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Environmental contaminants and their impact on subsurface water by using Water Quality Index (WQI) method of different wells - A case study of Wama Hagelo District, Western Ethiopia.

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ABSTRACT

The Water Quality Index (WQI) in different wells in Wama Hagalo district, Oromia region, western part of Ethiopia, was calculated in order to ascertain the quality of water for public consumption.WQI indicates water quality in terms of index numbers and offers a useful representation of overall quality of water. In this study, WQI was determined on the basis of various physic-chemical parameters, Ph, hardness ,calcium,magnesium,sodium,chloride,nitrite,TDS,iron,manganese,and fluorides. This has been determined based on the physic-chemical water sample analyzed during past time when the well-developed measured at the water works design and supervision Enterprise laboratory of Addis Ababa. The WQI for these wells ranges from14.39 to 83.36. The high value of WQI has been found to be mainly from the higher values of iron, nitrite, total dissolved solids, hardness, fluorides and manganese in the subsurface water. The results of analyses have been used to suggest models for predicting water quality. The analysis reveals that the some subsurface water of the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination. The computed WQI for point W4indicates an excellent quality of water while the value of W5 (42.64) falls within (26-50) of the classification of water quality based on weighted arithmetic WQI method and falls in the rank of good quality. The three wells namely of: Ketare, Laga Dhoke and Kushi Dima have poor quality of subsurface water and hence needs treatment before consumption. The WQI for the well point W6, ranges between 76-100 and indicates very poor quality of water which needs especial treatment to use it for drinking purpose. We already concluded that the WQI method is a very effective tool for determining the quality of water susceptible to leachate pollution and communicating it in an unambiguous manner to the stakeholders in the water industry.

Keywords : Parameters, Physico-chemical, Subsurface water, Water Quality Index, Weighted Arithmetic method.

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I. INTRODUCTION

Water is one of the most important major natural resources of the ecosystem, necessary for human consumption, domestic services, agriculture, industry, manufacturing and other sectors. The quality of the subsurface water receivers is influenced by pollution of soil and air, industrial and domestic waste disposal, organic components, pathogenic microorganisms, application of fertilizers and pesticides in agriculture .The subsurface water quality is normally characterized by different physico-chemical characteristics. These parameters change widely due to the various types of pollution, seasonal fluctuation, subsurface water extraction, The nature of the rock formations, topography, soils, atmospheric precipitation, quality of the recharged water and subsurface geochemical process and affects subsurface water quality (Todd, 1980, Fetter, 1994). Hence a continuous monitoring on subsurface water becomes mandatory in order to minimize the subsurface water pollution and have control on the pollution-caused agents.

Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of subsurface water. WQI is defined as a rating reflecting the composite influence of different water quality parameters. The use of water quality index (WQI) in determining the quality of both surface and subsurface water bodies have increased tremendously since the initial WQI developed by (Horton, 1965) and improved version by (Brown et al., 1970).

This is owing to the ability of WQI to provide a number, simple enough for the public to understand, that states the overall water quality at a certain location and time using the measured values of selected water quality parameters. In most cases, it is used to determine the pot ability of subsurface water. WQI is calculated from the point of view of the suitability of subsurface water for human consumption. Water quality index (WQI) is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues. Also, WQI depicts the composite influence of different water quality parameters and communicates water quality information to the public and legislative decision makers.

The objective of the study was to calculate the Water Quality Index (WQI) of six different wells in case of wama hagelo district, western Ethiopia in order to assess its suitability of subsurface water for drinking purposes. To determine the suitability of subsurface water for human consumption based on computed water quality index values for subsurface water of six different wells in study area. Calculate water quality index (WQI) by using the weighted arithmetic index method (WAWQIM) and compare measured values of the physic-chemical properties of water with standard permissible values.

