Management Plan to Reduce the Adverse Effects of Proximity of Dug Wells and Septic Tanks in Urban Area to Diminish Coliform Contamination

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Abstract— *Urbanization and migration of population towards cities become a new challenge nowadays in planning cities, particularly safe domestic water. One of the primary objective of sustainable development goal is to ensure the availability of good quality water for human consumption. Environmental engineers and scientists have the responsibility of monitoring the quality of sources for sustainable safe-water for human consumption. A major problem in northern Sri Lankan urban areas is the prolific occurrence of fecal coliforms in drinking water, obtained from dug-wells. The proximity of household septic-tanks and other related influences are attributed as the man causal factors of this crucial alarming thread. This article spells the results of an investigation conducted in Vavuniya Urban Council limits during 2009. The aim of this research is to assess the drinking water quality in Urban Council limits from an environmental management perspective, focused on identifying the relationships between well water quality and influence of the 'proximal influence of septic tanks'. It is found that more than 50% of the household dug-wells in the Vavuniya town are located well below the standard limit of 20 m distance from septic tanks. As such, a critical problem of coliform pollution is prevalent within the Vavuniya Urban Council limits. The research correlate this problem with alternate casual factors of urban water degradation and spells a management plan for the improvement of water supply for human consumption within this region*

Index Terms— *water resource in Sri Lanka, urban water supply, dug-well water quality, coliform contamination.*

1 INTRODUCTION

UNLIKE other natural resources, water is a unique resource, which renews itself. It is due to its constant circulation in the ocean-atmosphere-earth-ocean system. No matter how much water is consumed in daily life, its amount seldom dwindles. With time and under certain conditions water regains its properties and becomes fit for reuse. This is probably the reason why water resources appear to be unlimited for a long time. Irrigation of fields, orchards and estates claim almost 80% of the water consumed the world over. Unfortunately, 97.5% of all water resources on earth are salty. Consequently, fresh water including the one in glaciers accounts for only 2.5% Even here the most accessible one is as little as 0.3% moreover the natural distribution is extremely uneven. Many countries are short of this clean water (Sivakumar S S, 2015)

For the development that ensures the sufficient and quality water distribution to the public. In this concern the quality of water not easily identified because most of the quality parameters not visualized easily even the water tasteless, odorless, and colorless (Abhay, B, 2007). As such most of the communities in the third world face health problem arising from the consumption of poor quality of water. For example biological contamination of the water cause several water borne diseases. The water quality is must to ensure to prevent disease. Most of the people in the world do not pay enough attention to the quality of water they use for drinking (David K, Brad K, 1996).

Ensuring the quality water is provided for human consumption is a major responsibility of the environmental managers. The first step in the provision of quality drinking water is the assessment of the quality of water that can be obtained from various sources to feed in to the water supply network (Deb.G, Jim. H, Mark. F, 2008)

Vavuniya is the most important transport city in the Northern Province of Sri Lanka. The Vavuniya Urban Council is 21.5 sq.km areas. 40% of the total population within the UC limits (1.9% of total land area). Major water resources in the UC limits are,

- NWS & DB pipeline supply- 614,928 L/day
- Common Open dug well- 34
- Tube well- 104
- Domestic dug wells- 4147
- Fresh water tanks- 07

(Source: District statistical hand book of Vavuniya, 2007).

During the 1999 internally displaced period the population has suddenly increases in the Vavuniya District. After this, the

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domestic construction within the UC area rapidly increased without the recommendation of Urban Development Authority or other relevant stake holders. It may suspect the ground water pollution in the view of biological contamination of drinking water sources. In this paper it aims to the domestic septic tank influence on the dug well sources in the UC limits of Vavuniya in the dry zone of Sri Lanka.

UC have nine Grama Niladari Divisions (GND). According to the population distribution among the GN division based 'population weighted sample' was chosen for the analytical purposes. Ninety dug well (90) sample and one tube well sample from each GND was initially selected before go to the ground. In the meantime the questionnaire data was collected from the same households. This was an initial study for assessing the biological drinking water quality with the restricted resource and the limited period.

