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Water Quality Assessment of a Livestock Farm

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ABSTRACT

Frequent assessment of water qualities is pertinent as this ensure effective monitoring, sustainability and utilization. It is more indispensible considering the several human activities and indiscriminate discharge of toxic substance into the water resources. In this study, the water quality of groundwater and surface water are monitored at a livestock housing, Ladang 16, UPM. The aim of this study is to investigate the effect of cattle farming activity on qualities of the nearby water. Two wells were constructed at Ladang to monitor the qualities of the groundwater (MW 1 and MW 2). The water qualities parameters obtained for the surface water and groundwater quality were compared with raw and drinking water Ministry of Health (MOH) standard. The results revealed that the quality of groundwater and surface water are slightly polluted. This is because some of the measured parameters such as turbidity, NH3 and fecal coliform exceeded the standard. Water Quality Index (WQI) was used to characterize the surface water quality. Based on the six parameters (DO, BOD, COD, AN, SS, pH), the lake and river at Ladang are classified as Class III with the WQI values of 67.44 and 75.49, respectively.

KEYWORDS

Water quality index (WQI), monitoring well, cattle farm, groundwater and surface water

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INTRODUCTION

Improper management of livestock manure could contribute significantly to water pollution. To mention but few, some of the poor manure management includes manure spreading on compacted soils, excessive manure application and improper storage facilities. Runoff from dairy feedlot and holding areas couple with the poor management of manure has high potential to cause water pollution. This is because of the water-wash by the runoff which often got its way into the surface and/or groundwater.

Typically, a single dairy cow with weight of 590 kg produces 68.7 liter of manure per day which is equivalent to 1.135 population equivalent (PE) (Fleming & Ford, 2001). In this study, total number of cattle (dairy and beef) in Ladang 16 is 178 with a total of daily manure production of 12228 liter/day. This implies that the population equivalent is 202. Higher concentration of these substances may pose a threat to human health and could result in poor taste, odour or colour of the nearby water sources. Consequently, water quality will be deteriorated, thereby curtailing its sustainability and utilization. Polluted water can move from the point of contamination over to a wider area as well as percolating into the underground water. However, the risk to health will depend on the concentration and type of contaminants that present in the polluted water. Thus, water quality assessment is needed to ensure good monitoring and quality compliance to the established standard.

Generally, water qualities are comprises of the physical, chemical and biological characteristics. A healthy environment is where the water qualities comply with the standard and able to sustain an ideal ecosystem. Good water quality able to be used for farming, fishing, provides ecosystem habitats and for recreation and tourism. Table 1 shows the raw water and drinking water quality standard in Malaysia.

Table 1: Raw Water and Drinking Water Quality Standard (MOH, 2010)

Parameter	Symbol	Recommended Raw Water Quality	Drinking Water Quality Standard
		Acceptable value (mg/litre)	Maximum Acceptable Value (mg/litre)
Total Coliform	-	5000 MPN in 100 ml	0 in 100 ml
E.coli	-	5000 MPN in 100 ml	0 in 100 ml
Turbidity	-	1000 NTU	5 NTU
Color	-	300 TCU	15 TCU
pH	-	5.5-9.0	6.5-9.0
Total Dissolved Solids	TDS	1500	1000
Chloride	Cl	250	250
Ammonia	NH_3	1.5	1.5
Nitrate	NO_3	10	10
Iron/Ferum	Fe	1.0	0.3
Hardness	$CaCO_3$	500	500
Manganese	Mn	0.2	0.1
Chemical Oxygen Demand	COD	10	-
Biological Oxygen Demand	BOD	6	-
Mercury	Hg	0.001	0.001
Cadmium	Cd	0.003	0.003
Arsenic	As	0.01	0.01
Chromium	Cr	0.05	0.05
Copper/Cuprum	Cu	1.0	1.0
Sulphate	SO_4	250	250

Department of Environment (DOE) had last conducted river quality assessment since 1978. This is important to establish baseline, identify the changes in quality along with the source of pollutants. The water quality index (WQI) is an effective tool to provide feedback on the water quality assessment to the policy makers and environmentalist (Amadi et al, 2010). Table 2 shows the WQI classification that is computed based on 6 main parameters. WQI also serves as basic environmental assessment of water in order to determine the pollution load categorization and designation of classes for beneficial uses (Department of Environmental, 2006).

