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Microbial Water Quality Variations in Different Water Sources in the Pussalla Oya Catchment and Pollution Contributions by Communities

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ABSTRACT. *Natural water sources in Pussalla Oya catchment are prone to faecal pollution and it was reflected by Hepatitis A outbreak in May 2007. Although the faecal pollution is a common problem in the catchment, pollution contribution and severity could vary among the communities. A study was conducted to compare the water related issues among different communities in the Pussalla Oya catchment, assessing the variations in water quality and pollution contributions. Communities selected were Rothschild estate, Pussallawa town and Black Forest colony to represent estate, peri-urban town and village, respectively. Water quality analysis (total Coliform and Escherichia coli), questionnaire survey and field observations through transect walks were conducted to find the disparity in water quality and pollution contributors. Main consumptive water sources in all three communities exceeded the Sri Lankan drinking water quality standards. Higher E. coli count is found in wells closer to Rothschild estate dwellings and Black Forest colony reflecting potential groundwater contamination. Quality of consumptive water sources has statistically significant differences between dry and wet seasons in all communities. Comparatively higher pollution levels have been found at the outflow points in Pussallawa town due to unavailability of onsite wastewater treatment facilities and mismanagement of wastewater. The onsite wastewater treatments are not possible with respect to limited land availability and shallow groundwater levels. But the groundwater quality in Pussallawa town is comparatively better.*

INTRODUCTION

Pussalla Oya catchment, located closer to the Kandy-Nuwaraeliya district boundary, belongs to the mid country wet zone, WM_1 agro ecological zone characterized by steeply dissected, hilly and rolling terrains (NRMC, 2003). The average annual rainfall is 3175 mm (NRMC, 2003) distributed over 10 months. Therefore, the catchment is naturally water rich and different consumable water sources are available within the area in the form of surface water such as Pussalla Oya and its branches and groundwater such as wells and springs. Nevertheless, Pussalla Oya catchment is the source area for the 'Hepatitis A outbreak recorded in Gampola in May 2007' (Abeysinghe, 2007), one of the water related disasters that occurred in Sri Lanka during the recent past. Hepatitis A is a water borne disease

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spread through faecal-oral pathogens and the carrier is human faeces (Richard, 2001). This condition reflects that the available water sources in Pussalla Oya catchment are unsuitable for human consumption primarily due to the faecal pollution (Abeysinghe, 2007). Faecal pollution takes place chemically, physically and biologically where the biological pollution causes the spread of water borne diseases. Microbiological indicators can be used to detect the faecal pollution of water bodies (Ashbolt *et al*., 2001). *Escherichia coli* and total Coliform were selected as indicator organisms to identify the faecal pollution (Ashbolt *et al*., 2001; Nawas *et al*., 2005; Foppen and Schijven, 2006; Nawas, 2006; Foppen *et al*., 2008).

Sarkar *et al*., (2007) investigated an outbreak of acute diarrhoeal disease in a village in southern India through personal interviews of households. It was found that local cultural practices such as indiscriminate defecation in public places, washing clothes and cleaning utensils from water taps where the communities collect its drinking water, and poor engineering design and maintenance of the water supply system were the risk factors associate with outbreaks. Howard *et al*., (2003) strongly highlighted that there is rapid recharge of springs after rainfall leading to microbiological contamination. Improving sanitary conditions and local environmental hygiene are more important in improving the quality of the springs. Kulabako *et al*., (2007) reported from Kampala peri-urban areas of widespread contamination of the groundwater with high organic thermo-tolerant coliforms and faecal streptococci originating from multiple sources such as animal rearing, solid waste dumping, pit latrine construction and greywater / stormwater disposal in unlined channels. Palamuleni (2002) reported that groundwater and surface water sources in urban poor areas of Malawi are polluted due to improper sanitation facilities, domestic solid waste disposal and hygiene practices. Pritchard *et al*., (2007) reported that the total coliform and faecal coliform values in the wet season were much higher than those in the dry season. They also reported that approximately 80% of the shallow wells tested in the dry season and 100% of the wells in the wet season did not meet the drinking water quality guidelines. Similarly, Nawas *et al*., (2005) also showed that microbial contamination during the wet season was higher compared to the dry season in all the tested wells.