2 Statement of Research Problem

With regards to pipe-borne water supply, 412 domestic water connections in year 2006 were increased to 542 in year 2009 in the UC limits (avagare 40 connection per year), clearly indicates, the necessarily to increase the water connections. As the groundwater and the surface water sources in the area was in poor state, the National Water Supply &Drainage Board checked the water quality every two months before 2006, but now due to many constraints, they do not check the Drinking water quality. Therefore, to reduce the drinking water shortages it is essential to assess the water quality of the existing dug wells inside the UC limits to promote the use of dug well water. (Table 1.1 and 1.2)

Such testing also can be a venue to facilitate to identify suitable management options for enhancement of water quality in the area of concern. Moreover, this study also will look into the root cause of the pollution for grond with in the Vavuniya UC limits

3 Objectives of the Research

Main objective of this study is assessing the biological ground water quality in the Vavuniya UC limits from an environmental management perspective.

Specific Objectives are

- Assessing the influence by the septic tank to dug wells water quality in the UC limit
- Assessing the biological drinking water quality in the UC limits,
- Identifying the existing biological water quality,
- Identifying the root cause for lowering the ground water quality
- Suggest suitable management options to the operation and maintenance of dug wells and,

4 Review of Literature

4.1 Science of Water

'Water' is not just a word in our world, it is by-and-large the very essence of life, simply without water nothing happening in the world (water is universal solvent). Our living world consists three major spheres, i.e. atmosphere, lithosphere, hydrosphere, the hydrosphere consist, solid, liquid and vapor phases of water. 4.6 billion years ago the world (third planet in solar system) is a non-living things like other planet in our solar system, because of in that period, no water in our world, after certain period water available in our world in three phases, this help to form major water sources in the world, like Oceans, rivers, lakes, streams, and hydrological cycle. All the living things in the world need certain amount of water to fulfill their life. Water is the solvent, the medium and the participant in most of the chemical reactions occurring in our environment.

Water is the common name applied to the liquid form (state) of the hydrogen and oxygen compound H_2O. Pure water is an odor less, tasteless, clear liquid. Water has some interesting unique properties compare to other solvents in the world. We can freeze it, melt it, boil it and combine it. Water molecules are attracted to each other, creating hydrogen bonds. These strong bonds determine almost every physical property of water and many of its chemical properties too.

Water covers 71% of the Earth's surface on Earth, it is found mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapor, clouds (formed of solid and liquid water particles suspended in air), and precipitation Saltwater oceans hold 97% of surface water, glaciers and polar ice caps 2.4%, and other land surface water such as rivers, lakes and ponds 0.6% (Shiklomanov, 1999). A very small amount of the Earth's water is contained within biological bodies and manufactured products. Other water is trapped in ice caps, glaciers, aquifers, or in lakes, sometimes providing fresh water for life on land

4.2 Drinking Water Pollutants and Health Hazards in UC Areas

Almost all the water pollutant has a potential to health concern it may acutely or chronically, but the water pollutant consist different characters, so, its hazards is different from each other, and affected concentration is also differs. But some pollution is needs to highly considerable to human consumption. During the globalization all the industrial activities mostly oriented within the major cities and their surroundings, so, population of the cities or Urban Councils were rapidly increasing globally. The industrialization activities definitely affect the surrounding environment including the water resources. So, impropper environmental plan generating the water pollution. The all government needs to ensure the food security and water security. In the perception of the water, needs to ensure sufficient quality and quantity to avoid disaster a risk, obviously poor quality water is abarrier the development activities of any country.

Vavuniya is the mouth of access to the northern province of the Sri Lanka, it has one Urban Council (UC), and total land area of the UC is only about 21.5km² (total land area is 12793 Ha), 40% of the total population (population density 2,476/km²) living within the UC limits, this clearly indicating sustainable water for drinking is a high demanded one in Vavuniya UC. Major water resources within the UC limits of the Vavuniya are (Sivakumar S S, 2002),

- Irrigation Schemes
- Domestic and Agro dug wells,
- Sallow tube wells,
- Town water supply,
- Community wells.

These water resources may get pollution by the activity of the human and natural (underground geology). Following human activities cause to the water pollution within the UC areas (Sivakumar S S, 2008):

- Over exploitation due to the population growth,
- Urban waste water runoff,
- Market waste,
- Hospital wastes,
- Agricultural runoff,
- Institutional waste, and
- Poultry waste

These are the major sources generating the surface water pollution within the UC limits. So, water quality assessment within the Vavuniya UC limits needs to analyze under proper sampling methods. The quality water means it has no any potential to cause diseases to human, so, ensure this public health should be asses the water quality is very important within the UC limits, which leads to the sustainable development through to the community development. The millennium development goal 7 defined as 'Ensure environmental sustainability, through to the Targets of' Halve, by 2015, the proportion of people without sustainable access to safe drinking water (Deb *et al*, 2008) To reach the millennium development goal, the safe drinking water ensures the regional or local level, because goals proposed to the global level, but the activities should carried out with in local level.

