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Water Quality of Streams and Wells of North Perlis: A Comparative Analysis

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ABSTRACT

Water resources in catchment area came from various sources. Water from the surface infiltrate and leached down to the ground water. Land use activities on the surface will affect water quality of both surface and underground water. Underground water has been use by Malaysian as their water resources. Perlis and Kelantan are the two states in Malaysia that have a lot of wells still in use for water supply especially during dry season. This study investigates the spatial and temporal changes in water quality of surface and ground water of north Perlis from July 2001-December 2001. Results indicate that generally well water had lower physico-chemical values and nutrient content compared to stream water. A significant difference was observed for DO, pH, SRP and turbidity. The higher concentrations of calcium in wells reflecting the influence of geology on water quality. Nutrient contamination is minimal and the most probable source of water pollution is from agricultural runoff, fertilizers and domestic waste causing the water quality of north Perlis to degrade.

ABSTRAK

Sumber air di kawasan tadahan mempunyai pelbagai punca. Air permukaan menyusup masuk dan dilesap ke bawah ke dalam air bawah tanah. Aktiviti guna tanah di permukaan akan mempengaruhi kualiti air permukaan dan bawah tanah. Air bawah tanah telah digunakan oleh rakyat Malaysia sebagai punca air mereka. Perlis dan Kelantan merupakan dua buah negeri di Malaysia yang mempunyai banyak telaga yang masih digunakan untuk bekalan air terutamanya pada musim kering. Kajian ini menyiasat perubahan reruang dan masa kualiti air permukaan dan bawah tanah di utara Perlis dari Julai 2001 hingga Disember 2001. Hasil kajian umumnya menunjukkan bahawa air telaga mempunyai nilai fizikal-kimia dan kandungan nutrien yang rendah berbanding air sungai. Perbezaan yang signifikan didapati untuk DO, pH, SRP dan kekeruhan. Kepekatan kalsium yang lebih tinggi pada air telaga menggambarkan pengaruh geologi terhadap kualiti air. Kontaminasi nutrien didapati amat sedikit dan kemungkinan besar pencemaran air berpunca

daripada larian pertanian, baja dan sampah sarap domestik yang menyebabkan kualiti air di utara Perlis merosot.

INTRODUCTION

Water resources in catchment area came from various sources. Some are from flowing water and some are stored underground. The surface water is of a residence time of second to weeks while ground water could stay in the aquifer from year to thousand of years (Newson 1994). In many parts of the world, groundwater is the only source for drinking water and domestic use. In Alabama, USA, about 20% of the population uses private wells for their potable water supply and more than 50% of Alabama residents use groundwater as the drinking water source (Liu et al. 2005). Seventy-four percent of the public water-supply systems in the state rely completely or partially on groundwater (USGS 1990). In Malaysia, ground water has been one of the source of water for public consumption for many years before pipe water are supplied to the peoples of Malaysia. and now in some part of Perlis. Until now in some part of Perlis and Kelantan use ground water supply from wells are still in use for water supply and is an alternative water source especially during long dry season (Wan Ruslan Ismail 1994).

Surface water in river channel is maintained by water contribution from groundwater. Therefore flow in most streams are dominated by ground water inputs and the baseline chemistry and hydrology of streams is a function of the processes that occurred as precipitation percolated through soil horizon and moved along ground water flowpaths (Holmes 2000).

Depending on catchment characteristics precipitation takes different routes from upland to stream ecosystems, and these different flow paths influence material fluxes entering stream corridors. In forest and agricultural catchment with deep, well drained soil, precipitation percolates below rooting depth and does not again interact with vegetation until reaching the riparian zones When soils are shallow, vegetation throughout the catchment may intercept groundwater nutrients (Holmes 2000).

Ground water means different things to different people. Some investigators consider all subsurface water to be ground water, whereas others define ground water as noninteractive or as subsurface water entering a stream corridor for the first time (Holmes 2000). In this study we follow Triska's et al. (1989) and Holmes's et al. (1994) definition, where ground water is any subsurface water that does not yet exchanges with surface water which include all interflow, shallow groundwater and deep aquifer but excludes subsurface water in the stream corridor that interacts with surface water.

