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Applicability of Commonly Accepted Factors on preventing the Pit Latrines Correlated Ground Water Contamination in Kalpitiya Peninsula, Sri Lanka

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Abstract: The coastal dry zone areas of Sri Lanka mostly rely on ground water as the potable drinking water source because pipe born water is rarely provided. Most of the domestic units construct dug wells adjacent to houses where the ground water is exposed to fecal contamination due to pit – latrines. There available standards and commonly accepted factors regulating the construction of ground water extraction sources yet there is lack of evidence whether following them effectively prevent ground water fecal contamination. This research focus on applicability of commonly accepted factors on preventing the pit latrines correlated ground water contamination, taking twenty (20) sampling locations of Kalpitiya Peninsula of Sri Lanka as the case study area. The ground water was tested for Total coliform bacteria at 37 °C and E.Coil at 44 °C to identify the water quality level related to fecal contamination. The depth of water table, gap of infiltration layer, depth of latrine pit and distance between dug well and latrine pit were identified as the most commonly considered factors. Accordingly, case specific and area specific reasons apart from the 'commonly accepted factors' are highly influencing the pit latrines correlated ground water contamination in Kalpitiya Peninsula, Sri Lanka.

Keywords: Ground Water; Pit Latrines; Fecal Contamination; Common factors

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1. Introduction

Ground water is the extensively used water source in the developing countries of the world. Especially Asian countries depend on this precious resource where Sri Lanka is not an exception. The estimation of Sri Lankan ground water resources recorded as 7800 million m3 per year [7]. Shallow dug wells and deeper tube wells serve as the drinking water source for more than 80% of the Dry Zone coastal rural population of Sri Lanka [8]. Due to the vast utilization and less concern regarding the hydrological cycle, ground water has become one of the fast diminishing resource. Available ground water aquifers constantly threatened due to contamination caused futility. Among the reasons of contamination, fecal matter contamination is one of the most hazardous reason [8]. Pit latrines are the utmost popular method used in the rural coastal areas of the island for the disposal of human excreta. Standards regarding the distance from human excreta disposal point and the drinking water source which use ground water has been established in the country since Urban Development Authority Act No 41 of 1978. Ever since it has been included in other laws such as Local Authority laws and especially in the Public Health Inspector Manuals. Unlike in urban areas of the country, land availability in rural areas lead these standards unintentionally followed in most cases. Still, fecal matter contamination to the ground water highly considered as a matter which causes waterborne diseases in rural coastal areas. The most high risk diseases namely 'bacterial diarrhea' and 'hepatitis A' are the vastly recorded water borne diseases in Sri Lanka. These diseases are considered as resultant due to usage of contaminated drinking water and accord for 12% of the 'certain infectious and parasitic diseases' caused deaths in year 2006 according to the records of Department of Census & statistics. This rate has been doubled by the year 2012 where the number of deaths were 403 in 2006 [1] and 705 in 2012 [16]. The figures indicate it is extremely important to

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comprehend the reasons for ground water contamination due to fecal matter. This study focus on opening a discussion to fill the gap on 'does following the available regulations and standards matter in lesser exposure to fecal contamination of ground water?' The foremost objective of this paper is to identify whether the commonly accepted factors on preventing the pit latrines correlated ground water contamination are always applicable.

Ground water was vastly considered as filtered and purified by soil layers once the water entered to the ground and while it flow through the soil. This fact later identified as not correct all the time since microorganisms recognized as cultured in ground water same as they happen in surface water and soil [6]. Even though there are particular bacteria in groundwater that convey favorable processes, there are both bacteria and microorganisms which possibly cause diseases for human beings [3]. Especially the pathogens that occur due to fecal contamination are considered as conveyers of deathly diseases [16]. Basically, measuring the ground water quality related to fecal contamination carryout using several laboratory tests for microbiology. The main parameters usually testing are Total coliform, Fecal coliform, Enterococci, E. coli and Salmonella [2]. Among these the testing for Total coliform count and E.coil test are considered as most important. Table (01) describes the Sri Lanka standards 614 Part 2, 1983 which is valid up to present regarding the water quality measures related to Total Coliform and E.coli availability in Ground water.

