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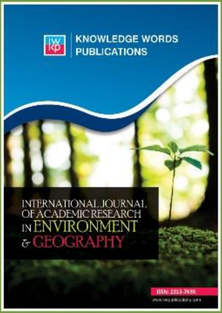

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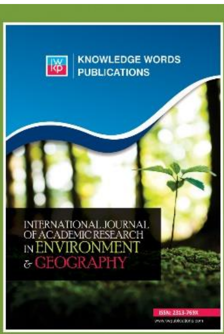

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Nutrients Contaminant on Monitoring Wells in Agricultural Areas of Kuala Langat, Selangor

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Abstract

Agricultural activities have become one of the prominent contributions to the level of groundwater quality. This paper aims to draw attention to the agricultural pollutants that are associated with the groundwater deterioration. The potential parameters distributions from agricultural areas into groundwater were found to be as nitrate, nitrite, phosphate, ammonia and phosphorous. MWD5 monitoring well shows the highest nitrate concentration. The lowest nitrate concentration recorded was in BKLTW12 monitoring well where this station is located at the North of Kuala Langat Reserve Forest. The nutrients contaminants from agricultural areas were also calculated to determine the accumulation in groundwater according to the different depth of aquifers. It was found that shallow aquifer was more susceptible to pollutants from agricultural areas where the nutrients contaminant will decrease with the increasing of depth. The result shows that nitrate to be below the recommended level for raw water guidelines of Ministry of Health Malaysia except for MWD5 monitoring well. Meanwhile, only BKLTW16, and MWD5 monitoring wells shows exceeded recommended level for ammonia concentration.

Keywords: Groundwater, Agricultural, Nutrients.

Introduction

Nutrients contaminant associated from agricultural practices contributes to the degradation of the groundwater quality. Agriculture has become a major source of groundwater pollution from the use of fertilizers and pesticides in agricultural fields besides the effluent from the industries. The non-point sources of pollutants derive from agricultural practices entered the groundwater bodies from erosion and run off. Fertilizers and manures enriched with nitrogen and phosphorus became the main contribution to the groundwater pollution. Deterioration of groundwater quality by fertilizer and manure apparently is much worse when compared to area of land used and urban fabric (Matiatos, 2016). According to Frink (1991) and Ongley (2005), the non-point pollution from agriculture significantly became the huge sources that contributes to the nutrient in groundwater

The land use has also become a consequential factor in the deterioration of groundwater sources. The land use from agricultural activities contributes to the major problems in degradation of groundwater pollutions. Nutrients contaminant from agricultural fields generally associated with the pollution in the surface water. Hence, the contaminated surface water causes the pollution of the groundwater sources. Surface water is more vulnerable to the nutrients contaminant and became the cause of the groundwater pollution. The groundwater is affected from the contamination of surface water because the groundwater is hydraulically connected with surface water as the interaction of these two types of water sources have interlink with the pollutant's accumulation (Harrison, 2018). Ironically, the excessive amount of nutrients emission to the water bodies resulted in the eutrophication in both surface and groundwater (Pieterse et al., 2015).

Nitrogen and phosphorus are the primary sources of nutrients contaminant in groundwater from agricultural fields. Nitrogen can be generally found in fertilizers and manures. Nitrogen that is normally present in the nitrate form is a very common pollutant where it generally enter the groundwater due to its solubility and can easily dissolved in groundwater (Novotny, 2015). Phosphorus is an essential macronutrient for plant growth which is available in rocks, soil and plants. Phosphorus commonly found in fertilizers and manures derives from the agricultural practices. Nitrate and phosphate are mutual concentration which is normally found in groundwater obtained from agricultural practices. The source of nitrate and phosphate in groundwater derived from the fertilizer and manure in agricultural areas (Carlyle & Hill, 2001). The application of inorganic fertilizers shows the increasing of nitrate and phosphate concentration which is the cause of deterioration in groundwater quality.