The growing interest on water resources scarcity and availability is a world-wide concern (Wan Ruslan Ismail 2000). There are various human activities that pollute water resources thus affecting the "availability" of water resources (surface water, subsurface and ground water). Contamination of ground water from agricultural practices has been associated with intensive use of mineral fertilizers leads to increasing level of nutrients in ground and surface waters (Ayoub 1999; Oenema et al. 1998) especially nutrients originating from non-point sources because non-point pollution is difficult to prevent compared to point sources which is relatively easy to target and control (Leeds-Harrison et al. 1999). The major non-point source of nitrate is agriculture (Schilling & Zhang 2004), primarily the widespread use of nitrogen fertilizers, application of livestock manure, legume fixation and mineralization of soil nitrogen (Hallberg 1987; Goolsby et al. 1999; Burkart & James 1999).

This paper discussed our investigation on the physico-chemical parameters and nutrient concentrations in surface water (streams) and ground water (wells) in north Perlis with the aim to investigate the spatial and temporal distribution and correlating the two water sources with human activities in the catchment area.

STUDY AREA AND METHODS

The study area is the catchment area of Timah Tasoh reservoir (Figure 1) located to the north of the reservoir. The study is a part of larger and broader studies on Timah Tasoh as has been described in many earlier reports (Wan Ruslan Ismail et al. 2002; Wan Ruslan & Ku A'edah 2002; Wan Ruslan & Zullyadini 2004).

This study investigates the nutrient concentrations in the surface water (streams) and wells in the Timah Tasoh catchment areas in North Perlis. Five stations were chosen (Figure 1) and water samples were collected in triplicates from the river and wells nearby the river.

The site description of land use in the catchment and land use in the vicinity of the wells is shown in Table 1. The land use in the vicinity of the well is the localized land use while the land use of the catcthment is a broader characterization of the land use type. The water depth ranged from 1 metre to almost 7 metres at Pelarit during low flow. Figure 2 shows the weekly precipitation patterns of Timah Tasoh watershed for 2001. Total precipitation was 5927mm with the highest rainfall recorded at Wang Kelian (1909mm), followed by Lubok Sireh (1587mm), Kaki Bukit (1319mm) and Padang Besar (1111mm) (Wan Ruslan & Ku A'edah 2002; Wan Ruslan & Malina 2003).

Table 1. Land use at the site and upstream of the site

Site	Land use at well site	Land use of the river catchment
Sg Tasoh	Human dwelling	Mixed land use
Sg. Jarum	Human dwelling	Mixed land use
Sg. Pelarit	Fruit orchard	Mixed land use
Sg. Seratak	Rubber and orchard	Rubber
Sg. Kg Aman	Rubber and wetland	Rubber