Table 1: Bacteriological Requirements for Potable Water (SLS 614 Part 2, 1983)

Source of Water	**Total coliform count /100ml**	**E.coil/100ml**
Public water supply (Municipal supply, Water board supply)	**3**	**Should be absent**
Individual or small community supply (Wel / Tube well)	**10**	**Should be absent**

Source: Water Resources Board - Sri Lanka, 2016 [11]

The main source of ground water fecal contamination in developing countries has been identified as pit latrines being in the proximity of drinking water source in number of studies [12]. Due to many conditions and site specific reasons the pathogens cultured in pit latrines has been detected even distant water sources more than 30 meters away from the latrine pit hence most of the regulations and guidelines necessitate pit latrines to be 30 meters or more away from the water sources [12]. The pathogens can transmit to ground water aquifers in two main ways. One is direct transmission where the latrine pit directly contact with the ground water flow and the other is indirect transmission where the pathogens diffuse with the seepage of latrine pit in to the saturated zone via soil layers [10]. One of the vastly discussed reasons for both direct and indirect transmission of pathogens is the distance between the dug/tube well and the pit latrine. Extreme distance a human excreta based pathogen will transfer via a ground with favorable soil is as distant as the groundwater flows in ten days in the particular area [5]. It is accepted that if the distance between wells and pit latrine is not satisfactory, bacteria and microorganism pathogens can transfer from the latrine pit to the ground water source [4]. When the parallel distance increases which the pathogens has to transmit into the saturated zone from the pit latrine point, it is held over and the possibility of pathogen's' destruction also increases [13]. This over and over proven factor has resultant guidelines to keep pit latrines and the water sources apart. Table (2) indicates the guidelines used in Sri Lankan context compared with the international guidelines.

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Table 2: Recommended setback distances for soakage pit

Standard	Recommended Distance
PHI manual, Sri Lanka	15 m / 50 feet
Sri Lanka Standards (SLS) 745	18 m / 59 feet
USA (Federal regulations)	30 m / 98 feet
WHO (wet areas with rapidly moving GW)	30 m / 98 feet

Source : (Werellagama and Hettiarachchi, 2004) [14]

Also the vertical separation between the latrine pit and the ground water table is considered as an important factor which is considered as the 'infiltration layer.' When the infiltration layer is higher additional time is added to the pathogens' transmission procedure lowering the risk of ground water contamination [13]. It is recommended that when the drinking water source is based on ground water and a pit latrine is to be built in proximity, the well have to be dug higher than at least 15 meters from the pit latrine [4]. The ground water level of a particular area is considered as another specific reason for higher contamination exposure. If the ground water lens is in higher elevation level which creates shallow aquifers or a higher ground water table, the risk factor to contamination arise due to pit latrine is considerable [9]. According to Kimani & Ngindu (2003), commonly used guidelines in most of the countries states that the pit latrine must be built at least 20 meters above the water table [4]. To maintain these guidelines the pit latrine depth need to be decide wisely. Accordingly, this literature review reveals that the distance between the ground water extraction source and the pit latrine, infiltration layer, ground water level, elevation and latrine pit depth mainly accord for availability of fecal contamination related pathogens in the ground water. There available different guidelines in both local and international level to prevent the fecal contamination which has been established upon various researches over time. Most of the studies in international context has proven following the standards cause lesser risk of ground water contamination. Yet it is very rare to find studies which has attempted to identify the effect of these guidelines in Sri Lankan context specially the coastal dry zone where more than 90% of the population relying on ground water sources. Also the standards provision in Sri Lanka is in half in figure when compared to the international figures. Therefore it is very important to study pit latrines correlated ground water contamination in the coastal dry zone of Sri Lanka.

