (VF). Figure 3 shows the variables after varimax rotation. From this analysis three PCs were obtained, explaining 74.37% of the variance in the raw data.

**Figure 3:** The variables after Varimax rotation.

VF1 has 28.06% of the total variance and has strong positive loadings of colour and turbidity. VF1 has negative loadings of pH, iron (Fe), manganese (Mn), ammonia (NH₃) and aluminium (Al). Turbidity in water was caused by suspended matter, such as mud, silts, delicately alienated organic and inorganic matter, soluble coloured organic matter, and plankton and other microscopic organisms. It can arise in drinking water if the water is inadequately treated or if sediment is re-suspended. Turbidity can also be resulted from biofilm or corrosion products in the distribution method. Soaring point of turbidity is capable to shield microorganisms from the disinfection and will trigger bacterial intensification. Low turbidity reduces the quantity of chlorine needed for disinfection of water and the chances for spreading contagious diseases. Elevated concentrations of iron and the poor sanitary conditions were detected in numerous water supplies in almost all large locations. It is possible for a large number of the water supplies in a country where turbidity is a main water quality crisis. The natural contributors were from anthropogenic sources (Rapid Assessment of Drinking Water Quality in the Federal Democratic Republic of Ethiopia, 2010). High level of turbidity in drinking water indicates the presence of disease causing microorganisms such as bacteria and parasites (Shittu *et al*, 2008).

Besides that, the runoffs from fields with high load of soil could lead to soil erosion. This will eventually contaminate the Gerachi River and Kubu River. Massive sediments due to surface runoff from road edges erosion explains the positive loadings of turbidity (Goontilleke *et al*, 2005). The huge runoffs from mudflow, landslide and erosions during heavy rainfalls are very harmful to the local water supply. Construction activities nearby the Sungai Geraci can increase the turbidity level. The high loading of colour in the drinking water has been a major problem in drinking water quality (Aini *et al*, 2007). Rotting organic objects such as dead leaves and grass are the general reason of true colour. This kind of colour is generally detected in surface water. Inorganic materials such as Cu or Mn were the reason for clear colour. The true colour of water can be differentiated from the noticeable colour by straining the

sample in order to eliminate the bigger organic constituents. Usually, the colour in water does not have health threat but there were a little exclusion. Gastrointestinal signs were due to a metal impurity, such as copper with a soft colour (Safe Drinking Water Foundation). Coloured organic matter such as humic substances, metals or highly coloured industrial wastes were the contribution factors for colour in drinking water. The combination of some wavelengths of light by coloured substances known as 'true' colour and the distribution of light by suspended particles jointly are called 'obvious' colour. This combination justifies the manifestation of colour in water.

Treatment eliminates a lot of the suspended material. Generally drinking water should be colourless. Oxidation with ozone and adsorption onto activated carbon are the two ways to eliminate true colour. Peculiar colour change is a caution that potential quality alteration and investigation is needed. They may, because deprivation of the source water, corrosion of distribution systems, and alteration in adsorptive treatment processes such as activated carbon filtration (Payment *et al.*, 2003). Coagulation and sedimentation were the common treatment method in huge plants. These methods consume alum and other chemicals to eliminate the materials that cause colouration of drinking water, before being pumped out to people's homes. Excess of dissolved organic material due to inadequate treatment may be the contributing factor. High disinfectant demand and the capability for higher production of excess amounts of disinfectant by-products causes a high loading of colour in the drinking water. The common causes of colour are also inorganic contaminants such as metals. The cleaning process of the water tanks in the water treatment plant also could cause cloudiness of the water. The high loadings of turbidity and colour is also contributed by the sewage waste from the aquaculture activity near Gerachi River.

The total variance of VF2 was 27.35% and showed positive loadings of pH, iron (Fe) and aluminium (Al) which is caused by the acid rain. VF2 has negative loadings of manganese (Mn), ammonia (NH₃), colour and turbidity. The acid rain can contaminate the drinking water. The pollutant content can change the pH of the water. Acidic or basic water is more difficult to be disinfected compared to water with a pH that is closer to 7.0. High loading of pH in drinking water may be due to pipe corrosion of the distribution system (Safe Drinking Water Foundation). The pH causes the treatment processes such as coagulation and disinfection with chlorine based chemicals to be affected. Alteration in the pH of source water should be investigated because it is fairly a stable parameter over the short period. An extraordinary alteration may result in a main event. Generally the pH is a part of the treatment process and is constantly observed (Payment *et al.*, 2003).

The strong loadings of Fe and Al were due to the usage of fertilizers in agricultural industry near the Gerachi River and Kubu River. Iron is vital for human health but at the same time it is also a noxious metal. Fe may be diluted in the drinking water. A lot of studies about the health benefits of Fe being carried out, but there is a lack of information regarding its toxicity (Joseph *et al.*, 2010). Elevated levels of residual iron in drinking water could be the reason for the neutralization of the disinfectants, the colour changes of water, and the presence of metallic savor of water. High-ingested iron can result in extreme levels of iron in the blood stream. Excess of Fe can harm the gastrointestinal tract cells and this will avoid them from regulating iron absorption. For each kilogram of mass, humans undergoes iron toxicity above 20 milligrams and 60 milligrams per kilograms is a lethal dose (El-Harbawi *et al.*, 2010). A variety of iron salts are part of the coagulation process during water treatment. Aeration of Fe within the soil can affect the standard of groundwater and surface water. Oxidation and low pH can cause suspension of Fe.