Different communities live in the Pussalla Oya catchment as peri urban towns, villages, and tea estates. In relation to pollution, each community generally accuses to others as the responsible group for water pollution (NWS&DB, 2007). These communities are highly variable in terms of facilities available, culture and behavior of the people, diseases burden for people, *etc*. This variation causes changes in the pollution level. Therefore, this study was conducted to compare the water related issues among different communities in the Pussalla Oya catchment, assessing the variations in water quality and pollution contribution among different communities. An effort was also made to comprehend the reasons for any disparity found.

MATERIALS AND METHODS

According to the land use pattern, different types of communities live in the Pussalla Oya catchment. Communities were selected using stratified cluster sampling technique (Kish, 1965) to analyze and compare the differences in water related issues among communities. Pussalla Oya catchment was mainly stratified into three according to the land use pattern, as tea estates, peri urban towns and villages (Figure 1). One cluster from each stratum, Rothschild estate, Pussallawa town and Black Forest colony was selected to represent estate, peri-urban town and village, respectively. Land area and population in each of the selected communities are shown in Table 1.

Water quality variability at inflow and outflow points of each community as well as groundwater quality within the community reflects the pollution contribution by each community. To analyze this variability, water samples were taken from each community on the basis of inflow and outflow points and 3 to 4 samples to represent the groundwater situation within the area. Eight samples were taken from April to July (end of the first inter monsoon and initial part of the Southwest monsoon) at two week intervals. Each sample was tested for indicator micro organisms; *E. coli* and total Coliform at the regional laboratory, National Water Supply and Drainage Board (NWS&DB), Sarasavi Uyana, Peradeniya. Drinking water quality values were compared with the Sri Lankan drinking water quality standards (Table 2). In addition, water quality values at measured locations were compared with each other within the same community as well as among the communities using the mean separation Least Significant Different procedure (Steel and Torrie, 1980) at 95% probability level. Reasons for the difference of water quality were examined through a questionnaire survey and field observations using six transect walks conducted during the study period.