Almost all the activities depend on the quality of water, so assessment of the water quality, is needs to be done for the sustainable developments. In future the population of the Vavuniya Urban Council will increases by the usual growth and urbanization, so the sufficient quantity and good quality of drinking water is seems to be under a immense problem. So, the concern about the water potential checking, quality source identification, alternative water source identification, existing management options, proposed improved management options, sustainability of water quality and quantity are the significant measures needs to be investigate.

Several water sources are uses within the UC area such as, dug wells, Tube wells, National water supply (from dug wells & tube wells) and bottled drinking water. The major drinking water source is dug wells within UC and sub urban areas in Vavuniya. Most of the people depend on the dug well water to drinking and other domestic purposes, to improve the dug well water quality needs to be investigat about the water quality, and pollutant root cause identification and proposed suitable improved management activities (Sivakumar S S, 2002).

5 METHODOLOGY

5.1 Analysis routine

This step-by-step analysis describes routines adopted as methodology for this investigation. A summarized version of the method used is given in Table 5.1. The entire analysis was performed in the following steps.

Table 5.1 the step by step analysis routine

Steps	Introduction (in brief)	Expected output
1. Selection of water sampling points	The number of sample points at each GND	Fair representation the water samples
2. Water sample collection	Using sterilized standerd packs	Proper uncontaminated sampling analysis
3. Conduct of lab analysis	Under OXFAM – GB lab at Vavuniya	Obtain concentration of fecal coli form
4.Comparison with the SL S	analyzed parameter compared	Assess the existing nature
5.Household questionnaire survey	Questionnaire survey conducted in parallel	Identify the causes for water quality issues, management practices
6. Compare with in the GN division	The statistical, mapping of analyzed data	Represent the existing biological quality in GNDs
7. Propose management options	how the local practices are	findout the suitable managemtn options

5.2 Study area

The study area of Vavuniya urban council is in fig. 5.1.

Figure 5. 1 Spatial distribution of sampling ponts- Google earth

5.3 Sampling Technique

Totally nine Girama Niladhari divisions (GND) namelynamely Vavuniya Town, Rmbaikkulam, Vairavapuliyankulam, Pandarikkulam, Thonikkal (Moontrumurippu included), Vavuniya north (Poonthoottam), Pattanichchippuliyankulam, Velikkulam, and Thandikkulam are within the UC limits was selected for this study. Based on 2008 records, the total UC population was 75,175 (UC Profile, 2008) and the corresponding population density was 2,476/km² within the UC limits.

Table 5. 2 selection of samples in each GND

GN divisions	Total Population	Sample size
Thandikkulam	15,067	18
Vavuniya Town	12,624	15
Thonikkal	11,569	14
Vairavapuliyankulam	10,006	12
Rambaikulam	9,132	11
Vavuniya North	7,392	9
Pandarikkulam	4,206	5
Velikkulam	2,807	3
Padanichipuliyankulam	2,372	3
Total	**75,175**	**90**

5.4 Selection of Sample Size

The Stratified population weighted random sampling techniques were used to select the number of sample in each stratum. Each GN division picks a random sample based on the proportion of the total population

.

Totally 90 dug wells were selected to collect water sample based on the proportion of population in each GN divisions, the following simple formula was used to choose to the sample size,

$$Sample\ Size = \frac{Population\ of\ the\ GN\ Division}{Total\ UC\ Population} \times 90$$

5.5 Selection of Sampling Points

The UC boundary and GN boundary was roughly over-laid on the Google image. Locating the dug well sampling points was based on the stratified random sampling[1] (every GN considered as strata to maintaining higher precision. In addition, the questionnaire survey also was conducted at every water sample collection points. The sampling points are denoted in the Figure 1, during the sample collection zero rainfall observed and whole sample collection during the period of March to May 2009.

5.6 Method of Sample Collection

The sterilized pack (Nesco WHIRL-PAK®) was used to collect the water sample to test for Maximum Probable Number (MPN) of fecal coliform bacteria. It readily transfers to the lab and the analyzed within two (02hrs) hours.

Approved membrane filter method used (Dell Aqua kit) for the fecal coliform assay.