Table 2: DOE Water Quality Index Classification (DOE, 2006)

Parameter	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	<0.1	0.1-0.3	0.3-0.9	0.9-2.7	>2.7
Biological Oxygen Demand	mg/l	<1	1-3	3-6	6-12	>12
Chemical Oxygen Demand	mg/l	<10	10-25	25-50	50-100	>100
Dissolved Oxygen	mg/l	>7	5-7	3-5	1-3	<1
pH	-	>7	6-7	5-6	<5	>5
Total Suspended Solid	mg/l	<25	25-50	50-150	150-300	>300
Water Quality Index	-	<92.7	76.5-92.7	51.9-76.5	31.0-51.9	>31.0

Calculations are performed based on their sub-indices. The sub-indices are named SIDO, SIBOD, SICOD, SIAN, SISS and SIpH. Every sub-index is calculated based on the certain condition. Table 3 shows the water classes and it uses. Final stage requires the combination of the calculated sub-indices in order to determine the overall WQI, based on the formula equation 1;

$$WQI=0.22\ SIDO + 0.19SI\ BOD +0.61SI\ COD + 0.15\ SIAN + 0.16\ SITSS +0.12\ SIpH \qquad (Eq.\ 1)$$

Classification of the water either in Class I, II, III, IV or V as in Table 3 is based on Water Quality Index (WQI) and Interim National Water Quality Standards for Malaysia (INWQS).

Table 3: Water Classes and Uses (DOE, 2006)

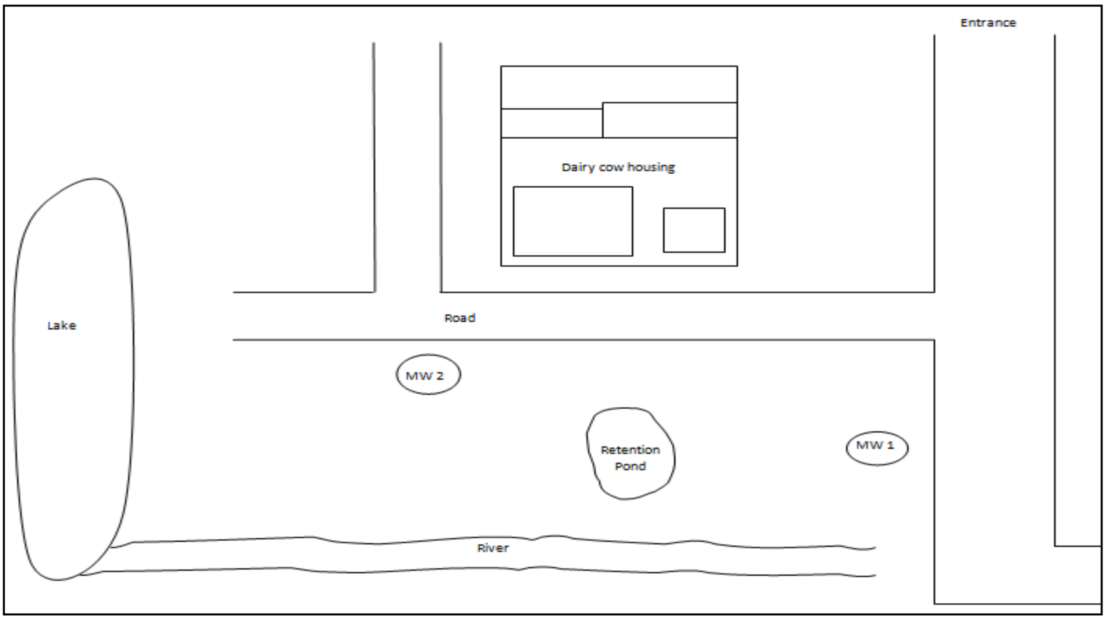
Class	Uses
Class I	Conservation of natural environment Water supply I - Practically no treatment Fishery I - Very sensitive aquatic species
Class IIA	Water supply III - Conventional treatment Fishery II - Sensitive aquatic species
Class IIB	Recreational use body contact
Class III	Water supply III - Extensive treatment required Fishery III - Common of economic value and tolerant species, livestock drinking
Class IV	Irrigation
Class V	None of the above