2. Materials and Methods

Firstly the case study area was decided for the study as Kalpitiya peninsula which include in the coastal dry zone of Sri Lanka. It was selected due to two main reasons. One is, Kalpitiya peninsula is being included in the Shallow aquifer on coastal spits and bar type. Kapitiya peninsula is described as a "compound spill" and it is shaped like a beckoning finger [8]. Second reason is unlike most areas in the country, ground water is the only water source other than rain water in this area since no surface fresh water sources available. Twenty (20) randomly picked sampling Dug Well locations representing each portion of the peninsula were selected for the testing. Water samples were collected using sterile glass bottles each tied with 3 to 5 meter lengthy threads. Two samples from each sampling location were collected for Total coliform test and E.coli test. The samples were placed in a container with ice as soon as collected and were transported to the laboratory within 8 hours. Two days were spent for the sampling procedure due to the higher distance between the sampling locations. GPS points were recorded in each point for identifying the position of the well and point elevation of the place. In-situ measurements using tape measure were recorded regarding the distance between nearest latrine pit to the sampling location, the depth of the sampling dug wells and water level of the wells. The latrine users were consulted in order to get details regarding the

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latrine pit depth and the conditions of latrine pit construction. In-situ observation regarding the condition of the dug wells, land uses and the on-site situation were recorded regarding each location.

Number present in 100ml of sample where Total coliform bacteria at 37 °C and E.Coil at 44 °C was the test method used in the laboratory in order to determine the presence of pathogens in the Sampling Dug Well locations. Comparing the results with the Bacteriological Requirements for Potable Water (SLS 614 Part 2, 1983), sampling dug well locations were put in to two categories as 'Satisfactory' and 'Unsatisfactory'. The water levels of dug wells were subtracted from point elevation from Mean Sea Level (MSL) measured using GPS. Since the peninsula is comprised with sandy soil layers all the pit latrine users mentioned the latrine pit depth as around 1.5 meters. Therefore latrine pit depth for all the 20 sampling locations were considered as 1.5 meters as an average value. By subtracting the point elevation of latrine pit depth from water level of dug wells from MSL the length of the infiltration layer was identified. All the unit measurement values were taken in meters. Since the values of bacteria count are in larger figures and other values in small figures, all the figures were converted in to base 10 logarithm values for the convenience of analysis. The Total coliform bacteria and E.coli presence is compared with the standards of distance maintenance since the available regulations indicate the distance between Ground water extraction point and the latrine pit as the most important factor to prevent ground water fecal contamination. It was not possible to carryout correlation or regression analysis due to the considered 20 sample size was not adequate. Therefore relationship between the presence of Total coliform bacteria and E.Coil count in 100ml and the Water levels of dug wells, Infiltration layer length and Pit latrine depth were attempted to identify using cluster analysis using PASW statistics18. The results of laboratory tests were analyzed applying inverse distance weighted (IDW) interpolation method in Arc.GIS10.3 in order to identify the spatial distribution of Total coliform bacteria at 37 °C and E.Coil at 44 °C in the Kalpitiya peninsula. The results of the analysis were logically compared with the in-situ observation records.

3. Study Area

Kalpitiya peninsula is located in North Western coastal belt of Sri Lanka which. It includes in the Dry zone climatic region between79° 40 and 7° 50′– 8° 30′ latitudes. Kalpitiya belongs to Puttalam district administrative boundaries of North Western province in Sri Lanka. Total population was recorded as 98,470 in the year 2011 including 49,397 male population and 49,136 female population (DC & S, 2011). The area has a multi-ethnic population consisting of Sinhalese, Tamils, Burgher and Muslims. The average annual rain fall of the study area recorded between 500 – 600 mm from the North East monsoon between December and February. Highest rainfall values area recorded usually on October, November and December. Average annual temperature of Kalpitiya area recorded as maximum of 31oC to minimum of 27oC. Humidity and evaporation is very high in this area according to the records of the Meteorological Department of Sri Lanka. As a costal split, elevation of most parts of the area do not surpass 10 meter. Kalpitiya peninsula includes in the Coastal Sand Aquifer and the groundwater "lens" mainly recharged during the North -East Monsoon period. The seasonal crop cultivations and coconut cultivations are the main land uses of the area. Lagoon and Marine fishing and prawn cultivations are highly active fisheries sectors and agriculture is the second most important income source.