5.7 Questionnaire survey

Questionnaire survey was conducted at all sampled points for the purpose of identifying the root causes for water pollution and to check current management practices to proposed management option to the sustainability of drinking water quality.

5.8 Method of analysis

The 'One way ANOVA' method was used to identifying the relationship between fecal coliform contamination and distance from septic tank.

5.8.1 One way ANOVA method

One way ANOVA technique was performed only for the determining the correlation between mean value of fecal coliform contamination and the mean value of distance from septic tank in statistical package Minitab 14.0. The derived p value and R^2 values used to check the biological water quality of the study area.

6 RESULT AND INTERPRETATION

The result showed that the 96% of wells surveyed are presence of fecal coliform. The mean value of the fecal contamination of Urban Council limit was 353/ 100ml. this result was indicating the dug well biological drinking water quality highly affected. The mean value of the septic tank distance from the dug well was 53.7 feet. (Table 6.1)

Table 6.1 comparison of mean of fecal contamination and mean of septic tank distance from dug well

	Mean value
Fecal coliform	353MPN/100ml
septic tank distance from dug well	53.7 feet

The result shows that the 4% of samples absence of fecal contamination, and 52% of samples fecal contamination more than 100, one sample indicated 3080 (Rambaikkulam) of fecal coliform contamination as very maximum of contamination (Table 6.2) (mean free residual Chlorine 0.0256 mg/L)

Table 6.2 the variation of fecal contamination in dug wells

fecal contamination	MPN/ 100ml
Absence	3 (4%)
More than 100	52 (57%)
Maximum	3080 (1.1%)

The comparison of GND in relation to the fecal coliform contamination graphs show the highest mean value of fecal coliform at Vavuniya North (588 MPN/100ml) GND followings are Pandarikulam (560 MPN/100ml) and Thandikkulam (425 MPN/100ml). The lowest mean value of fecal coliform contamination in Vavuniya Town (160 MPN/100ml) respectively. Followings Patanichipuliyankulam (204 MPN/100ml) and Vairavapuliyankulam (384 MPN/100ml) respectively (see figure 6.1).

The relationship of mean fecal coliform contamination and septic tank mean distance from dug well was positive. The R^2 value for the response of fecal contamination, predictor septic tank distance 84%, it's strongly evident to the fecal coliform contamination of drinking water from the adjacent septic tank.

The regression plot (figure 6.2) shows the decreasing level of fecal coliform contamination with the increasing distance from septic tank to the dug well.

Table 6.3 Regression result

Regression Analysis: Fecal contamination versus Distance

The regression equation is				
Fecal contamination = 1878 - 28.1 Distance				
Predictor	Coef	SECoef	T	P
Constant	1878.4	232.7	8.07	0.000
Distance	-28.07	4.325	-6.49	0.000
S = 91.4390 R-Sq = 84.0% R-Sq(adj) = 82.0%				

