Irob region's natural resource assessment that can prove food self sufficiency of its people

By Alema Tesfaye, Washington DC, USA

Part 1

Irob people are suffering from extreme poverty and complex problems primarily due to harsh natural environment, extreme shortage of cultivable land, recurrent drought etc. Besides, human induced problems such as the recent Ethio-Eritrean war worsened the matter. And the Ethiopian government is not doing anything to solve the problem.

After the destruction and looting of the meager resources by Eritrean forces, the whole Irob population became aid dependant for survival. However the aid that Irob people were getting from Catholic Church has been stopped by the Ethiopian government. And, unfortunately, the government is using the food aid undertaking as a tool to control and divide the Irob people. It is the strategy that the government is using to weaken the Irob people. Hence, hopeless young Irobs, that don't see any futurity in their homeland, are migrating to various middle-eastern countries such as Israel, Saudi Arabia, etc. through very dangerous itineraries facing extreme difficulties and death en route. This trend will endanger the very existence of the Irob people if not resolved. In order to avoid the worsening of this situation and eventual extinction of the Irob people, all Irobs in Diaspora and back home should form hand in glove type of network to coordinate the efforts of individual citizens so as to serve their people by contributing money to build small factories or other developmental task that I am going to list below. We, Irobs, must create mechanisms to save the Irob community from disappearance. The contribution of the Catholic Church is appreciable but there is still much more work to be done on this developmental task of the Irob district.

The total area of the Irob district is approximately $4000km^2$ with a population of about 40,000. Even though it has some mineral potential indications in fewer parts, Irob is neither an industrial nor mining district. But rather has good potential for agricultural development, building (construction) stone business and excellent water quality for commercial use. Irob district can prove food self sufficiency by implementing mechanized agriculture system at Sangade plain, and lower Endeli valley. Besides agricultural activities in Sangade plain, integrating efforts to start small factories that prepare the building stones (marble, granite) and Asmiba spring water development for commercial purposes can be very helpful in assisting to decrease the unemployment rate and improve the livelihood of the Irob youth (which would in turn reduce the migration to foreign countries). For long term economic stability and development of the district, it is absolutely necessary to implement mechanized agricultural system in Sangade plain integrating both groundwater and surface water resources of the area. I will be reasoning out why I said this later on in this article.

If Irob district has to feed its population on sustainable basis, it has to shift its traditional agricultural practice to mechanized modern agriculture using irrigation by withdrawing ground water from bore holes integrating with surface water resources. In Irob, we have predominantly rain fed agricultural practices and the rainfall in almost all parts of the district is erratic and unreliable. Therefore, there should be great need to combine rain fed and irrigation agriculture for purposes of enhancing crop production especially at plain lands of Sangade area. This will help in promoting food self sufficiency of Irob land. By the way, this author carefully studied water quantity and quality for agriculture in the Irob district in 2006. The title of the research study is

Geological and water resource study of the Irob district. It is found in Adigrat Catholic development association (ADAA) division of Adigrat Diocesan Catholic Secretariat (ADCS) and explains most of the natural resources that are found in Irob district. It includes mineral potential, water resource assessment for agricultural use, water resource studies and generally geological studies of the whole Irob district. In addition to that, the research contains the inventory and data base of the water resources of the Irob district. The water chemistry of the Irob district was done in the Ethiopian Federal and Central Laboratory, Addis Ababa, and was financed by ADCS, Adigrat.

For Irob people, food aid or other temporary assistances cannot be a permanent solution to the problem they are encountering. Hence introduction of modern irrigation, construction of factories of building stones and spring water development for commercial use have to be taken as basic steps to alleviate the problem of the community permanently. Therefore, the need for utilization of the groundwater (spring water) of Asimba, building stone sale for commercial purposes and implementing extensive agricultural system in a Sangade plain and lower Endeli valley is highly demanded.

Sangade plain is one of the potential areas for agricultural development in order to increase food self sufficiency of the Irob people. It is the plain with very high amount of ground water potential for irrigation purposes. If the Irob district has to feed its population on sustainable basis, Sangade plain must be chosen as a potential agricultural area. It is therefore, Imperative to develop the water resource of the Sangade plain for sustainable food-self sufficiency instead of focusing on rain fed and highly liable agriculture to recurrent drought. Two to three times in a year crops can be cultivated in a Sangade plain (via irrigation) by using both groundwater resources (from bore holes) and surface water resources (tapping at Ado Abe by constructing big Dam to store water). For this purpose drilling of deep bore holes are required at Sangade plain and every bore holes should be pumped and collected in storage tank at elevated ground in order to irrigate vast land of whole Sangade via gravity. This will be one of best solutions in order to prove the food self sufficiency of the starving Irob peoples.

Besides agricultural aspect, Irob district particularly Assimba, Undufe and Garabino terrain have significant groundwater (spring water) potential for commercial values. These spring waters are Ethiopian top class waters in terms of water chemistry that determines value for commercial use. This water can be bottled and sold as the best class highland waters in Ethiopia.