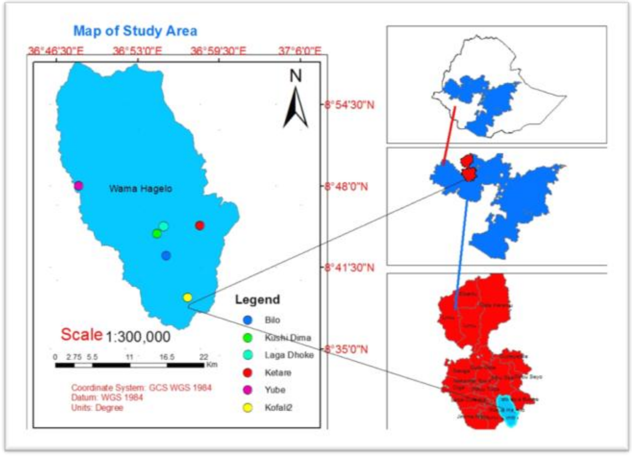
1.1 Location of the study area

The study area Wama Hagelo, district is bounded between 36^0 46′30″ to 37^0 6′ 0″ longitude and 08^{0}35′ 0″ to8^0 54′ 30″latitude, and is located in Oromia region, western part, Ethiopia. The study has six different wells, namely Ketare, Laga Dhoke, Kushi Dima, Kofali2, Bilo, and Yube. The whole roads up to the sites are accessible only during dry season, but from Nekemte up to Ana town are always asphalt roads and accessible in all seasons. For studying those wells the road is not fully accessible, especially from the large road up to the well sites because, topography is rolling and undulating.

Table 1: The location sites of the six wells

No	Well	X value **or** Longitude	Y value **or** Latitude	Elevation (m)
1	Ketare	0273915 or 36^{0}57′48″	0967528or 8^0 44′ 54″	1671
2	Laga Dhoke	0270936 or 36^{0}55′2″	0967392 or 8^0 44′ 57″	1577
3	Kushi Dima	0269952 or 36^{0}54′22″	0966377 or 8^0 44′ 22″	1586
4	Kofali2	0274417 or 36^0 56′ 56″	0956925 or 8^0 39′ 31″	1555
5	Bilo	0271303 or 36^0 55′ 6″	0963087 or 8^0 42′ 47″	1582
6	Yube	0258535 or 36^0 48′ 22″	0973465 or 8^0 48′ 8″	1361

“**Figure: 1** Map of the study area.



II. LITERATURE REVIEW

“Water is life”, “Health is Wealth“ and “Waste to Wealth” are popular sayings relating to life and wealth. Water is the most important natural resources of the ecosystem, having an important role for both drinking as well economic sectors. Subsurface water is one of the most important major natural resources necessary for human consumption, domestic services, agriculture, industry, manufacturing and other sectors (Alemayehu, T. 2006) The subsurface water quality is normally characterized by different physic-chemical characteristics. These parameters change widely due to the various types of pollution, seasonal fluctuation, subsurface water extraction, etc. Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of subsurface water. Subsurface water quality as one of the most important aspects in water resource studies is largely controlled by discharge and recharges pattern, nature of host and associated rocks, and contaminated activities (Ackah et al., 2011).

The nature of the rock formations, topography, soils, atmospheric precipitation, quality of the recharged water and subsurface geochemical process are some of the parameters affecting groundwater quality (Todd, 1980; Fetter, 1994). Rising of groundwater levels with an increasing trend of salinity may be because of the dissolution of rocks or mineral salts. Subsurface water quality has been deteriorating day by day because of shrinking water table, improper sanitation, introduction of chemical compounds, inefficient or less efficient irrigation practices, bad industrial waste management practices, and mixing of leachate being produced by indiscriminate disposal of industrial waste on land.

2.1 Physico-Chemical Parameters of Subsurface water

Drinking water is defined as having acceptable quality in terms of its Physical, chemical and biological parameters (W.H.O. 2012). Its quality can be determined by health organization who defines drinking water to be safe if and only if significant health risks during its life span of the scheme and when it's consumed. Chemical and physical parameters of subsurface water play an important role in assessing water quality (Kumaresan and Riyazuddin, 2005).Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are harmful for human health if they occurred more than defined limits (W.H.O. 2012 and U.S 2009).

The water quality can be assessed using physical, chemical and biological parameters; the harmful limits of those for human health being establish at international or national scale (WHO, EPA, MECC).The analysis of various physico – chemical parameters namely pH, temperature, total hardness, alkalinity, calcium, magnesium, chloride, sulphate, nitrate, DO, BOD, COD, TDS etc., were carried out – as per the methods described in APHA (1992).