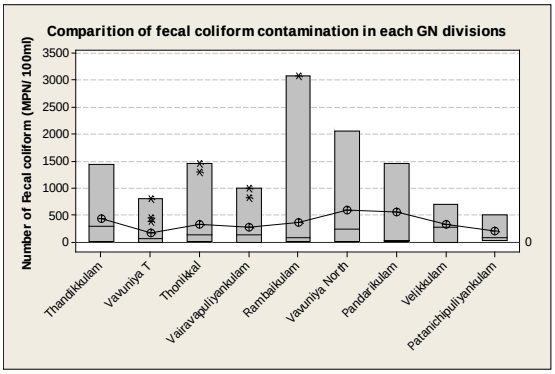


Figure 6.2 Comparision of fecal coliform contamination in each GND

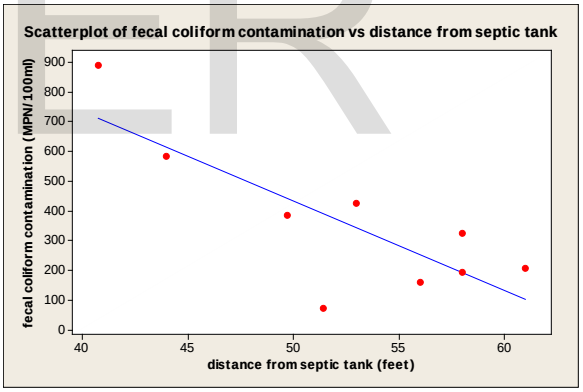
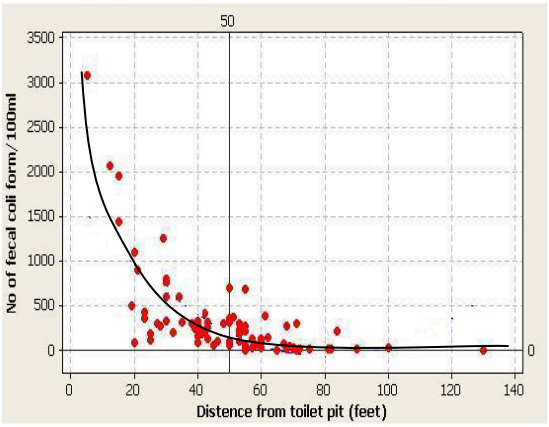


Figure 6.3 Scatter plot for fecal contamination vs septic tank distance

7 CONCLUSIONS

The resultant scatter pot (figure 7.1) shows the relationship between the Dug-well and septic tank distance in overall. 50% of the septic tank found within the distance of 50feet it strongly evident the influence on the fecal contamination in the dug-well water. The sanitation facility is water flushed type and soil is reddish brown earth and low humic clay (undulating terrain). The all septic tanks are brick lining circular type pits this able to facilitate the free movement of microorganism with ground water level change and the ground water level chang with in a year cycle almost fill during wet season and very low in peak dry season



vs septic tank distance in overall

According to the questionnaire analysis 80% of the householders using their dug well water for drinking purposes with in this 12% of the household do not practicing the chlorination to the water, rest of the (88%) householders applying preferred quantity of chlorine during the low level of water observed in the dug well (latter part of dry season). And the 82% of the households were practicing the traditional well cleaning practices i.e wash out whole water from well and thenapplying some quantity of powder chlorine in to the water. Most of the people areprefered to add low level of the chlorine due to the unplasent odor of chlorine.

The uncontrolled urban expansion without obtaining proper approvals and the perfprmance of the approving agencies are the major contributing factor to lowering the biological drinking water quality.

8 Recommendations

Removing biological polutants like fecal colifirm can be done using several treatment options but for in prevention is the sustainable option to safeguard the resource for that the lesilative implementation and the take the roles to strictly implements are the immense activity to avoid this kind of pollution from its root. The followings recommendations are xcommon to improve biological drinking water quality,

- enfoce the legislative system for a sustainable solution
- To prevent fecal coliform contamination, must have a suitable treatment facility system by considering the geographical and economic condition
- Keep recommended distance and improved designs for septic tank
- Requires to improve the monitoring system to improve the quality
- Need further vast studies and map in GIS flat form to identifying the biological water quality for urban planning
- Providing chlorination system for all households with the instructions
- Training and monitoring performance of personnel
- Prevention of storm floods into the wells
- Alternate water usage like Tube well water, bottled drinking water
- Usage of high technique filtering system to remove biological contaminants like UV filter

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Table 1.1: Water Supply from NWS&DB in year 2006 for the UC limits of Vavuniya (District Statistical Handbook, 2008)

No	Categories	No of connection	Supply per day(in Litters)	Supply per Year(in Cu. meters)
01	Domestic	412	226,065	82,514
02	NWS&DB Quarters	13	6,810	2,486
03	School	4	1,824	666
04	Government Quarters	287	183,897	50,383
05	Stand Posts	2	2,849	1,040
06	Garden Taps	1	11	4
07	Govt. Institution	54	34,517	12,599
08	Police Department	2	5,441	1,986

09	S-L Army (Bowser)	1	38,473	14,043
10	Commercial	260	96,647	35,276
11	Tourist Hotels	4	90	33
12	Institution	5	1,740	635
13	Religious	12	13,315	4,860
14	NWS & DB premises	4	3,249	1,186
	Grand Total	1061	614,928	207,711

Table 1.2: National Water Supply year of 2009 within the UC limits of Vavuniya (District Statistical Handbook, 2008)

No	Categories	No of connection
01	Domestic	542
02	NWS&DB Qts	15
03	School	4
04	Govt.Qts	295
05	Stand Posts	2
06	Garden Taps	1
07	Govt. Institution	57
08	Police Department	2
09	S-L Army (Bowser)	1
10	Commercial	260
11	Tourist Hotels	4
12	Institution	5
13	Religious	14
14	NWS & DB premises	4
15	Others	17
	Grand Total	1223