Oxidation of dissolved Fe particles in water changes the iron to red-brown solid particles and finally settles out in the water. The water with a red tint is formed when the iron remains as colloidal Fe (Bruce *et al.*, 2007). The most abundant metals in the earth's crust are irons. Fe pollution is a meticulous crisis for anaerobic groundwater supplies. Fe induces the growth of iron bacteria. This bacteria oxidizes ferrous iron to ferric iron. Iron problems also occur in some surface water, especially related to colloidal iron. The remaining iron in the drinking water content will act in response with disinfectants by counterbalancing them. This results in propagation of micro-organisms in water delivery systems. The growth of these micro-organisms can decrease the diameter of the pipe or result in corrosion (Desjardins *et al.*, 2002). The remaining iron in the recovered water may hydrolyze and remain within the pipeline system. Malleable residuals could result in the colour changes of water. Sometimes it results in complications of the drinking water system (Joseph *et al.*, 2010).

The divalent Fe (Fe²⁺) and the trivalent iron (Fe³⁺) in faintly alkaline medium forms ferric oxide Fe₂O₃ or ferric hydroxide Fe(OH)₃. Ferric hydroxide Fe(OH)₃ are insoluble. Ferric oxide crystallizes as Fe₂O₃•2H₂O or like Fe₂O₃•H₂O. The rising amount of iron in drinking water contributes to the discharge of malleable deposit into large water (Lehtola *et al.*, 2004). Overload of iron results is due to genetic disorder (haemochromatosis) due to increased iron absorption and from diseases that need regular intake of blood (Guidelines for drinking water., 1996). Fe and Al occurs naturally in soil and the mineral rocks. Soluble form of iron (Fe) can be formed when a number of complex reaction occur naturally. As a result this iron (Fe) will contaminate the water that passes through (N.F Gray:Drinking Water Quality:Second Edition). The high loading of Al in the drinking water may be due to excess usage as coagulant and flocculating agents to eliminate particulate matter including microorganisms and soluble organic matter in water

treatment plant (Harrison., 2001). Al residual in drinking water can be categorized as extremely reactive to non reactive. When the pH is very low Al dissolves more in the abdomen. The absorption in the abdomen is very risky. Chronic exposure to Al leads to various health complications (Joseph *et al.*, 2010). In human, Al disrupts the fundamental metals (oligo elements) and metalloids by changing their bioavailability. The aluminium ions reacts with metal ions such as zinc, iron, calcium and chromium (Namiesnik *et al.*, 2010). Al circulation in the brain leads to neurodegenerative diseases, including Alzheimer's dementia, Parkinson's disease, amyotrophic lateral sclerosis, and dialysis encephalopathy (Goncalves *et al.*, 2007). In the drinking water distribution system, residual aluminum can lead to the configuration of micro-flocs. Micro-flocs are source of malleable deposition in the distribution systems. Malleable deposits within the pipe system are source of biofilm. These deposits consist of a large component of bacteria. These bacteria are the sources of water born disease that might be present in drinking water (Morton *et al.*, 2005). These bacteria containing deposits are the sources of microbial nutrients. Soft deposits may influence the hydraulic of the pipe distribution. Aluminosilicates regularly deposits onto plumbing resources in pipeline.

Table 3: Loadings of seven measured variables on significant VFs for drinking water quality

Variables	VF1	VF2	VF3
pH	-0.109	0.913	0.020
Colour	0.960	-0.035	0.098
Turbidity	0.960	-0.051	0.103
Iron(Fe)-mg/l	0.112	-0.762	0.061
Aluminium(Al)-mg/l	0.176	0.700	0.174
Ammonia(NH ₄)-mg/l	0.070	0.000	0.846
Manganese(Mn)-mg/l	0.246	0.079	0.746
Eigenvalue	2.221	1.947	1.037
Total Variance (%)	28.060	27.353	18.957
Cumulative Total Variance	28.060	55.412	74.369

VF3 explained 18.96% of total variance and shows strong positive loading of NH₃ and Mn. VF3 has negative loadings of pH, Fe, Al, colour and turbidity. The high loading of NH₃ and Mn can be attributed to the effluent waste from aquaculture industry near the Sungai Gerachi (WWF 2002). The domestic waste and sludge discharge from the housing area nearby is also the contributing factor. Huge amount of Mn is due to faeces and a small portion is due to urine (Davis & Greger., 1992). Faecal Mn contains of undigested dietary Mn. In humans, elimination is biphasic (Sandström *et al.*, 1986; Davidsson *et al.*, 1989b). Sweat, hair and the milk of lactating mothers also the other contributors of Mn (Roels *et al.*, 1992). Generally anaerobic groundwater has a high concentration of dissolved manganese. In drinking water treatment, Mn in the form of potassium permanganate is used to oxidize and get rid of iron, manganese, and other contaminants (ANSI/NSF., 2000). Mn is a crucial constituent for numerous living organisms. Unpleasant health problems may be due to insufficient ingestion or overexposure (WHO., 2011).