Study Area

Kuala Langat is known as an agricultural hub and the study areas were consisted of palm oil plantation and other variety of crops and vegetables. The geological area represented a quaternary geology where it is consisted of marine and continental deposits which are silt, sand and peat with minor gravel (JICA, 2002). The groundwater recharges in these areas of monitoring wells were from the hilly areas and mountains upstream. Normally, the aquifers were extensively disseminated in the flat lowlands. The region in Peninsular Malaysia originated from igneous rocks and older bedrocks of the Mesozoic and Paleozoic eras (Hutchison, 1989). Kuala Langat monitoring wells were divided into two sub area which are the Northern Kuala Langat area and Southern Kuala Langat area. BKLTW12, MW01, MWD4, BKLEW2, MW05, BKLTW19, MWD2 and MWD5 located in Northern Kuala Langat are shallow in depth approximately in between 4 to 35 meters, while BKLTW16, J7-1-4, BKLTW11 and BKLTW15 monitoring wells located in Southern Kuala Langat are deeper where the deep wells are more than 60 meters. Figure 1 show the twelve monitoring wells that are tabulated in Kuala Langat area for analysis purposes.

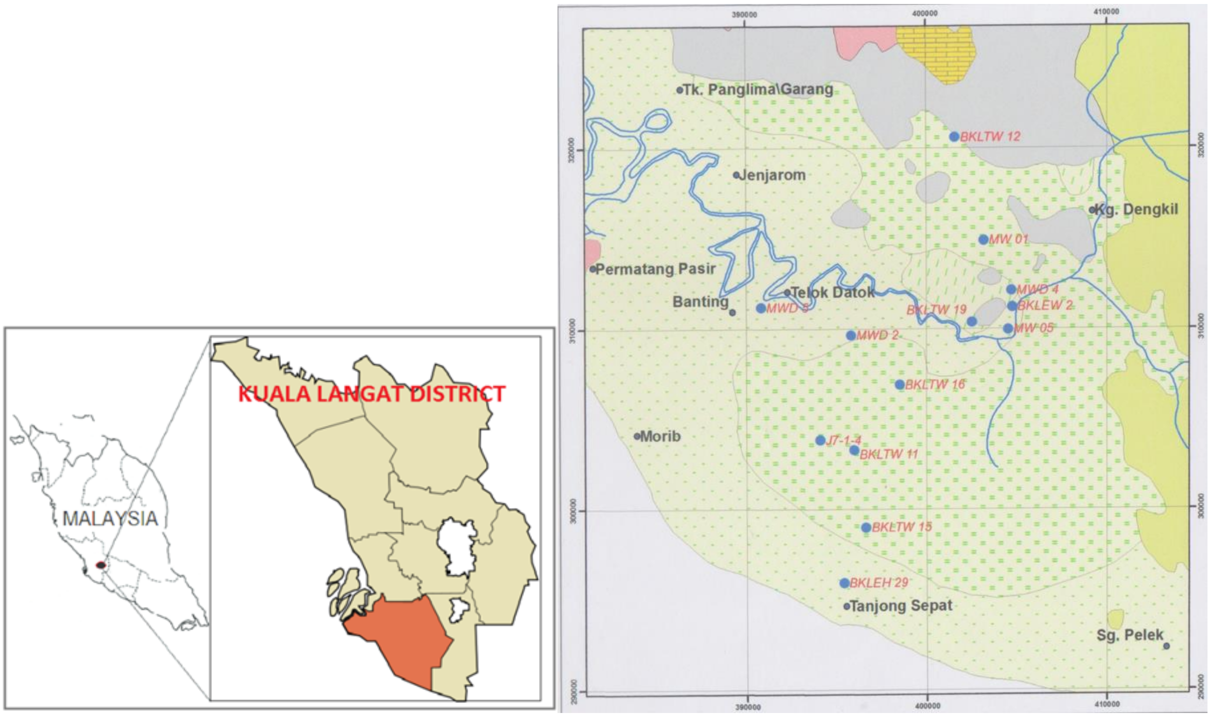

Figure 1: Monitoring wells in Banting, Kuala Langat

Methodology

Monitoring wells located in Kuala Langat agricultural areas were chosen for groundwater analysis. Twelve monitoring wells were sampled to analyze the potential agricultural pollution distributions in groundwater. In this study, is it found that the agricultural practices cause nitrate, nitrite, phosphate, ammonia and phosphorous to potentially instigate groundwater pollution. Groundwater sampling procedure and analysis was done following the APHA guidelines and The Mineral and Geosciences Department guidelines (APHA, 2012). Groundwater samples were collected at twelve monitoring wells from shallow groundwater which level was less than 22.0 m, intermediate level at between 22.0 m to 40.0 m and deep aquifer that was more than 40.0 m in depth (Sefie et al., 2015). The sampling sessions were conducted in the agricultural areas from February 2016 to February 2018. This field verification sampling is necessary to determine the selected water quality parameters. The groundwater samples were pumped using the submersible groundwater pumps and groundwater level meter were used to measure the groundwater depth before and after sampling process. Laboratory analysis for nitrate, nitrite, phosphate, ammonia and phosphorous were conducted following the HACH method. Cadmium reduction method using the Nitraver 5 powder pillows were applied to measures the nitrate concentrations in the groundwater samples. Meanwhile, phosphorous were measured using the PhosVer 3 powder pillows to determine the concentration in groundwater.

Results and Discussions

Nutrients Contaminant in Groundwater