4. Results and the Discussion

According to the field observations and tape measurement data 50% of the dug wells are situated full filling the minimum available requirement of distance which is 15meter/50feet between the well and latrine pit (Figure 01). Yet only 10 % of the locations meet the commonly acknowledged international standard of 30meter/98 feet distance while 5% of the locations only maintain less than 5meter distance. 30% of the wells and pit latrines owners are aware about the 15 meter/50feet requirement between the ground water extraction point and the on-site excreta disposal point while even though the required distance is maintained 70% of the constructers did not have the awareness regarding the

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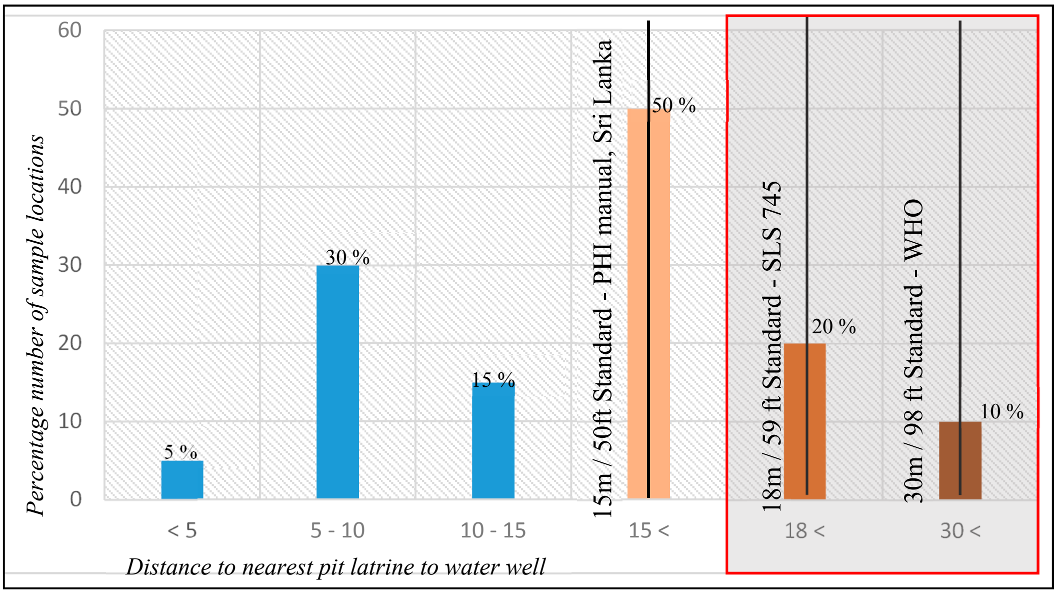
standards. They commonly have the knowledge passed through generations that do not hold any scientific grounds regarding well must be away from the latrine.

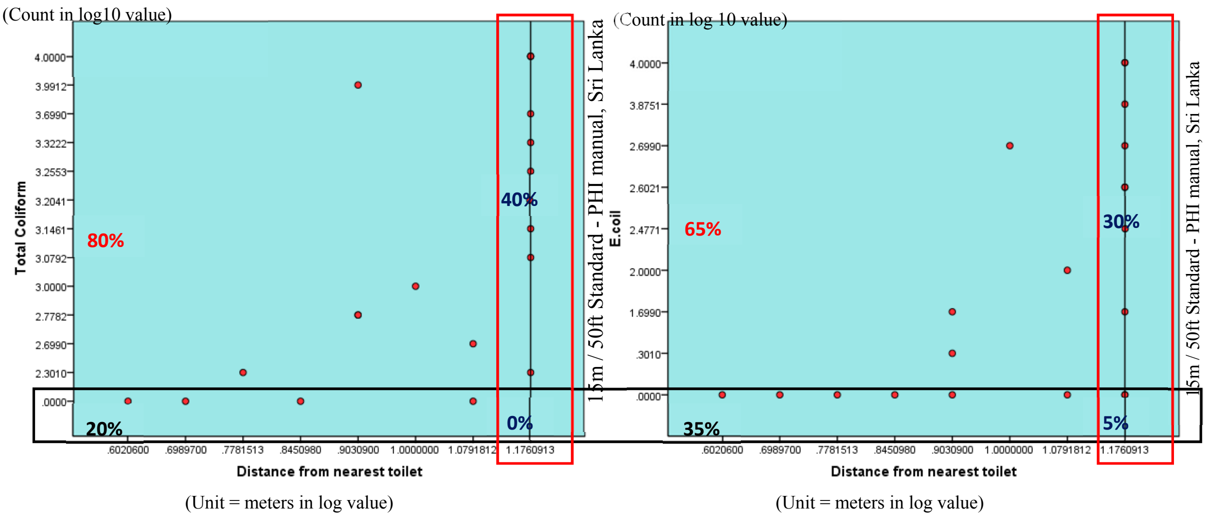
Figure 1: Distance maintenance requirements and the sample locations