2.2 Water Quality Index (WQI)

WQI is well known method as well as one of the most effective tools to express water quality that offers a simple, stable, reproducible unit of measure and communicate information of water quality to the policy makers and concerned citizens. It is thus, becomes an important parameter for the assessment and management of ground water (Chauhan A, et al., 2010) and (Sahu BK, et al., 1991).

The use of water quality index (WQI) in determining the quality of subsurface water bodies have increased tremendously since the initial WQI developed by (Horton, 1965) and improved version by (Brown et al., 1970). This is owing to the ability of WQI to provide a number, simple enough for the public to understand, that states the overall water quality at a certain location and time using the measured values of selected water quality parameters. In most cases, it is used to determine the potability of subsurface water.

The Water Quality Index represents a numerical expression that is used in the flowing water quality assessment in the United States of America, Canada, Spain, France, Germany, Austria, Italy, Poland and Turkey and has been widely applied and accepted in European, African and Asian countries. Starting with, (Horton, 1965) proposes the first computation formula with the intention of promoting an index that would comprise all data necessary for the establishment of the subsurface water quality. The index was firstly used with the purpose of revealing the physico-chemical changes occurred at the level of the flowing water quality following the monitoring and quality management activities, there was attempted through mathematical methods to indicate the global quality state of the surface waters with the help of a qualitative index.

The basic methodology used in the establishment of the value classes of the Water Quality Index was described for the first time by the (Environmental Protection Agency, region 10, USA, 1978/1979, 1979/80); it used various value intervals in order to set out the importance of each parameter in the computation of the index and, subsequently, it stipulated the establishment of a unique value that of the index. The subsequent development of the use of the Water Quality Index led to its use in the characterization of the entire aquatic ecosystem.

The water quality class is defined depending on the values of the physical, chemical and biological parameters and the establishment of the quality before the usage is crucial for various purposes, such as: drinking water, water used in agriculture, water used for leisure (fishing, swimming), or water used in industry. A general WQI approach is based on the most common factors, which are described in the following two steps:

2.4. Weighted Arithmetic Water Quality Index Method (WAWQIM)

The calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by (Horton, 1965) and developed by (Brown et al., 1972).The WQI, which is calculated using the weighted arithmetic index method (WAWQIM) is commonly used among researchers in developing countries where data collection infrastructure is not extensive for the database of the water quality parameters to be vast, and reliable rating curves are rare (Akhter, T., 2016). It is especially useful for determining the water quality at a place where data have been collected over a period of time for the specific purpose of determining the water quality.

Weight Arithmetic Water Index Method classified the water quality according to the degree of purity, using the most commonly measured water quality variables, such as temperature, pH, turbidity, faecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrates and total solids. The method has been widely used by various researches. The water quality data are recorded and transferred to a weighting curve chart, where a numerical value of WQI is obtained by using the following equation:

$$\mathbf{WQI}=\frac{\sum_{i=1}^{n} qiwi}{\sum_{i=1}^{n} wi}$$

Where: qi=quality rating (sub index) of i^{th} water quality parameter.
WI= unit weight of i^{th} water quality parameter.

III. MATERIALS AND METHODS

The water samples were collected from six different well locations of (W1, W2, W3, W4, W5 and W6, in the vicinity of the study area. Water samples were collected randomly from six wells at different locations during well completion and were sent to the water works design and supervision Enterprise laboratory for physico-chemical analysis. Physico-chemical parameters data were collected from six different wells (W1, W2, W3, W4, W5, and w6 in the vicinity of Wama Hagelo district of western part of Ethiopia.

3.1 Water quality measurements

The physico-chemical characteristics of water samples have been determined according to standard methods (ALPHA, 1992). Samples were tested for fifteen Parameters such as:- TDS, pH, Total hardness (TH), Calcium, Magnesium, Chloride, Ammonia, Sodium, Fluoride, TS, Potassium, Electrical Conductivity(EC), Iron, Manganese, and Nitrite.