The nutrients contaminant in groundwater derived from agricultural areas show the main contribution to the degradation on groundwater quality. The degradation of groundwater quality from livestock manures, fertilizers and pesticides in agricultural areas resulted in the ammonium, sulfide and methane emission into groundwater bodies (Lawniczak et al., 2016). The leaching of nitrogen and phosphorus from agricultural fields resulted in the high accumulation of nutrients contaminant in groundwater due to the excessive application from minerals fertilizers compared to the requirements of plant growth and this become some unfavorable circumstances (Billen et al., 2013; Kyllmar et al., 2014). The factor which influence the nutrients leaching into groundwater depend on the fertilizer's application timing, the soil properties, types of plants, organic matter structure, agronomic practices and cultivation methods (Bechmann et al., 2014; Kyllmar, et al., 2014). Nitrogen generally dissolve easily and soluble in nitrate form in percolating water while phosphorus showed less accumulation in groundwater due to the low mobility to the surface water and it also eroded with the soil particles (Lawniczak et al., 2016).

Majority of the monitoring wells shows high nitrate concentration compared to phosphate. According to Lake (2003), the application of nitrate is more than phosphate in fertilizer in agricultural fields. The high accumulation of nitrate in groundwater in current study shows similar finding with excessive of N content in groundwater sources in Poland arable land where intensive agricultural areas resulted huge N inputs compared to the urban and forest area (Lawniczak et al., 2016). Nitrate are highly soluble that can be dissolved in water and easily absorbed in the soil when compared to phosphate. Nitrate is a macro element that is more transient while phosphate is not absorbed and percolate into the soil easily (Lake et al., 2003). In addition, phosphate is slightly small and accumulate due to its small micro features and it will not be easily infiltrating into the soil. However, the usage of phosphate in agricultural areas is low. Nitrate common form which is derived from nitrogen can potentially attenuate ammonia concentration in groundwater. Therefore, the low ammonia concentration in several monitoring wells is associated with the high nitrate where ammonia attenuated with nitrate in groundwater (Atta, Yaacob, & Jaafar, 2015).

Referring to nitrite concentration, only a small amount was found in groundwater when compared to nitrate concentration. Nitrite is the unstable chemical constituent of nitrogen species and can easily transform to nitrate form. This situation explained the small amount of nitrite concentration in groundwater as it is not as dispersed in the environment (Atta et al., 2014). Figure 2 show the nutrients contaminants derive from agricultural areas in Kuala Langat into groundwater sources. Meanwhile, the BKLTW12 monitoring well show the lowest nutrients contaminant in the groundwater sources since this station has no agricultural areas and is covered with forest area. The nutrients contaminant showed low concentration in forest reserve according to the previous finding resulted in the low ammonium in forested catchment (Boyer, 2007; Galloway et al., 2003).