Keeping contact to high concentrations of Mn for years could result in toxicity to the nervous system and also causes a syndrome that resembles Parkinsonism. The elderly are more prone to this disorder. The latest Mn-Al prevents potential nervous system from being affected. This applies to those who are sensitive. Manganese does not generate supplementary form of toxicity such as cancer or reproductive complications (Connecticut Department of Public Health., 2003). Although Mn is a vital nutrient at low levels, persistent contact to elevated doses may be detrimental. There are significant statistics behind the neurological effects of Mn in both humans and animals. However there are small number of data that supports the relationship between oral exposure to Mn and lethal effects. EPA needs to issue a health consultative to offer guidance to people about the Mn concentrations for the prevention of wellbeing and organoleptic disorders. Ammonia is found in drinking water due to the disinfection process with chloramines. High loading of NH₃ is an important indicator of fecal pollution. Ammonia is present in most waters because of the organic dilapidation of nitrogenous organic compounds, eventhough it get in touch with groundwater and surface waters from manufacturing garbages effluents (EPA., 1976). The major contributor of the faecal pollution is due to the aquaculture pond near Gerachi River. The cement mortar used for covering the interior part of the water

pipes results in the discharge of considerable amounts of ammonia into drinking-water (WHO Guidelines for Drinking-water Quality: Ammonia in Drinking Water., 2001). NH₃ in drinking-water does not have critical health significance, and hence no health-related guideline values were anticipated. Nevertheless, NH₃ can be related to disinfection competence. These results in nitrite formation in. The nitrite formation results in the malfunction of filters for the elimination of Mn. Then it will lead to taste and odour disorders. NH₃ in drinking pipeline systems water may encourage the chlorine requirement. Eventually this may lead to a “break-point” chlorination incident (National Research Council., 1980). NH₃ and ammonium (NH₄) compounds were added to water to reduce the trihalomethane formation (Sacks *et al.*, 1984). NH₃ exists naturally in drinking water and may stratify in stored water (Amoore *et al.*, 1983).

4.0 CONCLUSION

Based on the prolonged observation of the concentration of the physicochemical levels in water distributed to the water supply system from the surface water and groundwater intakes in Kuala Kubu Bharu, it showed that the produced water are at par with the National Standards of Drinking Water standards. This study showed the importance of application and effectiveness of the easy but powerful statistical methods. This statistical analysis estimates and analyzes the multifaceted datasets to get a better picture of the water quality origin and its temporal variations. In this research, environmetric techniques were applied to investigate the physicochemical levels of drinking water quality in Kuala Kubu Bharu. For the temporal variation of physicochemical parameters, the DA gave an excellent results in discriminating the three drinking water classes with six and two discriminant variables assigning 91.87% cases precisely through forward and backward stepwise modes respectively. The PCA has shown seven parameters responsible for major variations in drinking water quality within the three classes (Raw Water, Settled Water and Clean Water). The main source of variation come from acid rain, soil erosion, mineral rocks, agricultural activities, aquaculture activities, water treatment plant and domestic waste.

Deterioration in drinking water quality was expected because it is always the centre of attraction of the nationwide. The availability to conserve the drinking water quality are plenty. The positive mindset should be implemented and exaggerated by instilling consciousness, fear and knowledge on water utilities in order to provide a good drinking water quality to the consumers. They should be able to face the challenges in the form of pollution so that the drinking water quality is always preserved. In addition every consumer should cooperate with each other (Aini *et al.*, 2007). This study has proven that the whole water sample meets the WHO limits for physicochemical properties. It means that water is not polluted. Nevertheless, regular monitoring should be done by the responsible authorities (Abulude *et al.*, 2006). In conclusion, multivariate statistical techniques serves as a tremendous examining device in the investigation and analysis of multifaceted data sets on the quality of drinking water and in understanding their temporal and spatial variations (Astel *et al.*, 2006).

Acknowledgements

First and foremost, I would like to thank my supervisor, Dr Normala Halimoon for being so kind to me and guiding me. My grateful thanks also goes to Dr Hafizan Juahir from Universiti Putra Malaysia (UPM). The moral support with valuable advices and guidance he gave me throughout this whole project have made me to face whatever obstacles that came acrossed. His willingness to motivate me contributed tremendous to my project. I would like to thank him for showing me some examples that are related to the topic of my project.

My special thanks goes to the Kuala Kubu Bharu Water Treatment Plant. Their cooperation and sincere help throughout this whole project is really appreciated. The valuable informations they provided was so usefull for my project.

Besides that I would like to thank the Faculty of Environmental Studies of UPM for offering this Environmental Research Project. This project has broaden my knowledge about the drinking water quality. Finally, I would like to express my gratitude to my family and fellow coursemates for their motivations and help. Without them, this research project would not have been possible.

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