An Assessment of Ground Water Quality in Selected Dug Wells in Vavuniya Urban Council Limit through Water Quality Index

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Abstract— *An assessment conducted in Vavuniya urban council limit from dug well water sample, the particular council consists nine Girama Niladhari Divisions. This study was assessed selected physio-chemical and biological parameters such as pH, electric conductivity, total suspended solids, total hardness, fluoride, nitrate, nitrate nitrogen, iron, free chlorine and total coli form in 90 dug well water. Totally six Girama Niladhari Division zone water quality index is below 50. This means the water quality is good. Other four Girama Niladhari Division zones water quality index are 92, 64, 63 and 58 respectively. This indicates the water quality is poor. The major reason for lowering water quality is the presence of fecal coli form, which is exceeded its allowable level.*

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

1 INTRODUCTION

URBAN development and water pollution are highly linked up with the rapid population development due to uncontrolled human activities. Vavuniya urban council (UC) is one of the transform city in Northern Province can say it's the mouth of the access to the province. Prolonged internal conflict in Sri Lanka leads the vavuniya population suddenly increased recently, due to that demand for safe water is an important topic here. Most of the people in this area relay on their own and public ground water sources such as open dug well and tube wells. The government institutions and other important buildings located in the core city have connected with the pipe born water.

There are more than 4000 domestic open dug wells, 34 common open dug wells, more than 100 common tube wells and around 1600 pipe connections to serve more than 40% of district population and thousands of daily travelers. And the UC has seven minor fresh water irrigation reservoirs for irrigated agriculture as main purpose and indirectly groundwater recharging the area. Apart from this there are several bottled water companies playing a crucial role to full fill the safe water needs.

Within the UC limit, building a house should associate with a construction of dug well is inevitable need. Dug wells are shallow from 45 to 60 feet meeting unsaturated aquifers and the saturated aquifer is more than 90 feet the tube wells are meeting this depth. After the internal displacement in mid of 90s and 2009 has created the population of the district is in significant increase. Considerable amount of people has purchased lands near town and build their own houses with at least one open dug well, without considering the environmental norms to protect ground water because the construction of most of the individual houses are without obtained a prior approval from local authorities.

Nevertheless it's obvious that the ground water been polluted in some extent by uncontrolled human activity after a booming of population. So it's necessary to check the water quality to ensure the domestic usage and to predict the level of pollution before facing an unsafe situation. For this assessment the UC divided in to 10 GN zones and the number of water sample selected based on the population of the particular zone.

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

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necessity of pipe borne water connections. As the groundwater and the surface water sources in the area was in poor state, the National Water Supply &Drainage Board checking 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)

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 to developing a water quality index for Vavuniya UC limits by assessing the selected chemical and biological ground water quality in the area.

Specific Objective is to assess the selected physio-chemical and biological quality of ground water through selected dug wells in Vavuniya UC limits.

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 planet 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 is a non-living things like other planet in our solar system, because no water in the 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 desires to ensure the water security. In the perception of the water, needs to make sure sufficient quality and quantity to avoid disaster a risk, obviously poor quality water is a barrier to the development activities of any country.

Vavuniya is the entrance of access to the northern province Sri Lanka, it has one Urban Council (UC), and total land area of the UC is only about 21.5km^2 (land area is 12793 Ha), 40% of the total population (population density 2,476/km^2) living within the UC limits, this clearly indicating sustainable water for drinking is a high demanded one. Major water resources within the UC limits of 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 will be increasing by the usual growth and urbanization, so providing the adequate quantity and good quality of drinking water is seems to be an immense problem. So, the concern about the water for potential checking, quality source identification, alternative water source identification, existing and proposed improved management options, sustainability of water quality and quantity are the significant measures needs to be investigated.

Several water sources been using 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 investigating about the water quality, find out the pollutant root cause/s and propose suitable management activities (Sivakumar S S, 2002).