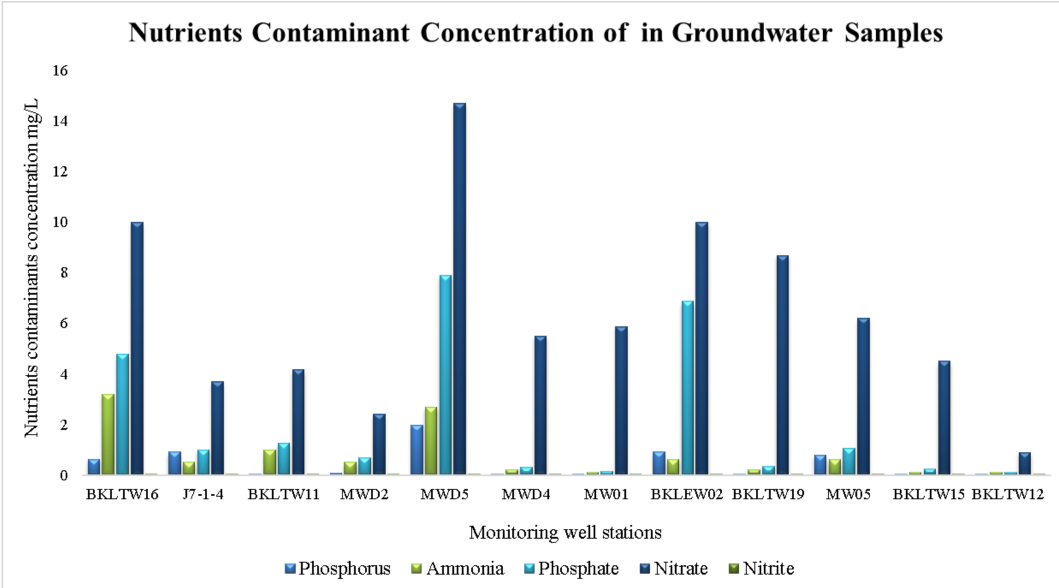

Figure 2: Nutrients contaminants in groundwater

Nutrients Contaminant in Relation to Well Depth

In this study, the researcher has found that nitrate concentration is decreasing according to the depth of the wells by increasing of depth wells. The nitrate concentration in deepest aquifer in current study where BKLTW11 monitoring well of 70 m depth showed the 4.16 mg/L of nitrate in the groundwater sample. This finding similar to the previous study in Xizhaotong aquifer in Shijiazhuang, China resulted the low nitrate concentration were 4.8 mg/L in the groundwater samples represent in the deep aquifer with the 100 m depth (Zhang et al., 2015). The low nitrate concentration in deep groundwater is caused by the denitrification reactions where it is associated with the nitrogen soil organic and precipitation (Zhang et al., 2015). Nitrate is inorganic compound which is stable in an aerobic condition, where with the increase of groundwater depth, the lower the nitrate concentration will be which is due to the low oxygen content in deep groundwater thus enabling the stability of nitrate. However, nitrate potentially transform to other oxides of nitrogen in anaerobic condition due to oxygen deficiency (Buss et al. 2005). According to Lawniczak et al., (2016), the high level of nitrate concentration in groundwater indicates the periodic excess level of fertilizer application in agricultural areas.

A similar finding of agricultural area in Hungary shows the shallow groundwater that is less than 20 meters is significantly more vulnerable to the agricultural pollutants and the nitrate concentration were decreasing according to the depth (Leone et al., 2009). Leone, (2009) also identify the high nitrate accumulation in shallow groundwater of less than 20 meter due to the assessment on groundwater flow regimes showed the hydraulic modeling and dating indicates very low velocity of groundwater flow (Leone et al., 2009). This condition showed that the pollutant has been saturated in shallow aquifer and nutrients contaminant derives from agricultural practices continuously increasing due to slow groundwater flow.

Shallow groundwater is more vulnerable to pollutants derives from agricultural practices such as fertilizers and pesticides. The pollutants contact the surface water and shallow groundwater through run off and leaching. The shallow groundwater then easily allows the agricultural contaminants to enter the aeration zones of groundwater recharges (Wang et al., 2018).

A soil characteristic can also be associated with pollutants indication in groundwater. The characteristic of the clay soil revealed to be less susceptible to pollutants due to its high organic matter contents, as the clay soil can potentially degrade the pollutant before it enters the groundwater. However, this study area shows the soil characteristic originated from the peat soil. Peat soil is a high porosity soil with sandy structures. The low organic matter in peat soil exhibit less availability for pollutants to be degraded by the organic matter.