Source: Compiled by author using the field survey data, 2017

The distribution of laboratory results of the presence of Total coliform and E.coli in the locations is illustrated in Figure (2) with reference to the minimum distance requirement of 15meters/50feet.

Figure 2: Total coliform & E.coli presence and the distance requirement



Source: Compiled by author using the field survey data and laboratory test results,2017

The illustrated figure (2) is compiled as taking all the Sampling locations which are similar or above the minimum distance requirement standard of 15 meters/50 feet in to one category for the convenience of interpreting the results. The pattern of Total coliform presence distribution indicate that only 20% of the sampling locations bear the required water quality standard of potable water source while 0% of the locations which reach the minimum distance requirement are recorded as having the required water quality level. 35% of the sampling locations achieved the obligatory standards for E.coli presence and 5% of those locations only included in the category of wells which reach the minimum distance requirement. When considering the presence of Total coliform, 80% of the sampling locations exceed the water quality standard level and 40% of that 80% locations are

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the wells which are within or the minimum distance requirement category. And also according to the E.coli presence standards 65% locations are unsuitable as potable water and 30% of these locations have met the minimum distance requirement.

Accordingly, only four (4) ground water extraction wells records satisfactory potable water quality level which is only 20%. And 80% of the wells are with unsatisfactory potable water quality level. Interestingly, all the four sampling locations which recorded the 'Satisfactory water quality' level do not reach the minimum distance requirement for the nearest latrine pit as indicated in Table (3). Only the sample well KWM05 is in 12meters distance from the nearest toilet. All the other wells are in below 10 meter category while KWM18A and KWM 27 both are in below 5 meter category. And also all the locations which are within the 20% of 18 meter distant requirement of PHI Manuel Sri Lanka category and 10% of 30meter distance WHO standard requirement category has recorded 'Unsatisfactory Water Quality' Level.

Table 1: The sampling locations which recorded "Satisfactory Water Quality" level

No.	Sample	Test Method: Nmber present in 100ml of sample		Remarks	*Distance to nearest toilets (unit = Meters)*			***Mean Water Level (Meters)***
		Total coil from bacteria at 37 °C	E.Coil at 44 °C		**Toilet 1**	***Toilet 2***	***Toilet 3***	
1	KWM 05	Nill	Nill	Satisfactory	12	*15<*	*15<*	2.66
2	KWM 18A	Nill	Nill	Satisfactory	4	*4*	*7*	1.15
3	KWM 24	Nill	Nill	Satisfactory	7	*8*	*15<*	2.65
4	KWM 27	Nill	Nill	Satisfactory	5	*15<*	*15<*	1.56