The purpose of this study is to monitor the water quality of river, pond and groundwater at Ladang 16, UPM. The livestock activities such as ranching, grazing, milking or diary operation and manure disposal exposed the water to pollution. More so, the livestock are positioned at the higher elevation, hence the pollutants is easily transported by runoff into the water-sources. Inaddition, river and lake located less than 10 m from the source of pollutants are potentially exposed to pollution. Therefore, the need for monitoring is imperative. The results of water quality assessment will be useful for environmental management at Ladang 16, Universiti Putra Malaysia to monitor of contaminants in water sources at Ladang 16, UPM.

MATERIALS AND METHOD

General Description of Study Area

This study was conducted at Ladang 16, UPM (Figure 1). The land area of the location and its elevation above sea level were 150,000 m^2 and 52.5 40 m, respectively (Figure 2). The number of the dairy and beef cattle in Ladang were 43 and 135, respectively. The average manure produce per cow was approximately 7.5 kg/day (5-10 kg per day). The main source of water in Ladang is the SYABAS pipeline water, which being utilized for the daily livestock activities. Quantitatively, the water used for cleaning purposes was approximately 25 L to 30 L for each cattle per day and the wastewater emptied into a retention pond. Two monitoring wells (MW1 and MW2) were constructed next to the cattle farm and next to a retention pond at 2.993113°N, 101.732°E and 2.99248°N, 101.7332°E, respectively (Figure 2).



*MW = monitoring well

Figure 1: Location of site.

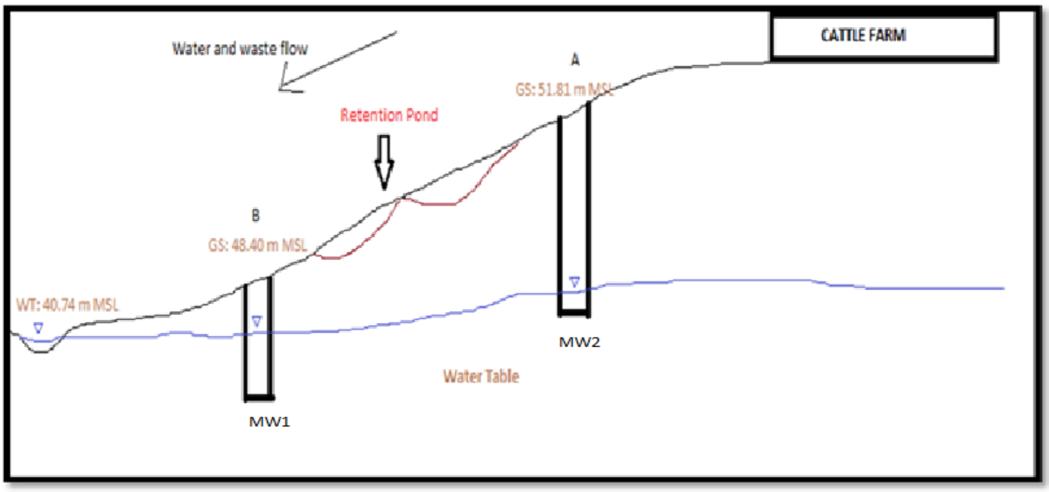


Figure 2: Cross-section of study area.

Water quality analyses and sampling

The portable sampler was used to collect groundwater at 10 m depth. The standing water in the well was pumped out from the well using mini submersible pump (Eijkelkamp). The amount of water pumped out depends on the volume of standing water. The water was extracted into a portable sampler using a peristaltic pump at flow rate ranged from 125 to 650 ml/min. The YSI portable meter was used to measure the pH, DO, salinity, TDS, turbidity and ammoniacal nitrogen. The groundwater and surface water (from lake and river) sampling began from January 2017 until February 2017 at interval of two weeks. The water quality analysis was conducted using DR/4000 Spectrophotometer at wavelength ranging between 190 and 1100nm for determining the concentration of the nitrate, copper, zinc, iron and sulphate. All the sampling and analysis of the various physicochemical attributes were done following the standard procedures as detailed in APHA (2005).