5 Material and Methodology

5.1 Study area

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

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

5.2 Sampling Technique

Totally nine Girama Niladhari divisions (GND) namely Vavuniya Town, Rmbaikkulam, Vairavapuliyankulam, Pandarikkulam, Thonikkal (Moontrumurippu included), Vavuniya north (Poonthoottam), Pattanichchippuliyankulam, Velikkulam, and Thandikkulam are within the UC limits were 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.

Table 5. 1 Selection of samples in each GND

Name of 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**

5.3 Selection of Sample Size

The Stratified population weighted random sampling techniques been 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 GN divisions, the following simple formula was used to choose to the sample size,

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

5.4 Selection of Sampling Points

Primarily the locations of sampling points were mapped using Google earth before entering in to the ground. The following table illustrates the GND zone and the number of sample been collected.

Table 5. 1 Number of sample collected in each GN zone

No	Name of GN Zone	Sample size
1	GN 1	17
2	GN 2	11
3	GN 3	07
4	GN 4	08
5	GN 5	10
6	GN 6	03
7	GN 7	04
8	GN 8	07
9	GN 9	10
10	GN 10	13
	Total	90

5.5 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 then analyzed within two (02hrs) hours.

Approved membrane filter method used (Dell Aqua kit) for the fecal coliform assay. Acredicted SLS methods followed during lab analysis.

For the water quality assessment the following parameters were selected based on the geographical features and the availability of testing facility.

Table 5.2 Selected parameters for testing

Parameters category	Selected parameters
Physical	pH, TDS, EC
Chemical	Fluoride, Nitrate, Nitrate-N, Total hardness, Iron and free chlorine
Biological	Total coli form (MPN)

This study was based on the ten parameters and the tested against Sri Lankan Standard (SLS) recommended to drinking water quality and the water quality index (WQI) was drived.

Table 5.3 SLS standard for water quality parameters

No	Parameters	Maximum permissible level
1	pH	6.5-8.5
2	TDS	1500
3	EC	3500
4	Fluoride	1.5ppm
5	Nitrate	45ppm
6	Nitrate- N	10ppm
7	Total hardness	600ppm
8	Iron	1ppm
9	free chlorine	0.2ppm
10	Total coli form (MPN)	10/ 100ml

5.6 Determination of Water Quality Index

Water Quality Index (WQI) was determined by using weighted arithmetic index (Khwakaram 2012) this method which different water quality components are multiplied weighted factor and are then aggregated using simple arithmetic mean. By using following equation calculated the rating scale of Qi for individual parameters;

Qi = {(Vactual-Videal)/ (Vstandered-Videal)*100}

Where,
Qi – Quality rating of ith parameter for a total n water quality parameters

Vactual – Actual value of the water quality pa rameter obtained from analysis

Videal – Ideal value that quality parameter ob tained from the standard tables

(V ideal for pH =7 and for the other parameters it is equaling to 0)

Vstandare – recommended standard of the wa ter quality parameter

The relative weight calculated by using follow ing equation;
Wi = I/Si

Where, Wi – relative (unit) weight for the nth parameter

Si – Standard permissible value for nth parame ter
I – Proportionality constant

The Wi (relative weight) to various parameters are inversely ptopotrional to the recommended standerds.

The WQI is,

WQI = ∑QiWi/∑Wi

where, Qi – Quality rating

Wi – Relative (unit) weight

The WQI divided in to 5 group based on the permissibility for human drinking use this score was set 0 to 100.

Table 5.4 water quality index level

Water Quality Index level	Description
Excellent quality	0-25
Good water	26-50
poor water	51-75
very poor water	76-100
unsafe for drinking	above 100

6 RESULT AND INTERPRETATION

The analyzed parameters average water quality values in all 10 GN zones are illustrated in the below table 6.1. The table 6.2 and table 6.3 describe the Qi value for the selected parameters and calculated of WQI value respectively.