The third important opportunity that the Irob district owns is building stone potential with high commercial values. Construction of factory for building stones is the third highest profitable thing that can be done in Irob land. Granite in the Irob land is one of the Ethiopia's highest quality building materials which are needed for construction purposes. Duto, Kitra, Asabol, the ridge extending from Kinkintay to Duto, and Assimba Mountain, is formed from the one of Ethiopia's highest quality granite. For this reason, at Asimba vicinity and at the above listed localities, construction of a factory that can produce granitic building/construction stones is highly recommended. The factory would be used to shape granite and make ready for sale. Granite is widely utilized as a key building stone for the construction of buildings. Since granite has hard texture and durability, it can serve as a major construction material. Besides granite, outcrops of marble occur at various places such as Getta terrain of Arae (Da-buda), Misdado slope of Arae-koma, Dawhan valley striking towards Sibida terrain, and Gebidawo, Ududa ridge. Particularly at Getta terrain of Arae-Koma, there is great quantity and quality of marble that can be used for commercial purpose. The marble at that vicinity is one of the top quality marbles in Ethiopia. In general, the stones used for building are those that have sufficient strength and rigidity to support free-standing structures, and are amenable to the technical and organizational resources of the culture wishing to use them.

I will try to elaborate the above three concepts (Mechanized agriculture in Sangade terrain, construction of factories for Asimba spring water development and construction of factory for building stone preparation for commercial purposes in Irob district) by using part1, part 2 and part 3 in this article.

1. Assimba spring water assessment and development for commercial use

The Entire area of interest which is Assimba Mountain and its neighboring mountainous area are found with in Denakil river drainage basin. Based on the table below, Assimba and its surrounding mountainous zone are classified as the ***Dega*** type of climatic conditions. Due to the Dega type climate and relatively higher amount of rainfall in the area, the recharge to groundwater through rain is high and the residence time of groundwater in fractures of the Assimba is small. Due to small residence time, the rock-groundwater interaction is also minimum resulting in the smaller mineral concentration in groundwater of the area.

Mean annual temperature	Temperature region		Region altitude
Less than 10° C	Kur	Alpine	Above 3300 m a.s.l.
10 - 15° C	Dega	Temperate	2300 – 3300 m a.s.l.
15 – 20° C	Weina Dega	Subtropical	1500 – 2300 m a.s.l.
Greater than 30° C	Kolla	Tropical	800 – 1500 m a.s.l.
Grater than 40° C	Bereha	Desert	Less than 800 m a.s.l.

Tab. 1. General climatic divisions of Ethiopia (NMSA, 1996).

1.1. Geological study of Assimba mountain and its surroundings

Precambrian Intrusive Rocks such as Assimba Post tectonic granite and its surrounding diorites have variable dimensions in the area. Based on their contact and other structural relationships, intrusives in Irob district are categorized into two groups.

I. Strongly deformed, white colored and highly weathered granodiorite (Waratle, Magauma, Gubi-Daya and Ado Abe-Daro post tectonic granodiorite).
II. Massive granite (Assimba, Duuto, Kitra and Asabol post tectonic granites).
These are classified as post-tectonic intrusives with respect to the deformation which produced the major fabric in the country rocks. Accordingly, I and II are post tectonic. Most of the granitoid are named after the locality in which they are exposed and show variations in composition, grain size, area coverage, color, etc.

They have mostly circular to sub-circular shape and form a relatively low-lying topography (except at Assimba) to highly rugged and incised topography. Compositional variation differs from place to place but mostly the out crops are made up of a composite mass consisting of pure granite, and biotite granite. Textural variation is also observed from locality to locality but generally the texture is medium to coarse grained with some phenocrysts, usually K-feldspars (>400mm long as in Waratle granodiorite), marginally deformed to massive. The Precambrian intrusive rocks, (meta granodiorite and granite units) form topographic features ranging from flat adulating hills at Waratle, Ado Abe, Magauma, etc to elevated ridges at Kinkintay, Asabol, Duuto (Magabidaga), Kitra (Dawhan), and Asimba. Granite forms the prominent mountain of Assimba with the height of about 3205 meters above sea level. Granodiorites seems to form rather lower areas with destructive radial drainage and clear jointing. This Granodiorites appear at Irob district in the areas such as Waratle, Sangede (Ado Abe-Daaro) and Magauma terrain. Post tectonic granites are mostly massive rather than foliated, more porphyritic and have more quartz veins. These granites also consist of subordinate diorites and granodiorites especially traced at Undufe, Elal Daga (Harade), and the whole Sabata terrain. Most of the tectonic structures such as, faults, young fracture and joint systems at Precambrian intrusive of Assimba and surrounding areas occurred in three sets of major directions. These are NE-SW, NW-SE, and N-S with subordinate E-W direction. NW, NE and E-W treading lineaments are most frequent in granitoids terrain and they have formed very deep, steep sided gorges with average height of about 50 meters. Since the Irob district is hard rock terrain, the rivers and their tributaries follow these main structural and tectonic features that are trending on the above mentioned directions. Ground water potential in this area depends mainly on intensity and extent of structures, and type as well as depth of weathering. Brittle deformation, depth of weathering, and fracture spacing play great role.