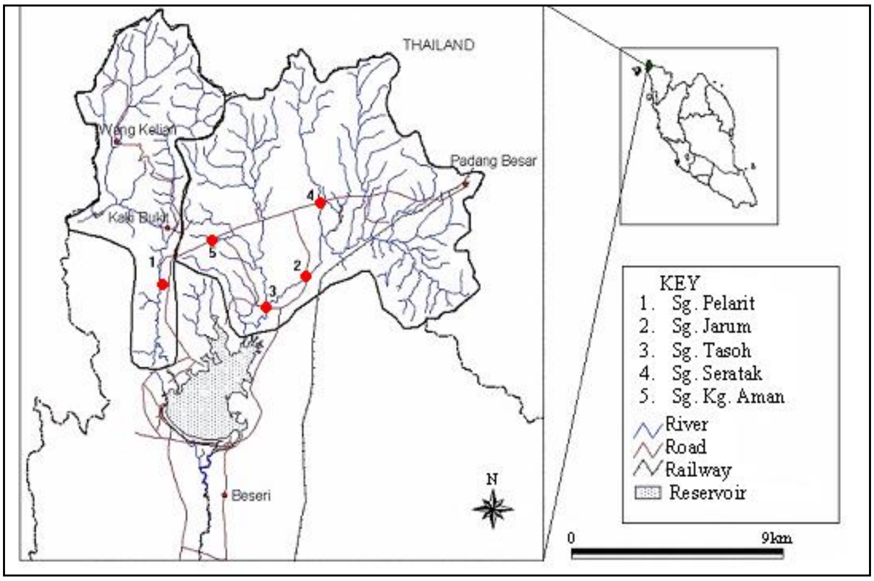

Figure 1. Study area showing the location of 5 sampling stations

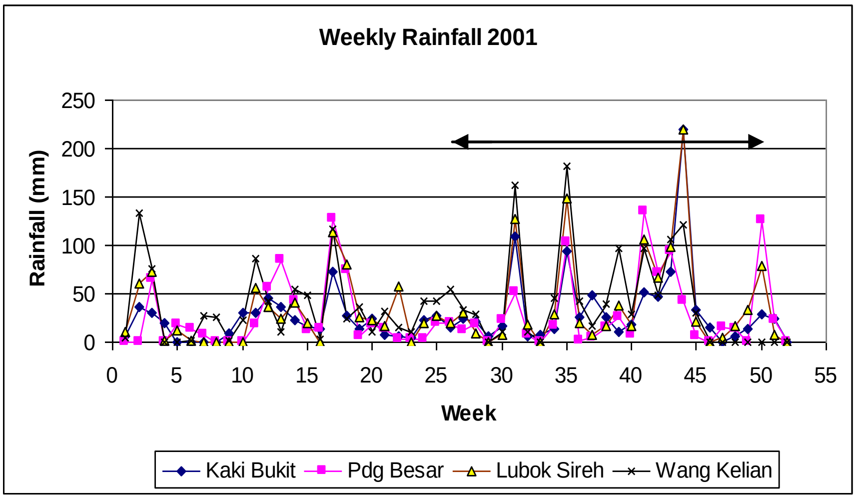

Figure 2. Weekly rainfall of the study area in 2001. Study period is from week 26 to 49 (arrow)

Water sampling program was carried out from July to December 2001 covering five stations shown in Figure 1. Water samples were tested in situ for pH, Conductivity, TDS and D.O. Samples were brought back to Universiti Sains Malaysia for further test for TSS, turbidity, nitrate and phosphate. The methodologies used for water analysis are summarised in Table 2. Mg, Na, Ca, K were also determined but only Calcium will be discussed in this paper.

Table 2. Parameters and methods used for water quality analysis

PARAMETERS	METHOD
Temperature	YSI 58 Dissolved Oxygen Meter
Dissolved Oxygen	YSI 58 Dissolved Oxygen Meter
pH	Eutech Instrument pH Meter
Conductivity	Eutech Instrument pH Meter
Turbidity	Hach DR/2000
Total Dissolved Solid	Hach conductivity/TDS Meter
Total Suspended Solid	Filtration using 0.45µm filter paper*
Alkalinity	Titration *
Nitrate	Cadmium reduction*
Soluble Reactive Phosphate (SRP)	Ascorbic acid reduction*
Cations (Ca, Mg, Na, K)	Atomic Absorption Spectrophotometer

*Standard Methods for the Examination of Water and Wastewater (17th ed.), APHA, Washington, DC. 1989

RESULTS AND DISCUSSION

The mean and ranges of the physico-chemical analysis of surface and well waters are shown in Table 3. Dissolved Oxygen, pH, turbidity and TSS, alkalinity, conductivity, nitrate and phosphate are higher in streams than well waters. Only calcium, on the other hand, is higher in wells than river water. Conductivity was lower in wells at Pelarit and Jarum compared to surface water and vise versa at Tasoh, Seratak and Kampong Aman (Figure 3). Stream pH was always higher than well pH with the greatest difference between stream and well pH was observed at Pelarit (Figure 4).

Table 3. Mean, maximum, minimum concentrations of physicochemical parameters and nutrients, and INWQS class (n=36 samples)