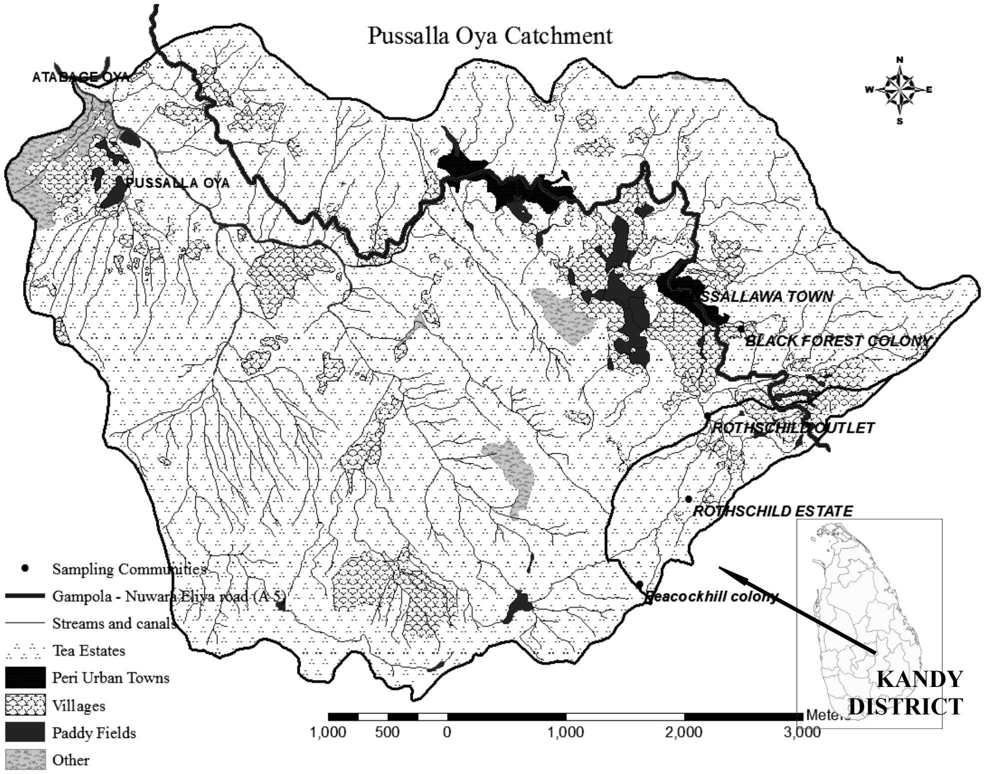


Figure 1. Pussalla Oya catchment

Questionnaire samples were selected using the stratified random sampling technique (Kish, 1965). The three different communities *i.e.* peri-urban, estate and village were taken as the stratification in the sample. Rothschild estate and Black Forest colony are found to be uniform within the community with respect to living conditions, and 35 household samples were randomly selected from each of the communities. However, Pussallawa town is a highly non uniform community. There are around 285 shops including restaurants, shops with and without residences, temporary stalls (fruits, vegetables, *etc*.), market with chicken (including slaughtering), other meat and fish stalls, slaughter houses, *etc*. Therefore, 35 samples were systematically selected to represent high pollution contributors and permanent places. The high pollution contributors were selected based on field observations. Information on water sources for different consumption activities and waste and wastewater disposal were collected through a questionnaire survey. Data collected from the questionnaire survey were analyzed using non parametric analysis (Steel and Torrie, 1980).

Table 1. Land area and population of the selected communities

Selected community	Area (km^2)	Population*	Population density (individuals/ km^2)
Rothschild – Total area	1.470	692	-
Rothschild – Residence area	0.106	692	6528
Pussallawa town	0.340	819	2409
Black Forest colony	0.130	292	2246

Source: *Grama Niladhari office, Pussallawa

Table 2. Sri Lankan standards for drinking water quality

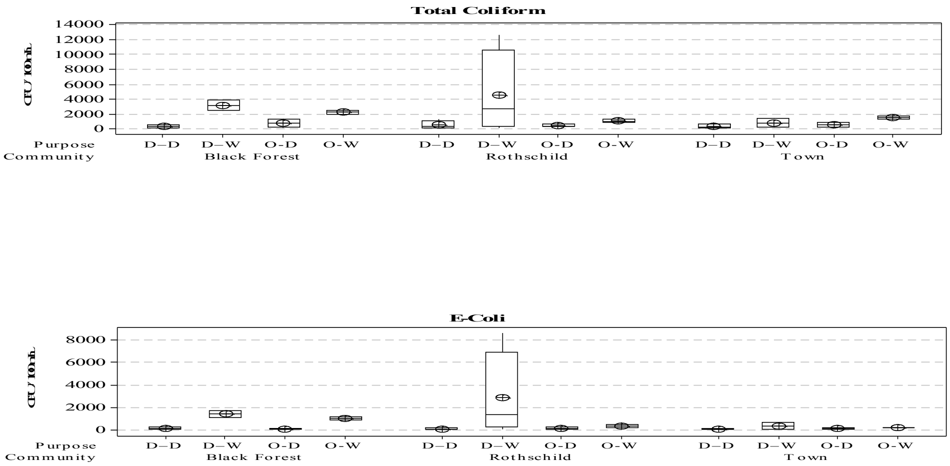
Parameter	Maximum (CFU/100 ml)*	
	Desirable level	Permissible level
Total Coliform at 35 ºC	0	10
E. coli at 44 ºC	0	0

* Colony Forming Units in 100 ml
Source: SLS 614: 1983 part 2

RESULTS AND DISCUSSION

Different types of water sources are used by the three selected communities and microbial water quality is found to vary among sources. According to the findings, all the consumable water sources (drinking and other consumptive) in three different communities exceeded the maximum permissible level for drinking water parameters in terms of total Coliform and *E. coli*. The total Coliform and *E. coli* give warning signs to express the possibility for faecal pollution. Similar warnings of groundwater contamination due to densely populated areas have been discussed by Nawas (2006). Areas with more than 16 septic tanks per one km^2 have a potential to contaminate the groundwater (Larry and Robert 1985) and all the three communities studied had cesspits or septic tanks more than this limit.