RESULTS AND DISCUSSION

Water Quality Analysis

Generally, it was observed that the contaminants in the groundwater flow from higher elevated area. From the result of water assessment, it shows that the concentration of contaminants was higher in MW1 compared to MW2. This is because the elevation of source of the pollution is higher than MW1 while MW2 is the least. Also, the contaminants could infiltrate into the groundwater and flow downwards into the rivers and pond.

Table 4 shows that TDS for lake and river are 57.36 mg/L and 49.46 mg/L, respectively. The results of TDS for both water sources are within the acceptable range. Interestingly, the highest TDS was measured at MW1 (123 mg/L) located about 5 m from the feedlot and milking center. Also, organic sources such as decaying organisms (plants and animals) or agricultural runoff may also contribute to the TDS. However, high concentration of TDS is an indication that the water sources had been polluted. Seepage from the feedlot may discharge dissolved salt into groundwater and/or directly into the surface water due to run-off. Hence, this process might increase the salinity concentration of the groundwater and surface water. Highly saline water is undrinkable and not suitable for agricultural purpose. The result of salinity for lake and river are 0.04 ppt and 0.03 ppt, respectively. This type of water is classified as freshwater as the salinity concentration is less than 0.5 ppt, thus it is suitable for agricultural purpose.

The fecal coliform (FC) concentrations were detected below limits for MW1 and MW2 with 2 and 10 CFU, respectively (Table 4). The values were increased from 50 CFU in river to 100 CFU in pond. All the FC concentrations were considered below the recommended maximum allowable limit by NWQS for Malaysian rivers which is 5000 cfu/100. Study by Fawaz et al. (2013) at 8 stations along Sungai Semenyih reported that FC were within the range 433 cfu/100 mL at station 1 and 145667 cfu/100 mL at station 6 during raining season. At this season, the highest amount of effluents containing greater concentrations of pollutants from the livestock farms (poultry, goats, and cow farms) is expected. This could increase the level of nitrogen, phosphorous and fecal coliform bacteria count in the water (A.A. Oketola et al., 2006).

Table 4: Result of Water quality Analysis of Groundwater and Surface Water

Parameter	Concentration in MW1	Concentration in MW2	Concentration in Lake	Concentration in River
Turbidity (NTU)	*11.63±9.39	*7.10±2.02	*27.1±17.35	*13.45±14.29
Temp (°C)	28.4±0.85	27.8±1.25	*27.3±0.94	*27.1±1.37
TDS (mg/L)	123.18±6.22	32.83±2.22	*57.36±8.13	*49.46±13.0
Salinity (ppt)	0.088±0.005	0.02±0.0	*0.04±0.01	*0.03±0.01
Chemical (Inorganic)				
Ammonium (mg/L)	*5.80±1.33	*1.10±0.12		
TSS (mg/L)	*207±113.76	*66.25±68.28		
Nitrate (mg/L)	*1.43±1.85	*1.28±1.10	*1.7±1.95	*1.4±1.74
Sulphate (mg/L)	*15.03±4.94	*1.73±0.39	*2.58±0.95	*1.98±0.67
Iron (mg/L)	*2.78±1.56	*0.81±0.36	*0.92±0.18	*0.61±0.12
Potassium (mg/L)	7.09	5.26	2.49	0.726
Heavy Metals				
Copper (mg/L)	0.13	0.088	0.091	0.075
Microbiological				
Fecal Coliform (Cfu/100ml)	2	10	>100	>50

ND = Not Detected; *values are means of the repeated experiments ± standard deviation

Table 4 shows that the turbidity values varied between 7.1 and 27 NTU and that the lake in the downstream recorded the highest reading. Base on the DOE standard, only the turbidity concentrations below 25 NTU is considered suitable for domestic use (DOE, 2006). Prevalently, turbidity is an indication of presence of suspended particles such as silt, debris, plankton, clay, organic matter, and other microscopic or decomposers organisms. Also, water flow in the pave ways expose it to a higher concentration of suspended solid, this could significantly increase the turbidity and declination in clarity.

The murkier water in general was ascribed to the higher amount of sediments. This can also be the indicator of a high measured turbidity, and stream flow, surface runoff, and overland flow in natural waters also increase the turbidity levels in the water (A.A. Oketola et al., 2006).