	Parameters	Mean	Mini-mum	Maxi-mum	INWQS Class
Streams					
	pH	7.20	6.87	7.49	1
	D.O.	5.53	4.06	7.19	2
	Temp (C)	26.9	24.6	28.9	1
	Alkalinity (mg/l)	210.65	90.85	504.09	
	TSS (mg/l)	3	1	28	1
	Conductivity (µS/cm)	304.48	202.93	358.08	1
	Turbidity (FTU)	45.22	14.07	292.2	3
	NO3 (mg/l)	0.894	0.70	1.031	1
	SRP (mg/l)	0.087	0.036	0.19	2
	Ca (ppm)	29.66	20.02	39.86	
Wells					
	pH	6.43	6.04	7.02	1
	D.O.	2.17	0.77	3.13	4
	Temp (C)	26.7	25.1	28.8	1
	Alkalinity (mg/l)	178.81	107.00	386.09	
	TSS (mg/l)	0.9	0.02	2	1
	Conductivity (µS/cm)	295.84	249.5	342.86	1
	Turbidity (FTU)	13.98	3.78	39.73	1
	NO3 (mg/l)	0.688	0.145	1.63	1
	SRP (mg/l)	0.036	0.008	0.086	2
	Ca (ppm)	33.39	24.51	52.67	

FTU= Formazin turbidity unit.

Overall, the difference between surface and ground water is not significant (α=0.05; P<0.001) except for D.O, pH, turbidity and SRP. In other studies, researcher found that a sharp contrast between light soluble ions concentrations in groundwater and river flow as the result of dilution of polluted groundwater by much cleaner water of deeper aquifers

(Banaszuk et al. 2005). However, ground water in this study is considered as a shallow aquifer or shallow wells (depth of head ranging from 0.5-3m during high flow, 2-7 m in dry period) and thus dilution due to deeper aquifers is not applicable in this study.

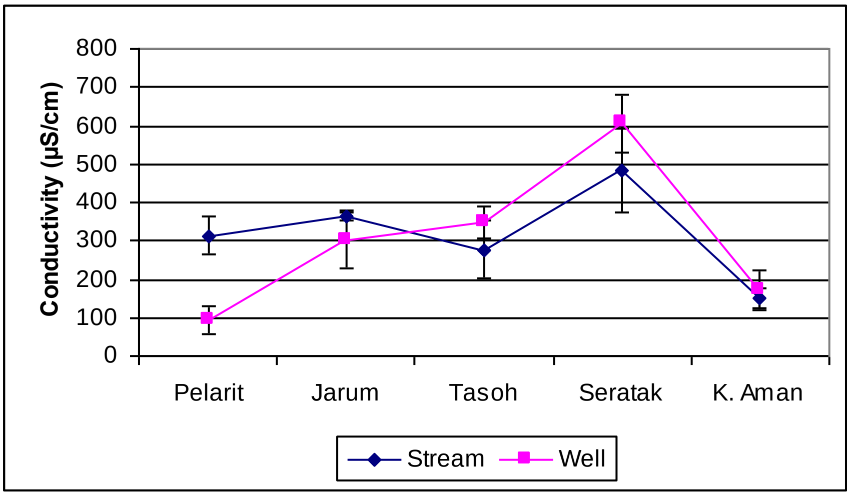

Figure 3. Conductivity of streams and wells in the study catchment during the study period

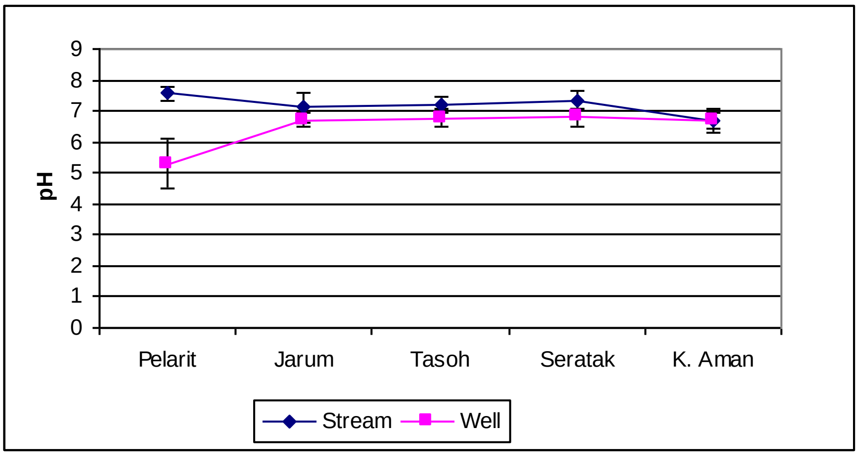

Figure 4. pH of streams and wells in the study catchment during the study period

Temporal Variation

Temporal variations of dissolved oxygen (D.O.) in Figure 5 shows that DO in stream are always higher by almost 3 fold due to the flowing stream water than in (stagnant) well water. The highest difference in concentration occurs in October (wet months). DO in well decreasing from start of sampling in July and decreasing to about 1.0 mg/l in the dry December 2001.