Source : Compiled by authors, 2017

According to the literature review 80% of the precedent studies have identified a negative strong co-relation of distance between the well and latrine pit and presence of Total coliform and E.coli. It means when the distance between the two points increase the presence of pathogens decrease and vice versa. Yet this case study do not express such relationship. The results reveals that maintaining the 'minimum distance requirement' alone is not enough for preventing fecal contamination of the ground water extraction sources. The relationship between the water level (WL) and pit latrine depth (PLD) also express an unpredictable behavior pattern. For an example, in the sample KWM15 ; Water level is below the Pit latrine depth , therefore the gap of infiltration layer (IL) is low and the presence of Total coliform and E.coli is high. At the same time, , in the sample KWM 16 ; Water level is very high above the Pit latrine depth , therefore the gap of infiltration layer is longer but the presence of Total coliform and E.coli is high as same as in the sample KWM15. This behavioral chaotic pattern is informatively illustrated in the figure (3). Accordingly, these analysis results highlight the presence of associated case specific reasons in each sample location are strongly significant for pit latrines correlated ground water contamination in Kalpitiya peninsula

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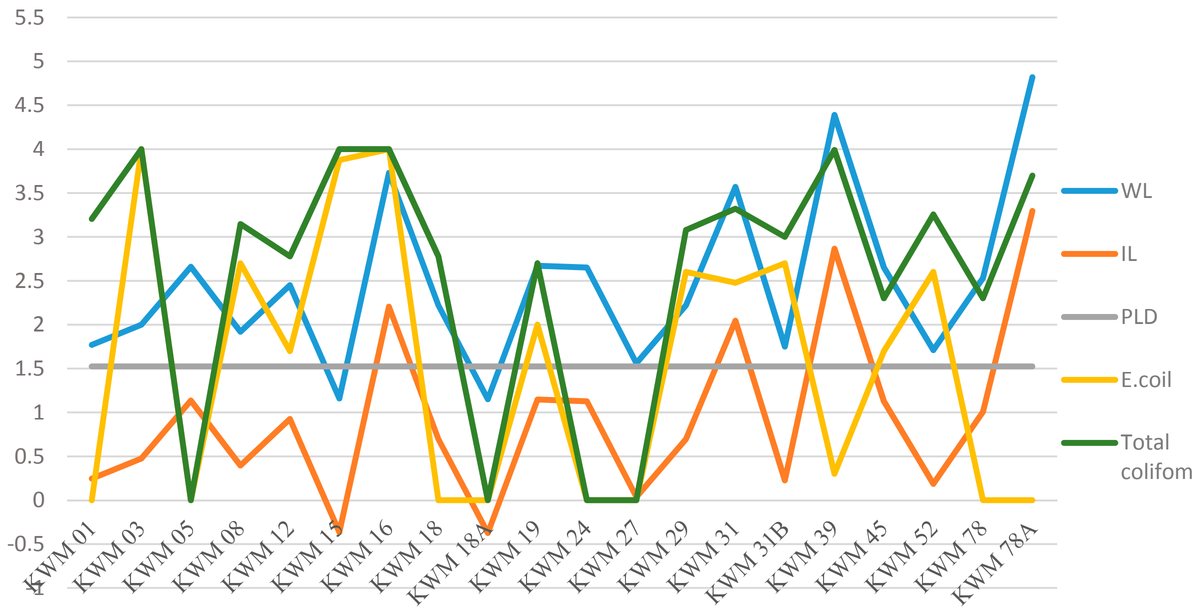
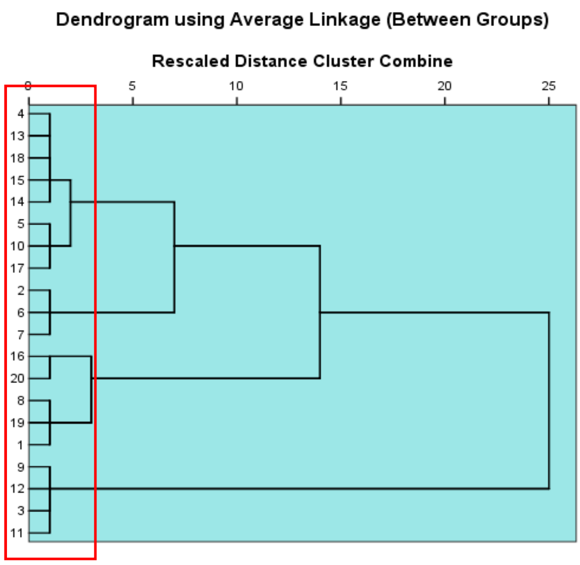
Figure 3. The behavioral chaotic pattern of Common Factors