- pH and electrical conductivity(EC) were assessed by potentio-metric method.
- The concentration of Total hardness, calcium and magnesium were measured by EDTA titrimetric method.
- Concentration of Ammonia was measured by Nessller method.
- Chloride contents were measured by Mohr Argent metric titration.
- Determination of fluoride and nitrite was done by using UV Spectrophotometer and the Soluble Potassium and Sodium were determined by using flame photometer apparatus.
- The Heavy metals Fe and Mn were determined by using 1, 10-Phenothroline and Period ate Oxidation methods respectively.

3.2 Calculation of WQI.

Water quality index (WQI) is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues. WQI is defined as the rating that reflects the composite influence of the different parameters. The WQI, which is calculated using the weighted arithmetic index method (WAWQIM), is commonly used among researchers in developing countries where data collection infrastructure is not extensive for the database of the water quality parameters to be vast, and reliable rating curves are rare.

- ***Weighted Arithmetic Water Quality Index Method :***

Weighted arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables. The method has been widely used by the various scientists, for calculating WQI, the sub index (SI) is first determined for each parameter, which is used to determine WQI as per the following equation:

$$WQI=\frac{\sum_{i=1}^{n} qiwi}{\sum_{i=1}^{n} wi}$$

Where: qi=quality rating (sub index) of i^{th} water quality parameter.

wi= unit weight of i^{th} water quality parameter qi, which relates the value of the parameter in polluted water to the standard permissible value is obtained as follows:

According to (Brown, R. K. et.al, 1970), the value of qi is calculated using the following equation:

$$qi=100\left[\frac{(Vi-Vio)}{(Si-Vio)}\right]$$

Where, Vi= estimated (observed) value of the i^{th} parameter

Vio= ideal value of the i^{th} parameter in pure water

Si= standard permissible value of the i^{th} parameter

All the ideal values (Vio) are taken as zero for drinking water except pH and dissolved oxygen (Sahu, B.K. et. al 1991). For pH, the ideal value is 7.0 (for natural/pure water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated from the following equation:

$$qpH=100\left[\frac{(VPH-7)}{(8.5-7.0)}\right]$$

Where, = observed value of pH,

For dissolved oxygen, the ideal value is 14.6 mg/L and the standard permissible value for drinking water is 5 mg/L. Therefore, its quality rating is calculated from the following equation:

$$qDO=100\left[\frac{(VDO-14.6)}{(5-14.6)}\right]$$

WhereVDO = observed value of dissolved oxygen

The unit weight or Relative weight (wi) was calculated by a value which is inversely proportional to the recommended standard (si) of the corresponding parameter.

$$Wi=\frac{k}{Si} \quad \text{or} \quad Wi=\frac{\frac{1}{\sum \frac{1}{si}}}{si}$$

Where, K = proportionality constant and can also be calculated by using the following equation:

$$K=\frac{1}{\sum \frac{1}{si}}$$

The rating of the water quality using the above method is shown below table.

Table 2: Rating of Water Quality for various WQI values (Brown, R. K. et.al, 1970)

WQI	Rating of water quality	Grading
0-25	Excellent	A
26-50	Good	B
51-75	Poor	C
76-100	Very poor	D
Above 100	Unsuitable for drinking	E

IV. RESULTS AND DISCUSSION

4.1 Results

The Measured Values of the Water Quality Parameters and (W.H.O.2008) Guidelines .The computation formula applied for the determination of the Water Quality Index on the different wells in Wama Hagelo district includes fifteen physico-chemical parameters that are registered by the water works design and supervision Enterprise laboratory Water Quality Assessment of Addis Ababa. The measured values of the water-quality parameters and standard permissible values of W.H.O guidelines, which are universally accepted as the permissible values for the water-quality parameters, have been categorized and presented in Table 3. In order to include the impact of microbes on the WQI, a non-zero value was specified for faecal coli form bacteria count. There is no specified value for dissolved oxygen (DO) in the W.H.O guidelines and is thus excluded from the selected parameter used for the calculation of WQI.