Dissolved oxygen concentrations measured at all sites across streams and wells were highly variable. DO for streams ranged from 1.5 to 8.00 mg/l. Low DO concentrations occurred in wells ranging from 0.3 to 4.5 mg/l (Figure 5) and based on this low DO level, water quality is classified into class 3 of the Interim Water Quality Standard for Malaysia, INWQS (Tong & Goh 1997). Overall, mean DO concentrations in streams were between 4.06 and 7.19 mg/l across all sites, and the overall, mean DO concentrations in wells were between 0.77 and 3.13 mg/l across all sites (Figure 5).

Similar to DO concentrations, pH was not consistently influenced by the effluent discharge and was generally between 6.87 and 7.49 pH units in rivers, and between 6.04 and 7.02 pH units in wells.

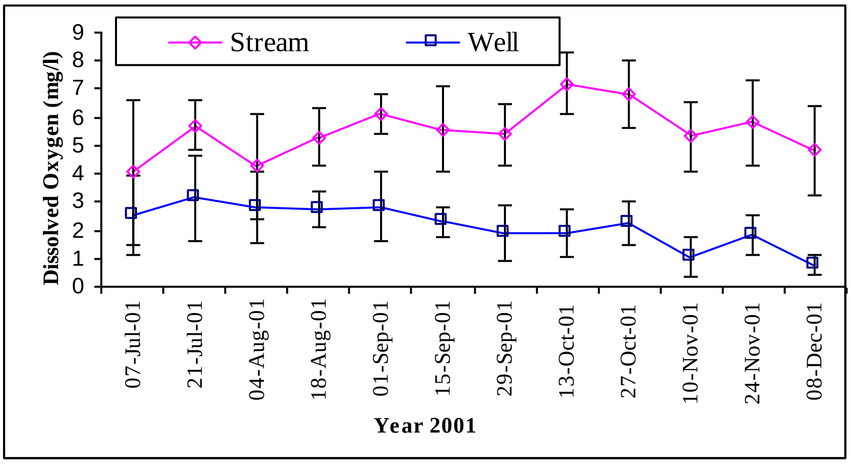

Figure 5. Temporal variation of D.O. during the study period

Alkalinity and Calcium

Alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH. Because alkalinity and pH are so closely related, changes in pH can also affect alkalinity, especially in a poorly buffered stream (http://bcn.boulder.co.us/basin/data/BACT/info/Alk.html).