Source : Compiled by authors, 2017

It was performed the cluster analysis using all the possible factors including the count of Total coliform and E.coli, depth of the water table, gap of infiltration layer, depth of the latrine pit and the distance between the dug well and latrine pit. The resulted Dendrogram plot is illustrated in figure (4).The cluster analysis results reveals higher distance before two clusters were created which express that the sample locations are with poor similar combinations between the factors considered to form possible homogeneous clusters. Accordingly, even though the commonly considered factors are continuously proven by scholars as immensely important for the fecal contamination of groundwater related to pit latrines, this case study reveals there are case specific combination of other factors which increase the pathogens' contact with ground water. Therefore while focusing on the common standards, the site specific reasons need to be identified to protect the ground water table.

Figure 4: The results of the Cluster Analysis



Source : Compiled by authors, 2017

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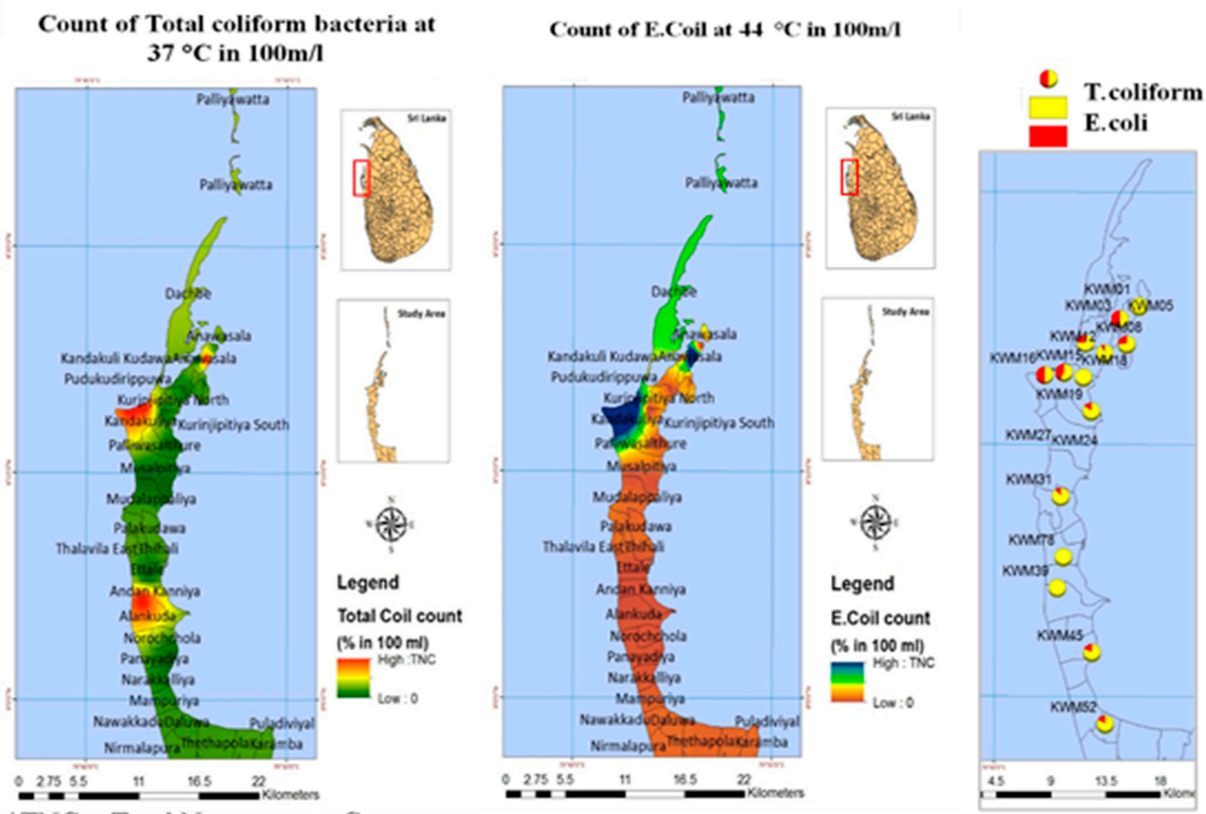
The spatial distribution pattern of Total coliform and E.coli bacteria resultant from the interpolation (IDW) of the count presence in twenty (20) sample locations is illustrated in figure (5). Areas around Kandakuliya and Annawasala Grama Niladhari (GN) Divisions indicated the highest contamination levels with both bacteria types. Especially the presence of E.coli bacteria indicate the possible threat of fecal contamination from human excreta to the ground water table of the area. It indicate the Northern portion of Kalpitiya peninsula is with higher possibility to be with contaminated ground water.