7 DISCUSSION AND CONCLUSION

The resultant Six GND zones are shown the WQI below 50. It showes the quality of water is good with in this the GN3 show excellent water quality. On the other hand, four GND zones are shows their water quality poor. GND7 has very poor water quality. The major reason for lowering water quality is due to the exceeded level of fecal coli form in the dug wells. This is due to the septic tanks located in the visinity to the dug wells.

The limitation of study was the sampling period. Sampling been done during the period of March to May and the water table in this period was relatively high. For better understanding we needs to assess throughout the year and to asses more parameter to determine the WQI for the zones more clearly and accurately and will help to city planing.

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

Table 6.1 Water quality in all GND zones

No	Parameters	GN 1	GN 2	GN 3	GN 4	GN 5	GN 6	GN 7	GN 8	GN 9	GN 10
1	pH	7.3	7.3	6.8	6.7	7.0	7.9	7.3	7.4	7.6	6.8
2	TDS	1106	938	1921	846	1256	717	703	1003	598	837
3	EC	1587	1365	1414	1299	1641	1063	1044	1458	967	722
4	Fluoride (ppm)	0.68	0.57	0.48	0.47	1.00	0.38	0.51	0.64	0.16	0.69
5	Nitrate (ppm)	8.3	17.9	12.4	9.3	6.7	5.0	3.7	8.0	8.1	26.8
6	Nitrate- N (ppm)	1.9	4.0	2.8	2.1	1.6	1.2	0.8	1.8	2.1	6.1
7	Total hardness (ppm)	525	276	465	423	562	443	411	501	351	406
8	Iron (ppm)	0.07	0.17	0.00	0.07	0.27	0.03	0.26	0.14	0.03	0.06
9	free chlorine (ppm)	0.04	0.02	0.00	0.03	0.02	0.00	0.02	0.03	0.05	0.03
10	Total coli form (MPN)	349	120	71	369	425	324	890	550	582	192

Table 2.2 Qi value for the all parameters

GN zone	GN1	GN2	GN3	GN4	GN5	GN6	GN7	GN8	GN9	GN10	Qi
Fluoride	68	57	48	47	100	38	51	64	16	69	0.6667
Nitrate	827	1787	1241	934	672	503	365	804	808	2681	0.0222
Nitrate - N	192	405	281	211	162	117	83	184	209	607	0.1000
Iron	7	17	0	7	27	3	26	14	3	6	1.0000
Free Chlorines	4	2	0	3	2	0	2	3	5	3	5.0000
Total hardness	87	46	77	71	94	74	69	83	59	68	0.0017
TDS	74	63	128	56	84	48	47	67	40	56	0.0007
pH	50	51	105	116	78	11	55	45	22	106	0.1176
EC	45	39	40	37	47	30	30	42	28	21	0.0003

Total coli form	**2181**	**749**	**446**	**2307**	**2656**	**2025**	**5563**	**3439**	**3638**	**1203**	**0.1000**

Table 6.3 calculation of WQI

GN zone	GN1	GN2	GN3	GN4	GN5	GN6	GN7	GN8	GN9	GN10
Fluoride	68	57	48	47	100	38	51	64	16	69
Nitrate	827	1787	1241	934	672	503	365	804	808	2681
Nitrate - N	192	405	281	211	162	117	83	184	209	607
Iron	7	17	0	7	27	3	26	14	3	6
Free Chlorines	4	2	0	3	2	0	2	3	5	3
Total hardness	87	46	77	71	94	74	69	83	59	68
TDS	74	63	128	56	84	48	47	67	40	56
pH	50	51	105	116	78	11	55	45	22	106
EC	45	39	40	37	47	30	30	42	28	21
Total coli form	2181	749	446	2307	2656	2025	5563	3439	3638	1203
∑Wi	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01
∑WiQi	333	224	147	337	410	254	646	448	442	317
WQI	*47*	*32*	*21*	*48*	*58*	*36*	*92*	*64*	*63*	*45*

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