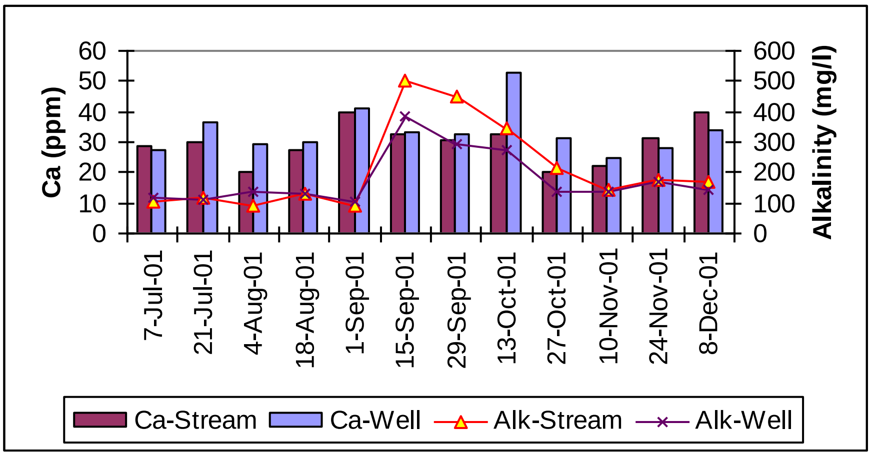

Figure 6. Temporal variation of alkalinity and Calcium during the study period

In this study, the alkalinity in rivers and wells are almost the same with only slightly higher concentration in stream water during July to early September but the reading rose up to 500 mg/L in mid September associated with concentration of probably waste water discharge during low flow (Figure 6). The effluent from household and urban areas of Padang Besar can add alkalinity to a stream in during low rainfall in September 2001. Carbonates are added to a water system if the water passes through soil and rock that contain carbonate minerals, such as calcite ($CaCO_3$). Where limestone and sedimentary rocks and carbonate-rich soils are predominant waters will often have high alkalinity. Northern Perlis is predominantly limestone (Kamal Roslan & Che Aziz 2001) and this influence the Ca content and alkalinity of the streams and wells water. Figure 7 shows the Ca distribution during the study period. Most of the Ca concentration were above 20 mg/l and are higher in wells rather than stream due to the close contact of ground water with the geology of the area adding more carbonate to the ground water. Higher rainfall amount from October to November 2001 seem to have little effect on the calcium concentration (Figure 7). Thus the increase in alkalinity in September (Figure 6) is caused by other additional factors such waste water discharge and effluent from human settlement in the catchment area mentioned earlier.

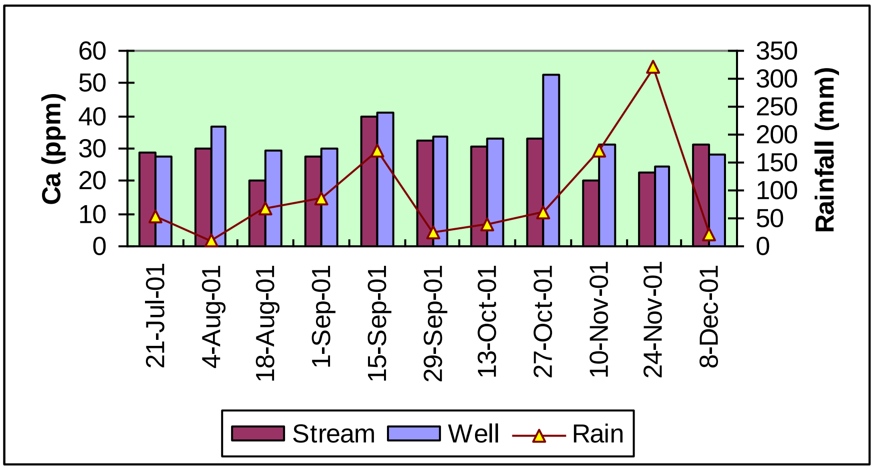

Figure 7. Temporal variation of Calcium concentration during the study period

Soluble Reactive Phosphate (SRP)

The inorganic form of phosphorus is soluble reactive phosphorus (SRP) also known as orthophosphate, PO_4-P (Neal et al. 2003). SRP is generally considered to be more readily available to plant for growth (Smith et al. 2005; Ekholm & Krogerus 2003). SRP is the only form of phosphorus that is generally regarded to be directly available and rapidly assimilated by bacteria and algae (Currie & Kalff 1984) and the most abundant form and the most widely measured (House et al. 1995; Holtan et al. 1988).

Highest and more dispersive concentrations of SRP were observed in surface water of Jarum and Kg Aman (Figure 8) while higher concentration of SRP in wells was observed at Pelarit and Kg. Aman. SRP were higher in rivers compared to wells. This could be related to runoff water and overland flow carrying surface runoff and soil erosion which is responsible phosphate is lost from agricultural land (Sharpley et al. 1994). On the other hand, other studies also showed that higher SRP were absence in groundwater at the upland perimeter suggests that fertilizer applications on cropland do not influence SRP inputs to the river (Carlyle & Hill 2001).