Figure 5: Results of the Inverse Distance Weighted Interpolation Analysis (IDW) – GN wise Spatial pattern of Total Coliform and E.coli bacteria



*TNC = Total Numerous to Count

Source : Compiled by authors, 2017

It is obvious that 80% of the sampling locations are exposed to fecal contamination and the interpolation results indicate the contamination threat is spreading over the Northern portion of the case study area. Pit latrines are the only fecal matter containing source yet the commonly accepted factors related to pit latrines do not extend a help to identify the pattern of fecal contamination of the area. Therefore the applicability of those factors as indicators of protecting ground water from fecal contamination is proven to be in question by the results of this study.

5. Conclusions

Ground water is the most important water source for both domestic and agricultural practices in Kalpitiya peninsula. Most of the population depend on this priceless resource as their only drinking water source in the area. As a low lying coastal belt this area is experiencing with the tragic issue of ground water contamination. Especially, fecal contamination of ground water has become a threat to the hygiene of the inhabitants. Mostly practiced human excreta disposal method in this area is the use of pit latrines. The pit latrines are evident to be the point pollution source of fecal contamination of ground water in the area. This study was carried out on the foremost objective of identifying

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whether the commonly accepted factors on preventing the pit latrines correlated ground water contamination are always applicable with reference to the case study area. According to the literature review it was identified that to evaluate the ground water of an area's level of contamination with fecal matter, the testing for Total coliform count and E.coil tests are considered as most important. Therefore, twenty (20) randomly picked sampling dug well locations representing each portion of Kalpitiya peninsula were selected and samples were collected considering all the necessary conditions for the laboratory testing. Under the literature review it was identified that, the depth of the water table, gap of infiltration layer, depth of the latrine pit and the distance between the dug well and latrine pit are the most commonly considered factors in evaluating the reasons for pit latrines related ground water contamination. Therefore the relevant data from all the sampling location for each factor were collected and analyzed using PASW statistics18. According to the cluster analysis results, there is very poor possible homogeneous pattern can be drawn between the considered factors of the sampling locations and presence of pathogens in ground water. The results of laboratory tests were analyzed applying inverse distance weighted (IDW) interpolation method in Arc.GIS10.3 in order to identify the spatial distribution of Total coliform bacteria at 37 °C and E.Coil at 44 °C in the Kalpitiya peninsula. The derived maps indicate the Northern portion of Kalpitiya Peninsula is mostly exposed to the threat of ground water fecal contamination. Therefore the results of this study highlights apart from the commonly accepted factors on preventing the pit latrines correlated ground water contamination, it must consider case specific and site specific factors related to this menacing issue. When considering the derived results, it can assume that the soil condition of the area, condition of the latrine pit, condition of the ground water extraction point (Dug well/ Tube well), adjacent land uses, pattern of the surface water flow and many other factors related to a particular area may have association in accelerating or minimizing the rate of ground water fecal contamination. Hence, it is high time to identify the case specific and area specific reasons apart from the 'commonly accepted factors' on pit latrines correlated ground water contamination not only in the case study Kalpitiya Peninsula, but also in the threaten areas mostly in the dry zone coastal belt of Sri Lanka.

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