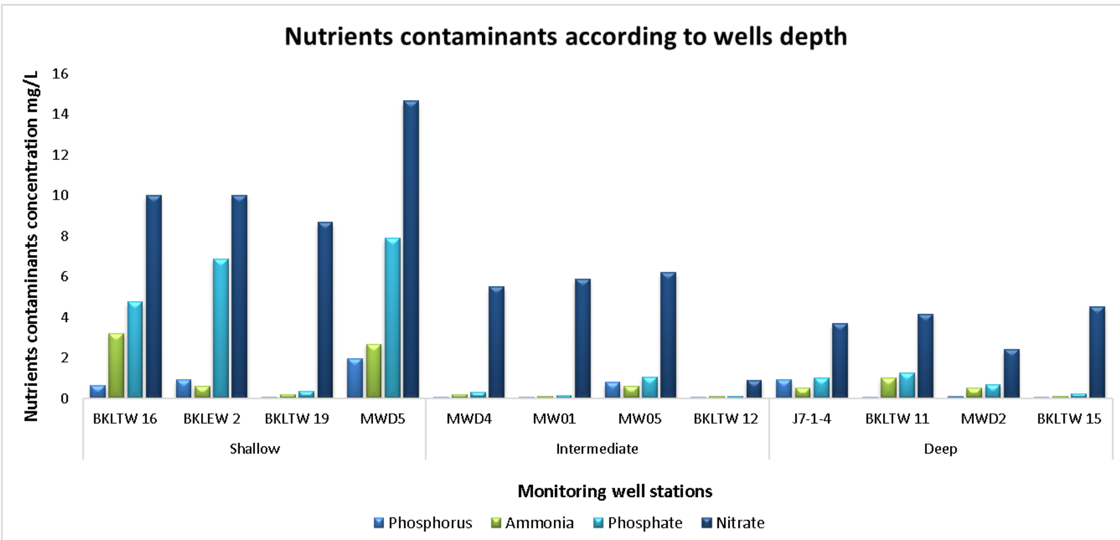

Figure 3: Nutrients contaminants according to wells depth

Comparisons of Nutrients Contaminant with Established Guidelines

The estimation on the pollutants extent from agricultural fields significantly can determine the quality of groundwater in current study areas. The quality of groundwater was evaluated by referring to the Ministry of Health recommended level for raw water. Referring to the Ministry of Health raw water guidelines, nitrate and ammonia were evaluated for groundwater quality determination. The nitrate concentration in monitoring well stations only show one of the monitoring well exceeded the maximum permissible limit. The MWD5 monitoring wells shows nitrate concentration of 14.67 mg/L where the allowed level of nitrate in raw water by Ministry of Health is 10 mg/L. Figure 4 show the comparisons of Ministry of Health recommended level of freshwater on nitrate concentration for monitoring wells stations in current study.

By using the raw water guidelines from Ministry of Health, the concentration of ammonia in the monitoring wells station revealed only two stations has exceeded the recommended level. The BKLTW16 and MWD5 monitoring wells shows exceeded recommended level for ammonia concentration whereby the Ministry of Health set of 1.5 mg/L for allowable ammonia concentration in raw water. However, ammonia concentration was above the permissible limit of 3.2 and 2.67 mg/L for both monitoring well stations respectively. The comparisons of Ministry of Health recommended level on freshwater on ammonia is shown in Figure 5 for each monitoring well stations.

Meanwhile, nitrate and ammonia concentration for other monitoring well stations show below the level recommended. The groundwater sources in Banting, Kuala Langat is not significantly vulnerable to the agricultural pollutants. The nutrient pollutants will generally be degraded by the microorganism in soil and water before the pollutants can enter the groundwater sources.

In terms of health issues, the exceeded level of nitrate concentration in a human body can potentially cause the Methemoglobinemia disease or baby blue syndrome, where consumption of drinking water that contains excessive amount of nitrate concentrations can affect the infants. In addition, a high level of nitrate in human body that accumulates through water consumption can cause gastrointestinal diseases and birth defects (Zhai et al., 2017). According to Su et al. (2013), the irrigation on agricultural sewage showed high risks to the human health due to nitrate pollution on groundwater referring to the health risk model of non-carcinogens pollutant (Su et al., 2013).