Quality of drinking and other consumptive water sources were varying among communities as shown in Figure 2. According to the results, both indicator bacteria levels were found to be non-significant between drinking and other consumptive water sources either during the dry period or wet period within the same community. However, statistically significant levels of indicator bacteria were found between dry and wet seasons for all communities. Comparatively better water quality in consumable sources based on the average values was found from the Pussallawa town. Quality of the consumable water sources was nearly similar in Rothschild estate and Black Forest colony.



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D-D Drinking water sources in dry season
D-W Drinking water sources in wet season
O-D Other consumptive water sources in dry season
O-W Other consumptive water sources in wet season

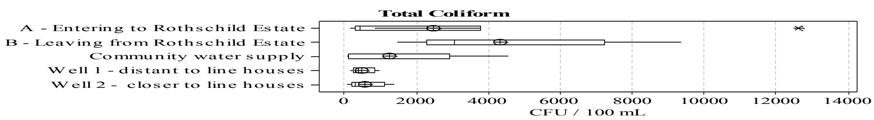
Figure 2. Water quality variations in drinking and other consumptive sources among the communities (except water from the NWS&DB).

Rothschild estate

Estate community lives in line houses which are densely populated (Table 1) within a small land area. Sixty household units located together is the largest line house in the Rothschild estate. Nearly 86% of the studied population use water from canals that originated in peacock colony for drinking and kitchen requirements. These water sources are untreated wastewater drained from the upstream communities. Rest of the line houses receives water from the community water supply (*Samurdhi*) system. The water source for the community water supply is also the same drain canals which are used by the other line houses upstream. Both water sources are found to be having poor quality water. Average total Coliform and *E. coli* levels in *Samurdhi* water source during the study period was 1218 CFU/100 ml and 383 CFU/100 ml, respectively and the same indicator levels in the water inflow to the estate is 2457 CFU/100 ml and 1463 CFU/100 ml (Figure 3). This colonized watershed area of the canal is creating water pollution problems for the downstream water users. In some instances, the water quality deterioration is visible as discoloration of water, presence of debris, *etc*., but the communities use the same source due to unavailability of a better quality water source. Because of the water quality and quantity issues in the area, residents harvest rainwater. Collected rainwater is used in toilets or for washing utensils but not for drinking and food preparation purposes.

Nearly 72% of the families have individual toilets and others share their relatives' toilets. All the toilet pits are single soakage pits/cesspits. It was found that wells located closer to line houses had comparatively poor water quality than those located away from the houses. Mean *E. coli* count was nearly double (Figure 3) in tested wells closer to line houses (185 CFU/100 ml) when compared with the wells distantly located to line houses (89 CFU/100 ml) reflecting the potential contribution for groundwater contamination from the line houses. Possible reasons for this contamination could be unsuitability of soakage latrine pits located in line houses and/or direct disposal of faecal waste (open defecation by children / kids stool). Land suitability for septic tank systems depends on the type and porosity of the soil (soils that are too coarse or too fine can limit the effectiveness of the treatment system), depth to the seasonally varied water table or bedrock and distance between water wells and septic tanks (Nawas, 2006).

Comparatively higher levels of total Coliform and *E. coli* were found at the outflow point when compared to other water sources available within the estate (Figure 3). Potential reasons for this pollution could be due to poor sanitation such as unavailability of toilets for the estate community (no toilet facilities are available in the school where most of the estate children are present during the school hours), improper construction and poor maintenance of toilets and toilet pits, improper disposal of animal waste and poor storage and application of animal manure into tea plantations. Animal manure also contains considerable amount of Coliform and E- Coli (Exner and Spalding, 1985; Goss *et al.*, 1998).