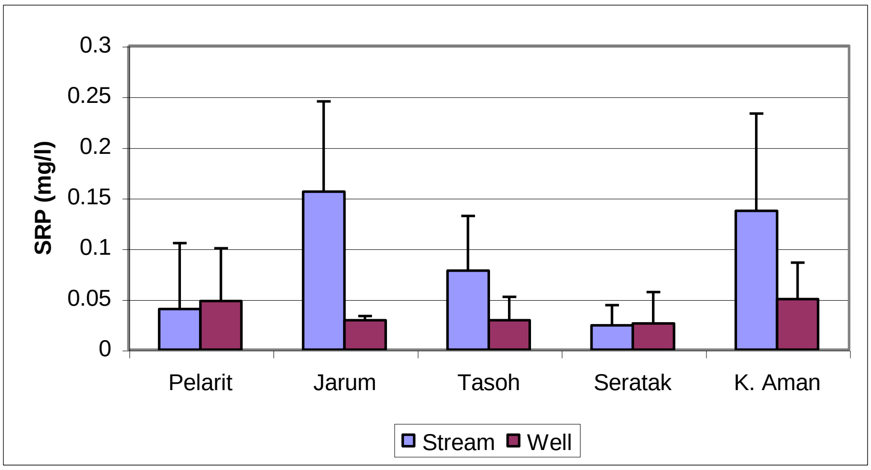

Figure 8. SRP concentration in the study catchment during the study period

The elevated SRP concentration observed in August 2001 in stream waters is suspected to be due to the flushing of nutrient in runoff water by rain from end of July to early August 2001. While higher rainfall in October 2001 cause the dilution of SRP as observed from 13 October 2001 to 10 November 2001 (Figure 9). Phosphorus concentrations generally decrease with increasing discharge, what may be linked to dilution of P species derived from groundwater and point sources by near surface runoff under stormflow conditions (Jarvie et al. 1997).

The elevated phosphate concentration in wells and streams was observed in a short brief of dry period at the end of September 2001 and in dry December 2001. In Malaysia temperature are high, and coupled with low redox potential create ideal conditions for release of P from internal sources, which should be regarded as an important factor controlling P fates in aquatic (wetland) system and it's subsequent export (Banaszuk & Wysocka-Czubaszek 2005).

Some increase in phosphorus concentration also took place in the early stage of flood (on the rising limb of the hydrograph on 13 October 2001), as river outflow was mainly fed by surface runoff. Surface runoff and soil erosion are accepted to be the main mechanisms by which phosphate is lost from agricultural land (Sharpley et al. 1994).

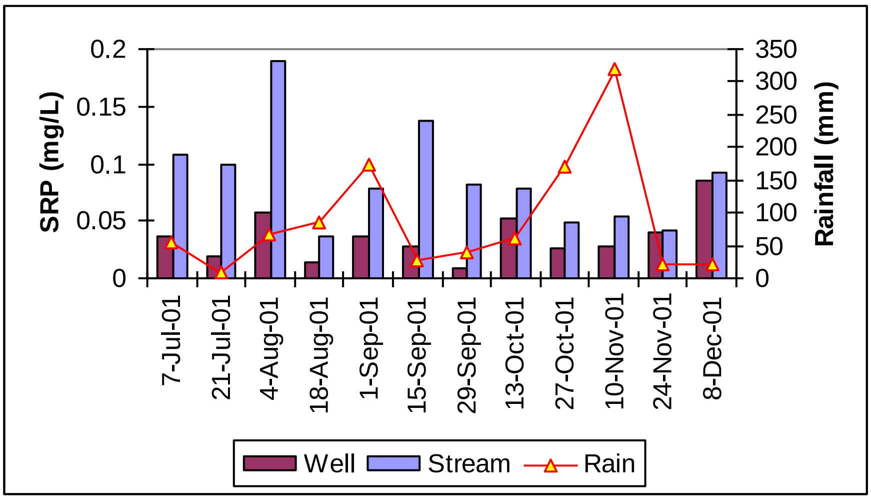

Figure 9. Temporal distribution of SRP in wells and streams showing the effect of rainfall on SRP

Nitrate (NO_3-N)

The mean nitrate content of groundwater sources and river water are below 2 mg/l. Thus all water in wells and rivers in this study sites is still safe for drinking. The highest concentration was recorded at Pelarit well (mean: 1.63 mg/l; range 0.37 – 0.97mg/l). However, these nitrate levels are far below the 10 mg/l for nitrate as set DOE Malaysia standard for ground water. This 10 mg/l level is also the Maximum Contaminant Level (MCL) by US EPA under the Safe Dinking Water Act (US EPA 1996).