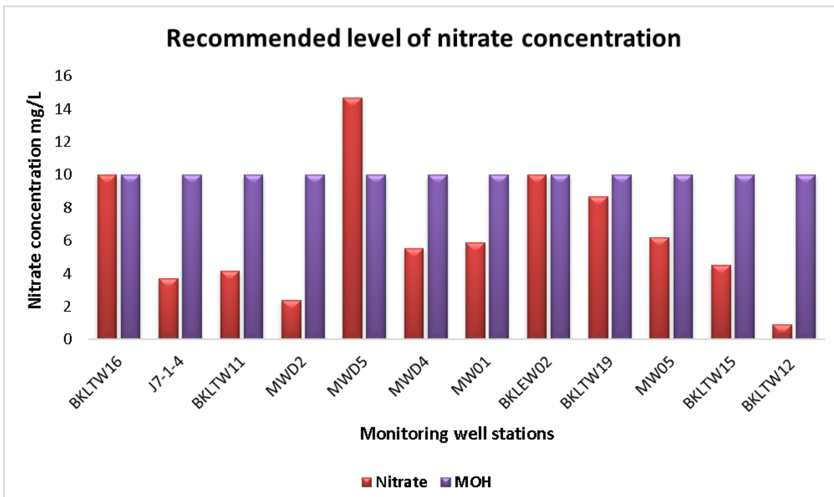

Figure 4: Recommended level of nitrate concentration

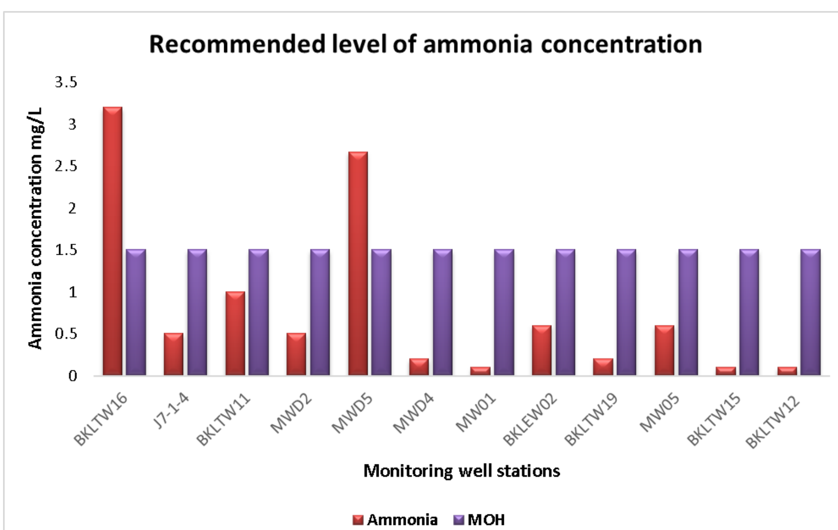

Figure 5: Recommended level of ammonia concentration

T-Test Analysis

The t-test analysis was conducted to determine the significant difference of nutrients contaminants in groundwater using the p-value. The analysis of nutrients contaminants in groundwater was summarized in Table 1. The mean concentration of nutrient contaminants in monitoring wells in Kuala Langat was in the order of nitrate>phosphate>ammonia>phosphorus>nitrite and as shown in Figure 6. Nitrate resulted from the high concentration of nutrient contaminant in groundwater are 6.38 mg/L. However, groundwater sources in Kuala Langat monitoring wells are shown to be not exceeded the recommended level of nitrate concentration is 10 mg/L. Meanwhile, nitrite shows the lowest concentration in groundwater sources in the current study is 0.01 mg/L.

The concentration of phosphorus, phosphate, and ammonia, nitrates and nitrites show the p-value is less than 0.05 of the nutrients contaminant in the 12 different monitoring well stations. The research also shows a 95% confidence interval obtained from the analysis of the study. The t-Test analysis indicates there was a significance difference between nutrients concentrations across the groundwater samples. However, the low p-value from the t-test analysis not solely to conclude the groundwater quality has deteriorated from the nutrient contaminants from agricultural practices. This situation caused the test value from t-Test analysis was appear as zero which means none of the quality of groundwater has degraded from the nutrients compounds in agricultural areas. In addition, the test value explains the nutrients contaminants to the groundwater samples were considered as uncontaminated. Meanwhile, there have no benchmarking values in the current study to conclude the contaminated groundwater samples from the nutrients compounds. Therefore, this analysis revealed the groundwater quality not vulnerable to the nutrients contaminants from agricultural practices.