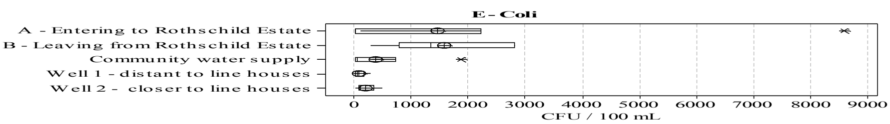


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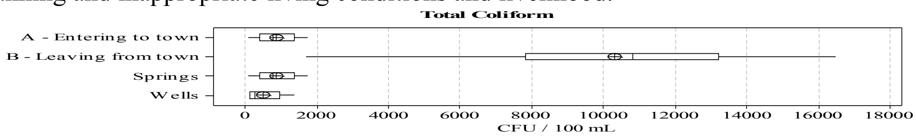
Figure 3. Average water quality variations within the Rothschild estate Pussallawa town

Majority of the city dwellers (nearly 88%) have NWS&DB water connections out of which 54% use own wells as supplementary source to fulfill other domestic requirements. The NWS&DB water is primarily used for drinking. The main reason for this practice is to minimize the water bills. Rest of the city dwellers use groundwater from springs and wells. Groundwater sources in Pussallawa town shows better quality when compared to other communities studied (Figure 2). Toilet pits are totally lined with single compartment (but cannot be considered as septic tanks) and city drainage canals are totally lined within the city limits. Unlined cesspits and drainage canals cannot be used in this area due to seepage from shallow groundwater (a few centimeters from the land surface). Leakage through these linings might be the cause of existing slight pollution levels in the groundwater within the city. On the other hand, potential for groundwater contamination through leakages of the cesspits /drainage canal is minimal due to the negative hydraulic gradient towards groundwater.

Pussallawa town is located in a mountainous area beside the Nuwara Eliya-Gampola road. Land area available in the upward sloping side is limited so that shops have been constructed up to the mountain cut. There is not enough space to construct individual simple wastewater treatment plants and there is no common or centralized wastewater treatment system. People in almost all the shops dispose their graywater directly into the drainage canal. This creates critical conditions in places such as slaughter houses. Blackwater disposal systems are totally underground and are not visible. Information about the sewerage disposal is mainly collected from questionnaire survey and connected with other visible factors to realize the accuracy. Some shop owners have leased the property and present users are unaware of the exact nature of the underground blackwater disposal mechanism. According to some of the shop owners, their toilet pits are totally concrete lined with single compartment, and the manholes are located inside the shops. As mentioned by residents, those tanks are unloaded by using gully suckers once in one to two years. However, filling of toilet pits once in one to two years is not a reasonable answer when compared to the number of people and frequency of usage. These tanks are not only filled by solids, but also by water used for washing and flushing the toilets. If the tank is fully sealed, both solids and liquid will accumulate and the tank will be filled within a short period. On the other hand, almost all the hotels provide toilet facilities to their customers. Therefore, toilet usage is very high especially during the Nuwara Eliya festival season. These two factors are totally controversial with respect to their answers on emptying the toilet pits. the only possible answer for the problem could be either removal of the liquid part or removal of the whole content in the pit.

There are two possibilities for the removal of the liquid portion i.e. direct disposal into drainage canal daily or temporary storage and disposal at once into the drainage canal. People who are living closer to the town area complain about the bad smell coming from the drainage canal in the evenings as well as during rainy periods. Overflowing of toilet pits might be a reason for bad smell during the evening and toilet opening might be the reason for bad smell during the rainy periods. This possibility of opening toilet pits during the rainy period was also observed by the research team. Some people dispose solid waste into the canal through canal openings. The drainage canal is underground, covered from top. Therefore, cleaning has become a difficult task. Sometimes canal blockages, water stagnations and anaerobic degradation will take place within the drainage canal, creating bad odour during some periods. All these reasons might be leading to significant increase in the pollutant level ($P < 0.01$ for both total Coliform and *E. coli*) at outflow water quality when compared with inflow point and groundwater quality (Figure 4). Additionally, high population density produces a massive pollutant load from a small area where there is not sufficient space and time for natural treatment to take place. The main reason for this type of environmental disaster is unorganized urbanization, including inappropriate town/city planning and inappropriate living conditions and livelihood.