Table- 3: Measured values of the water quality parameter and WHO Guidelines

Physico-chemical parameter water analyzed results									
	Measured values						Ethiopian standard (mg/l)	WHO maximum allowable concentration (mg/l)
Parameter	Well.1	Well.2	Well.3	Well.4	Well 5	Well 6		
	Ketare	Laga Dhoke	Kushi Dima	Kofali2	Bilo	Yube		
T.D.S (mg/l)	260	350	236	342	184	478	1000	1000-is used for palatability
E.C us/cm	473	507	360	496	296	790	-	-
PH	6.65	6.96	6.52	6.54	6.22	6.8	6.5-8.5	6.5-8.5
Sodium (mg/l Na)	44.5	41.5	13	39.5	11	87.5	200	200
Potassium (mg/l K)	3.6	4	4.2	4	3.9	17.8	15	12
Total hardiness(mg/l $CaCo_3$)	171.36	179.52	210.12	214.2	161.16	275.4	300	500
Calcium (mg/l Ca)	42.43	42.43	47.33	42.51	31.82	72.62	75	200-Expressed as Hardness
Magnesium (mg/l Mg)	15.67	17.63	22.03	25.9	19.58	22.52	50	150-Expressed as hardness
Total Iron(mg/L Fe^{+2} &Fe^{+3})	0.26	0.35	0.48	0.21	0.05	0.54	0.3	0.3
Manganese (mg/l Mn)	0.07	0.07	0.06	Trace	0.07	0.09	0.5	0.1
Fluoride (mg/l F)	0.39	0.66	0.05	0.37	0.45	0.46	-	1.5
Chloride (mg/l Cl)	1.03	1.03	1.03	2.06	1.03	31.91	250	250
Nitrite (mg/l NO_3)	0.02	0.007	0.012	0.005	0.01	0.018	-	0.2
Ammonia(mg/LNH_3)	0.04	0.05	0.37	0.25	0.21	0.19	-	-
Total solids	282	398	266	374	192	514	-	-

Source: *Water Mineral and Energy Department, EastWollega Zone; Nekemte; Ethiopia*

The quality ratings, unit weights, standard permissible values, and the calculated WQI of the subsurface water of different wells are presented in Table 4.

Table- 4: Calculated values of WQI

Parameter	Si	⅟si	Wi	W_1	W_2	W_3	W_4	W_5	W_6	W_1	W_2	W_3	W_4	W_5	W_6
				q_1	q_2	q_3	q_4	q_5	q_6	Wiqi	Wiqi	Wiqi	Wiqi	Wiqi	Wiqi
PH	8.5	0.12	0.006	78.24	81.9	76.7	76.9	73.18	80.00	0.4694	0.4914	0.4602	0.4614	0.439	0.48
Sodium	200	0.005	0.00026	22.25	20.75	6.5	19.75	5.5	43.75	0.0058	0.0054	0.0017	0.0051	0.00143	0.0114
Total Fe	0.3	3.3	0.173	86.67	116.6	160	70	16.67	180	14.99	20.17	27.68	12.11	2.88	31.14
Manganese	0.1	10	0.52	70	70	60	Trace	70	90	36.4	36.4	31.2	Trace	36.4	46.8
Fluoride	1.5	0.66	0.035	26	44	3.33	24.66	30	30.66	0.91	1.54	0.116	0.8631	1.05	1.073
Chloride	250	0.004	0.0002	0.412	0.412	0.412	0.824	0.412	12.76	$8.24e^{-5}$	$8.24e^{-5}$	$8.24e^{-5}$	0.00016	$8.24e^{-5}$	0.0255
Nitrite	0.2	5	0.26	10	3.5	6	2.5	5	9	2.6	0.91	1.56	0.65	1.3	2.34
Calcium	200	0.005	0.00026	21.21	21.21	23.66	21.26	15.91	36.31	0.0055	0.0055	0.0061	0.0055	0.0041	0.0094
Magnesium	150	0.006	0.00035	10.45	11.75	14.68	17.27	13.05	15.01	0.0036	0.0041	0.0051	0.0060	0.0045	0.0052
Hardness	500	0.002	0.0001	34.27	35.9	42.02	42.84	32.23	55.08	0.0034	0.0036	0.0042	0.0043	0.0032	0.0055
TDS	1000	0.001	$5.2e^{-5}$	26	35	23.6	34.2	18.4	47.8	0.00135	0.00182	0.00123	0.00178	0.00096	0.00249
	$K=\frac{1}{\sum(\frac{1}{si})}=0.052$		∑wi=0.99					∑wiqi		55.52	59.67	61.19	14.25	42.22	82.53
								$WQI=\frac{\sum WiQi}{\sum Wi}$		56.08	60.27	61.8	14.39	42.64	83.36