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Table 1: Mean and standard deviation of phosphorus, ammonia, phosphate, nitrate and nitrite (mg/L) in monitoring well stations (n = 12)

Samples	Phosphorus	Ammonia	Phosphate	Nitrate	Nitrite
Groundwater Sources	0.45± 0.61	0.81± 1.03	2.05± 2.80	6.38± 3.85	0.01± 0.01

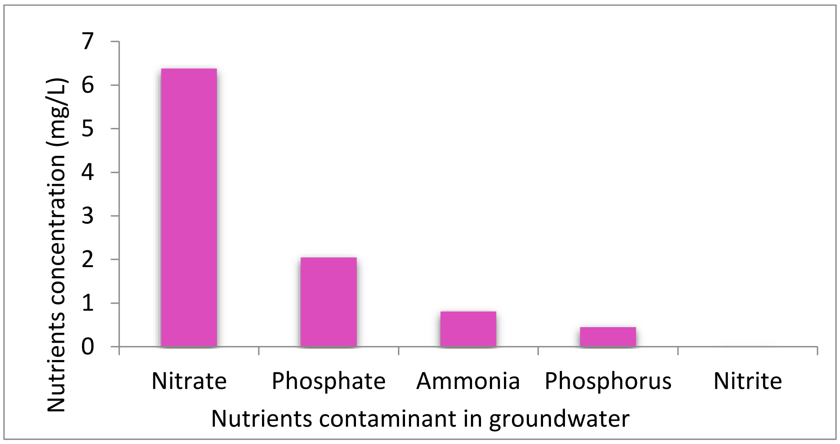

Figure 6: Mean concentration of nutrients contaminant in groundwater (mg/L)

Table 2: Mean and standard deviation from t-Test analysis

One-Sample Statistics

Parameters	N	Mean	Std. Deviation	Std. Error Mean
Phosphorus	12	0.45	0.61	0.18
Ammonia	12	0.81	1.03	0.29
Phosphate	12	2.05	2.80	0.81
Nitrate	12	6.39	3.85	1.1
Nitrite	12	0.01	0.01	0.003

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Table 3: Significance p value from t-Test analysis

One-Sample Test

Parameters	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Phosphorus	2.57	11	0.02	0.45	0.06	0.84
Ammonia	2.73	11	0.02	0.81	0.16	1.47
Phosphate	2.54	11	0.03	2.05	0.28	3.83
Nitrate	5.74	11	0.00	6.38	3.93	8.83
Nitrite	4.36	11	0.00	0.013	0.00	0.02

Conclusions

The nutrients contaminant in the groundwater sources of Kuala Langat agricultural areas shows that the quality of groundwater is not susceptible and deteriorates with the pollutants derives from agricultural practices. Nitrate resulted the significant nutrient contaminant in groundwater compared to other parameters due to easily absorbed in soil and high potential to dissolved in water. The agricultural practices not significantly vulnerable to the groundwater quality. Phosphorus, phosphate and ammonia, nitrates and nitrites concentration in groundwater are revealed to be below the recommended level by established guidelines.

The findings of this research contribute to the different theoretical perspectives on the major contribution of agricultural practices to the deterioration on groundwater quality. The nutrients contaminant in groundwater sources in relation to groundwater depth has been analyzed and is found that the pollutants from agricultural practices have been potentially degraded by the microorganism in soil and water. Denitrification process in deep groundwater significantly shows the reduction of nitrate. Besides, the nutrient contaminant does not continuously accumulate in groundwater and the groundwater quality in current study has sustainability on the quality. The groundwater sources in this study areas are suitable for domestic purposes and irrigation and not vulnerable to the agricultural pollution.

Recommendations

The good agricultural practices should be emphasized in every agricultural fields to ensure the sustainability of groundwater quality. Moreover, planting cover crops on the soil surface can also help in managing and controls the nutrient contaminants from the agricultural activities from infiltrating into groundwater. In addition, agricultural practitioners should have an awareness to protect environment and natural resources. The initiative to obtain the certification of Malaysian Good Agricultural Practice Schemes by Ministry of Agricultural is encouraged to ensure the groundwater not vulnerable to the excessive nutrients form agricultural practices which according to permissible limits.

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