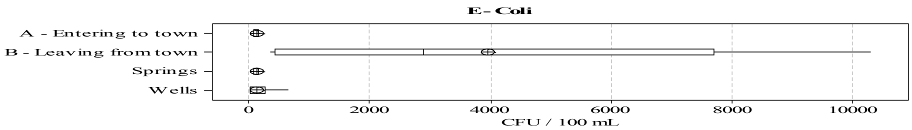


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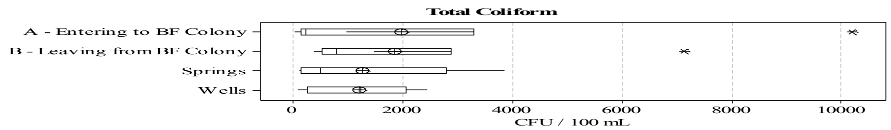
Figure 4. Average water quality variations within the town area

Black Forest colony

Black Forest colony is located in a hilly area (elevation varies within 950–1010 m) and a tributary of Pussalla Oya (drainage canal) flows through the valley. Main domestic water sources are wells contributing nearly 70% of the requirement. Almost all the wells in the area are located closer to the drainage canal (within 0.5-2.0 m distance). With respect to groundwater availability , according to the people, through their own experience, 6-12 m deep excavations are needed to receive water. Nearly 46% of the studied population use spring water for drinking and kitchen requirements, and wells for other uses. Presence of springs is not possible under these deep water table conditions, but two springs could be observed in the area that is used for common use. Those springs are located away from the stream. People believe that this spring water is good in quality as it is considered to be groundwater. According to the water quality analysis, the average value of total Coliform levels in wells and springs were found to be similar (about 1200 CFU/100 ml), but a higher average of E- Coli level in springs (547 CFU/100 ml), and was found compared to the wells (380 CFU/100 ml), 145% higher *E. coli* content in springs than the wells. This poor water quality condition is not satisfactory especially when people believe that groundwater is not contaminated. However, the data collected during this study period is not adequate to explain the hydrogeology and microorganism transport mechanism within the groundwater system. Detailed studies are needed with respect to water flow condition and transport mechanism in order to address the potential of groundwater contamination within this area.

People in the Black Forest colony have their individual toilets inside or closer to the house with a cesspit and they do not directly dispose black water into the drainage canal. On the other hand, graywater disposal is similar to all other communities which are directly disposed to water bodies or surrounding area. Additionally, solid wastes are dumped to the stream beds and are observable in this community.

The groundwater pollution in the Black Forest community is found to be comparatively higher than the other two communities (Figures 2 and 5). Additionally, the water qualities in inflow and outflow points were found to be similar within this community. However, the potential for groundwater contamination has to be studied further due to this situation. The minimum required distance between latrine pits and wells should vary with the soil type, *i.e.* nearly 15 m for septic tanks and 45 m for cesspits (Werellagama *et al*., 2003). Cesspits in Black Forest colony are located very close to wells, as close as 1 m distance in some situations.