4.2 Discussion

This study was done to check the water quality in different wells in case of Wama Hagelo district for assessment of drinking water. This has been determined based on the eleven physico-chemical parameter measurements of: pH, total hardness, calcium, magnesium, sodium, chloride, nitrite, total dissolved solids, total iron, manganese and fluorides.

4.3 Water physical parameters

The most common physical parameters of water: pH, total hardness and total dissolved solids (TDS) have been determined. The pH values in the study area ranges between 6.22 and 6.96 with mean value of 6.615.The pH value indicates the water ranges from acidic water to neutral water conditions. The value of total hardness ranges from 161.16 mg/l to 275.4 mg/l. The value of total hardness is marked under the desirable limit of W.H.O i.e., less than 500mg/l. Hence subsurface water in part of study area is slightly hard to moderately hard.

4.4. Water Chemical Parameters

The most common chemical parameters of water: major cations (Na^+, $Mn^{2+,}$ Ca^{2+} and Mg^{2+}) and major anions (Cl^-,and No_2^-) and in addition to Fe^{+2} and F- which are naturally very variable due to local geological, climatic and geographical conditions have been determined.

The analytical results of sodium concentration in the study area range from 11mg/l to 87.5mg/l. The value of sodium, W.H.O has prescribed highest permissible limit of 200mg/l in drinking water. The concentration of sodium is observed under the permissible limit of W.H.O in the study area for all wells.

- The analytical result of calcium concentration in the study area ranges from 31.82mg/l to 72.62mg/l. The highest desirable limit of calcium in drinking water is 75 mg/l and maximum permissibility limit is 200 mg/l in drinking water. The value of calcium ranges under desirable limit for all wells, in the study area.

- The analytical results of magnesium concentration in the study area ranges from 15.67mg/l to 25.90 mg/l. Magnesium deficiency is associated with structural functional changes in the study area.

- The Chloride concentration in the study area is ranges from 1.03mg/l to 31.91mg/l. This indicates large variations of concentration, and less than the permissible value i.e,250mg/l. There is no wide variation of fluoride content in the study area, ranges between 0.05mg/l to 0.66mg/l. The whole study area is showing under the permissible limits of drinking water standards.

- The nitrite content in ground water in study area varies from 0.005mg/l to 0.02 mg/l.It is observed that all wells are having under the permissible limit W.H.O of 0.2mg/l. Drinking water standard indicated no subsurface water pollution.

- Generally from the above physico-chemical parameter measurement results of table 5, both *physical parameters:* pH, TH and total dissolved solids (TDS) and chemical parameters : major cations (Na^+, $Mn^{2+,}$ Ca^{2+} and Mg^{2+}) and major anions (Cl^-,and No_2^-) and in addition to Total Fe and F^- are less than the world Standard Desirable limits.

  The concentration of manganese (Mn^{2+}) is very small compared to W.H.O standard permissible limits at well four, Kofali2. This indicates that the subsurface water of this well is very suitable for drinking purposes and human healthy.

4.5 Based on the above WQI calculation results

Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are harmful for human health if they are more concentrated than defined limits. Therefore, the suitability of water sources for human consumption has been described in terms of Water quality index (WQI), which is one of the most effective ways to describe the quality of water. In this research, the computed value of WQI from table 5 ranges from 14.39 to 83.36.

The lowest value has been recorded from w_4, and then w_5 and w1, i.e., 14.39, 42.64 and 56.08 respectively. Whereas the maximum value has been recorded from w_6,w3 and $w_2$with corresponding value of 83.36, 61.8 and 60.27. The computed WQI values of these wells are classified into four types according to water quality classification shown by Table 3 above. These category are excellent, good, poor and very poor.