Water Quality Index (WQI)

WQI for lake and river in Ladang were determined using equation 1. In this equation, the water qualities parameters were attached with different level of significance (Naubi et al, 2015). DO is the most important parameter, as it assigned 22% of total weights. Results for water qualities index for lake and river are shown in table 5.

Table 5: Monitoring of Water Quality Index Parameter

Parameter	Concentration in Lake	Concentration in River
DO (mg/L)	4.23	6.34
DO (%)	53.43	74.13
BOD (mg/L)	9.58	11.96
COD (mg/L)	25.6	12.8
AN (mg/L)	0.20	0.14
SS (mg/L)	124.75	105.5
pH	7.43	7.61

Dissolved oxygen for lake and river were 4.23 and 6.34 mg/L, respectively. Higher DO values represent good water quality and best for a healthy ecosystem (WHO, 2006). BOD for lake and river were respectively determined to be 9.58 and11.96 mg/L. this index indicates the amount of dissolved oxygen consumed by micro-organism to decompose the organic. Higher level of BOD swiftly decreases the amount of DO due to dense bacteria that depend on the limited available oxygen. More so, this may considerably hamper the stability of the aquatic ecosystem due to the depleted DO However, the lake and river are moderately polluted due to the nearby animal farming as unpolluted water typically has a BOD below 1 mg/L. COD value usually greater than BOD values and it is typically less than 20 mg/L for unpolluted water. Levels of COD concentration for lake and river were determined to be 25.6 mg/L and 12.8 mg/L, respectively. The higher concentration of COD in the water renders it unsuitable for aquatic lives. . In this study, the COD concentration in the lake is higher than the river. This implies that the lake is more polluted than the river.

Ammonia might occur in water bodies due to the microbial decomposition of nitrogenous compounds in organic matter. Also, animal waste such as urine and dungs is another source of Ammonia when discharged directly into water bodies. This could considerably increase the concentration of ammoniacal nitrogen in the water. Ammoniacal nitrogen is one of the most serious pollutants because of its health hazard (Wang et al, 2010). Though, Ammoniacal nitrogen for lake and river were determined to be 0.2 mg/L and 0.14 mg/L, respectively, as in Table 5.

Suspended solids (SS) are natural pollutants and it is capable of increasing the turbidity of surface water (Mahvi & Razazi, 2005). The Level of SS for river might change rapidly and unpredictably due to the water depth and velocities (Richard et al, 2008). The determined average concentration of SS for the lake and river as in Table 5 are 124.75 mg/L and 105.5 mg/L, respectively. The SS concentration for both water sources are below the maximum permissible level.

pH is not a problem for these type of surface water as the pH values for lake and river are 7.43 and 7.61 which are within the acceptable MOH range (i.e. 5.5 - 9.0) for the raw water. Low pH causes toxic elements and compounds to become available for uptake by aquatic plants and animals (Karthik et al, 2014). While, higher pH values ease the solubilization of ammonia, heavy metals as well as salts in the water bodies.

Based on the determined value of WQI for the lake and river which were 67.44 and 75.49 respectively, both water are categorized in Class III. Though, both water are slightly polluted as the WQI values are within 60-80. As in Table 3, water in Class III required extensive treatment to act as water source. However, these waters are suitable to be used for agricultural purposes such are livestock drinking and irrigation.

Trend of Water Quality Parameters

Figure 3 represents the graph of ammonia concentration at various location of Ladang. Increasing trend of ammonia concentration at each location can be seen. Ammonia and its ionized form (ammonium, NH_4^+) were present in animal waste. Presence of such compound might occur from the microbial decomposition of nitrogenous compounds in organic matter.