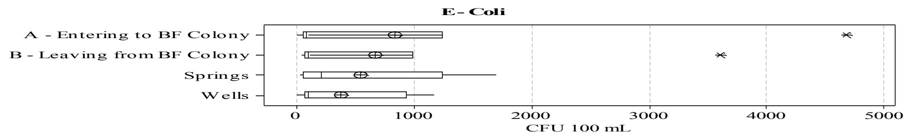


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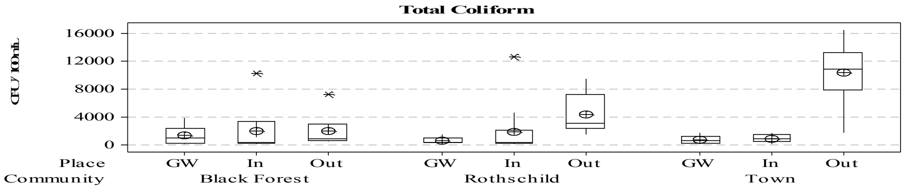
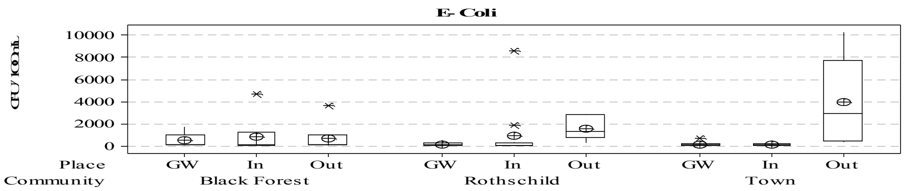
Figure 5. Average water quality variations within the Black Forest area

Disparity in pollution contribution among the communities

Difference between water quality at inflow and outflow points in a particular area indicates the pollution contribution from that area. The average water quality variation of surface (inflow and outflow) and groundwater among the three different communities are shown in Figure 6. The outflow water quality was significantly poor when compared to inflow and groundwater quality in Pussallawa town and Rothschild estate. The highest pollution level of outflow water was found from the Pussallawa town area followed by the Rothschild estate. Poorest groundwater quality was found in Black Forest colony, while a comparatively good quality value was found in the Pussallawa town. Overall water quality variation among the communities is shown in Table 3. According to Table 3, poorest water qualities in terms of average, maximum and minimum can be found from the Pussallawa town, followed by Rothschild estate. Comparatively better water quality can be found from the Black Forest colony.





⊗ Mean * Out liars
Gw Groundwater (Existing water within the area)
In In flow water to the area
Out Out flow water from the area

Figure 6. Average water quality variations within three different communities

Table 3. Overall water quality variation among the communities

Communities	Average	Maximum	Minimum	SD ±
Total Coliform				
Rothschild estate	1807	12600	36	2941
Black Forest colony	1577	10200	24	2418
Pussallawa town	3109	16460	86	4818
E. coli				
Rothschild estate	739	8580	4	1675
Black Forest colony	608	4680	0	1184
Pussallawa town	1081	10300	9	2488

Note: SD = Standard deviation

CONCLUSIONS

The consumable and drinking water quality are different among the communities and all exceeded the maximum permissible level for drinking water parameters in terms of total Coliform and *E. coli*. Both these indicator bacteria levels are found to be non significant (at 5% level) between drinking and other consumptive water sources, while statistically significant levels were found between dry and wet seasons for all communities. Comparatively, the poorest consumable water quality based on the average values is found from the Black Forest colony. Comparatively higher levels of total Coliform and *E. coli* are found at the outflow point when compared with other water sources available within individual communities in Pussallawa town and the Rothschild estate.

The average *E. coli* count is more than double in tested wells closer to line houses in Rothschild estate, compared to wells distantly located to line houses, reflecting the potential contribution of groundwater contamination from the line houses. Groundwater sources in Pussallawa town shows better water quality compared to other communities. Totally lined toilet pits and city drainage canals cause minimum groundwater pollution within the city limits. The direct disposal of waste and wastewater into the drainage canal leads to increase in the pollution level significantly in outflow water from the city limits. The main reason for this higher level is unavailability of onsite wastewater treatment facilities and mismanagement of wastewater. The onsite wastewater treatments are not possible with respect to limited land availability and shallow groundwater levels.

As for the Black Forest colony, the difference between the average water quality of inflow and outflow points remain similar showing less contamination within the community. When compared to the other two communities, Black Forest colony shows the highest possible contamination of groundwater.

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