The computed value of WQI for well 4, 14.39, indicates excellent quality of subsurface water because the computed WQI value falls less than 25.And the computed value of WQI for W5 shows a good quality of subsurface water, since it ranked between 26-50.Whilethe computed value of W_1, W_2, andW3, that is 56.08, 60.27, and 61.8 respectively, falls within (51-75) of the classification of water quality based on weighted arithmetic WQI method as indicated by table 3 above. It clearly depicted that, they fall in poor quality, and figure out as the subsurface water is not fit for drinking purpose. So it follows that untreated water from the Ketari, Laga Dhoke and Kushi Dima is poor quality and must therefore be treated before use to avoid water related diseases. In a similar way the WQI for w6, Yube, ranges between 76-100, indicating a very poor quality of subsurface water, which needs a serious treatment before using it.

Generally, the value of WQI for the subsurface water of the one which is excellent well is 14.39. This indicates that the quality of water with in Kofali2 is excellent and favorable for drinking purposes. Also the calculated value of subsurface water for wells of Bilo (42.64) shows a good quality of subsurface water for drinking purpose, but the value will approaches to the value indicating poor quality water, and hence requires time to time quality test. Only one subsurface water well has excellent water quality and good for drinking purpose. The high value of WQI has been resulted due to Magnesium, and manganese in subsurface water. The higher values of Total Solids, Total hardness and alkalinity are due to mixing of sewage and leaching from waste sight. All these factors may pose health hazard on long term and can degrade quality of drinking water, therefore required to be treated for drinking purpose.

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the use of WQI, analysis, the computed value of WQI ranges from 14.39 to 83.36. The minimum value has been recorded from w_4, w_5 and w1, i.e., 14.39, 42.64 and 56.08 respectively. While maximum value has been recorded from w_2, w3, and w6, i.e., 60.27, 61.8 and 83.36 respectively.

The computed value of WQI for $w_4$indicates excellent quality of subsurface water because the computed WQI value falls less than 25. And the computed value of w_5 (42.64) falls within (26-50) of the classification of water quality based on weighted arithmetic WQI method as given in Table 3. It is good quality, indicating subsurface water for drinking purpose, but needs time to time treatment. The WQI for the well point $w_{1,}$ w2, andw$_3$ ranges between 51-75, indicating that poor quality of subsurface water for drinking purpose.

Finally, WQI is a powerful, well known method as well as one of the most effective tools to express water quality that offers a simple, stable, reproducible unit of measure and communicate information of water quality to the policy makers and concerned citizens. Also it is a simple tool that can be used to accurately determine the quality of subsurface water. Whereas the quality of subsurface water in Wama Hagalo of East Wollega zone, in the vicinity of different wells is determined by this methods and one well is excellent, hence gets A grades, one well is good, so it gets B grades and three wells have poor quality of water for drinking purpose and hence gets C grades. The one which gets D grade has very poor quality of subsurface water, i.e., w6.

6.2 Recommendation

The quality of water may affected by different activities in years, months, weeks and days, so it's good to analysis quality of water from time to time. Hence a continuous monitoring on subsurface water becomes mandatory in order to minimize the subsurface water contamination and have control on the pollution-caused agents. On the basis of the study area we strongly recommend the following points:

- ✓ Better if essential minerals should be added to the desirable limits in the ground water to improve the quality of water for drinking purpose.
- ✓ The wells those of Ketari, Laga Dhoke and Kushi Dima have poor quality of subsurface water, hence needs treatment prior to using it for drinking purpose. It had better if another well is developed instead of Yube well, since it has a very poor quality of subsurface water. On the other hand, Bilo well has good quality of subsurface water and used for drinking purpose. With some sort of time to time analysis, it should be being utilized as before.Kofali2 well which has excellent quality of subsurface water is used for drinking purpose rather than the other and therefore, suitable if use it as it is.
- ✓ This research paper can aid the management and future development of subsurface water resources in Wama Hagelo district and used as secondary data for further investigation by other researchers in the future.
- ✓ Better if the potability of subsurface water of the area is determined by using other methods rather than water quality index method(WQIM).

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