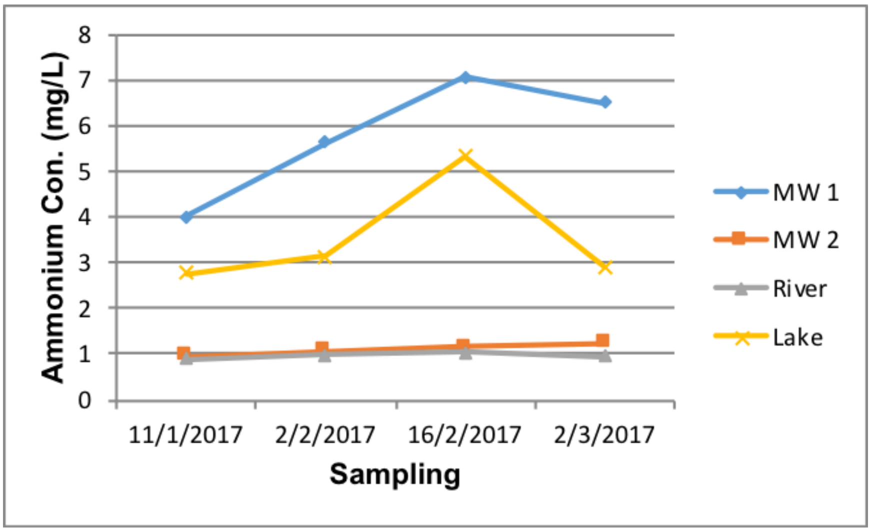


Figure 3: Ammonia Concentration along Sampling Locations

This ammonia can be converted into nitrate and nitrite by the bacteria. The presence of high amount of ammonia in raw water may cause depletion in oxygenation process due to the presence of dense nitrifying bacteria. Thus, this resulted in moldy and earthy-tasting water. Human beings are less sensitive to ammonia in water,but long term exposure of water which has more than 1 mg/L ammonia concentration may cause damaging to internal organ (Wang et.al.,2010).

Figure 4 shows the graph of fecal coliform concentration at various location of Ladang 16. Increasing trend of fecal coliform concentration at each location can be seen. It can be said that the fecal coliform count increase from upstream area to downstream area. The presence of the fecal coliform might indicate that the water bodies had been contaminated with the fecal materials which come from the livestock waste. It might have entered into the water bodies by runoff of the washed manure, especially during the rainfall. Lowest amount of the fecal coliform was observed in MW 1, although it is located very near from the cattle housing and feedlot while the highest count was detected in the lake. There is also high probability for other pathogenic bacteria to be present in the water body due to high amount of fecal coliform. Besides, exposure to high amount of fecal coliform might give possible health risk, increased in turbidity value, unpleasant odor and increased in oxygen demand.

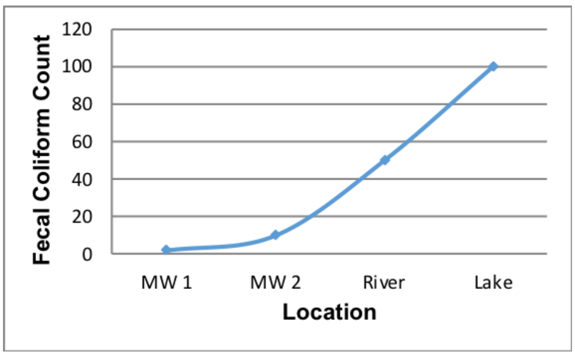


Figure 4: Fecal Coliform along Sampling Locations

Results of the analysis are compared with the standard water quality. The results shows that the quality of groundwater and surface water at the Ladang 16 are slightly polluted as some of the parameters (turbidity, NH_3, Fe, K and fecal coliform) had exceeded the standard. This could be due to the recurrent runoff, particularly during the rainy season. Also, rainfall could increase the infraction rate of the manure and this pose the risk of groundwater contamination

Furthermore, the presence of the fecal coliform in the water sample indicates that some of the animal waste had contaminated the water bodies. Though, the concentration of the heavy metal such as Cu in the groundwater and surface water is still at low level.

CONCLUSION

The quality assessment of the groundwater and surface water at Ladang 16 using physical, chemical and biological analysis were conducted. Based on the water quality parameters measured, groundwater and surface water source at Ladang 16 is not suitable to be used for drinking purpose due to the non-compliance to the standard (DOE).. Hence, the water sources surrounding livestock farm needs regular monitoring, since the accumulation of the pollutants have detrimental effects on the water quality. Based on the DOE procedure, the surface water are categorized in Class III which suitable to be used for agricultural activities (livestock drinking and irrigation). In a conclusion, both of the water supplies required extensive treatment before being used by human.

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