From this study we found that the nitrate concentrations in surface water are always higher than wells water (Figure 10). Similarly, surface runoff is thought to be responsible for higher nitrate in surface water than well water as previously described in SRP.

During the whole sampling period, the highest nitrate concentration (18 mg/l) that exceed the DOE ground water standard and US EPA MCL was recorded in well at Pelarit on 29 September 2001 during a brief dry period. The high nitrate content could have been wash and leached down the soil column during the earlier rainfall recorded on the 1 September 2001 (see rainfall on Figure 9). The delayed flow is estimated about one month from rainfall on 1 September 2001. Thus removal of agrochemicals, e.g. nitrate in groundwater is controlled by groundwater flow patterns (Cey et al. 1999). This is because nitrate (NO_3-N) is the form of nitrogen, freely mobile in the soil solutions and potentially vulnerable to leaching below the rooting zone as water moves through the soil (Hooda et al. 2000). Nitrate is also readily moves with water in soil because of anion repulsion whereas the anion repulsion forces NO_3-N ions away from the soil particles where water velocity in the soil pore is slowest, and out into the pore where the water velocity is the fastest (Hanson & Trout 2001).

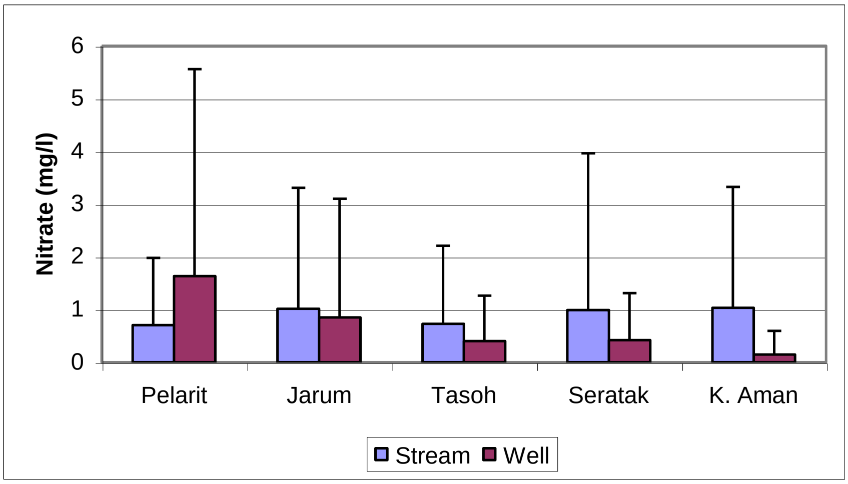

Figure 10. Nitrate in streams and wells of Timah Tasoh catchment during the study period

The agricultural soils surrounding Timah Tasoh could also contribute to the nitrate in wells and river water observed in this study. According to Stalnacke et al. (2003), large losses of nutrients from agricultural soils are often caused by intensive use of fertilizers, especially in situation when fertilizer use exceeds the nutrient requirements of the crops. As crop rarely use more than 50 % and 20 % respectively of applied N and P fertilizer (Holford & Doyle 1993), the remaining unused nutrients are vulnerable to loss from the soil system to watercourses and may ultimately result in eutrophication problems (Sharpley & Menzel 1987). Banaszuk et al. (2005) argued that nitrate attenuation occurs during groundwater movement through mineral alluvia where geochemical conditions (low redox potential) are conducive to denitrification. They (Banszuk et al. 2005) also found that the highest nitrate (given as NO3) and potassium concentrations were found in groundwater under the fertilized cropland in the spring. The high nitrate content at Pelarit could be coming from agricultural land in the catchment area in the vicinity of the studied well.

CONCLUSION

Water quality in both surface and ground water of north Perlis is still safe for drinking based on the nutrient contaminant however not really suitable based on D.O in wells. The surface water and well water are not significantly different from one another but certain elements and parameters do differ significantly such as D.O, pH, turbidity and SRP. The increase in alkalinity, nitrate and phosphate in rivers is influenced by surface runoff during rainy season responsible for transport of waste water discharge and effluent from human settlement, eroding soils and fertilizers from agricultural field. The agricultural soils surrounding Timah Tasoh reservoir is postulated to be the main source of nutrient in surface and ground water of north Perlis.

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