1.2. Hydrochemistry of Groundwater in Granitic and Dioritic intrusive rocks of the Assimba and surrounding Area.

To analyze the suitability of ground water for drinking and commercial purposes, it was compared with Ethiopian standards for drinking water published in Negarit Gazeta No.12/1990 and World health organization (WHO). The physical and chemical characteristics of ground water determine its usefulness for various purposes such as agriculture, industrial and domestic water supplies

Property	Ethiopian standards [1] and MoWR Guidelines [2] (mg/l)		Assimba and Undufe area (mg/l)	
	2	Maximum permissible level	Range	Number of exceeding values
Na[2]	358		5-27	None
Ca[1]	75	200	22- 75	None
Cl[1]	200	600	5- 44	None
Cl[2]	533			
B[2] (HBO_2)	0.3			Not analyzed
Dissolved (free) ammonia[1]	0.05	0.1	Not analyzed	
Fe[1]	0.1	1		Not analysed
Fe[2]	0.4			
Mg[1]	50	150	4 -18	
Mn[1]	0.05	0.5	Not analyzed	
Mn[2]	0.5			
SO_4[1]	200	400	13 - 45	None
SO_4[2]	483			None
TDS[1]	500	1500	145– 433	None
Total hardness ($CaCO_3$)[1]	100	500		
Total hardness ($CaCO_3$) [2]	392			
pH[1]	7.0 - 8.5	6.5 – 9.2	6.8– 7.9	None
pH[2]	6.5 – 8.5			
NO_3[1]	10	45	0.9- 10.0	

$NO_3^{(2)}$	50			
$F^{(1)}$	1	1.5	0.04 – 0.43	
$F^{(2)}$	3			

Table 2. The suitability of Asimba water resources for drinking and commercial use.

Hydrochemistry of ground water of the aquifer developed in fractures and joints of intrusive rocks (Assimba granites, and diorites of Undufe and Elal Daga) in the study area is represented by 10 samples analyses. The suitability analysis is done based on both Ethiopian water quality and world health Organization (WHO) standards. The groundwater of all these rocks is mainly represented by calcium bicarbonate types since the springs of very good yield are emerging from fractures of the intrusive rocks at recharge zone with excellent water quality for every purposes. Their bicarbonate concentration ranges from 88 to 265 mg/l and the sulfate levels are very law ranging from 13 to 35 Mg/l. Chloride ions are small in amount (mean=22.8 mg/l) and nitrate levels are insignificant in the area (<mean=3.5 mg/l) and far below the highest desirable level of Ethiopian and WHO standard for drinking water. The mean value of electrical conductivity of the water points from these intrusive rocks is 404 us/cm, which is far below permissible level of Ethiopian drinking water standard and agricultural standards. The mean TDS value of the springs emerging from igneous intrusive rocks is 304 mg/l. however the water is rather neutral, its mean PH equals 7.3. The SAR value of the rocks lies below 0.5. Because of the above parameters, ground water from fractured granitic and dioritic terrain of the Assimba and surrounding area is excellent for agricultural, domestic, and industrial purposes. Above all, the waters in these areas are highly recommended for highland commercial purpose as its ionic constituents match with the standards of the highland waters.

The above and remaining other parameters are below the highest desirable limit of Ethiopia standard of drinking water and irrigation. All these mentioned water quality indicators make, in general, the granites and diorite, good water for diverse purposes, including drinking, industrial and agricultural purpose. The waters in the Granitic terrain of Assimba as the whole and Dioritic terrain of Undufe, Elal Daga and surrounding areas are of excellent quality for highland water commercial use. Generally the Electrical conductivity (EC), Total dissolved solids (TDS) and Temperature values increase as one goes from highland (Assimba top) to lowland area, suggesting the direction of groundwater flow from Asimba mountain tip towards the lowland areas, to all directions. The highland areas shows relatively lower Electrical Conductivity (EC) and Total Dissolved Solids (TDS) values which are indications of short residence time of ground water suggesting an area of recharge and the opposite is true for lowland areas, surrounding deep gorges. Generally EC, TDS and Temperature values increases along the flow path from recharge (Assimba mountain summit) to discharge areas at which springs are discharging (emerging).

1.3. The water of Assimba is one of Ethiopia's best for commercial purposes.

The water from Assimba granite and Undufe and Elal Daga diorite are highly recommended for highland water that are fit for commercial purposes. For this purpose, Assimba mountain spring waters as a whole such as Hundub laye, Sankiyayeto, Kaebe, Buulo adding with Elal Daga and Bire springs can be tapped at their eyes and accumulated in one clean reservoir then pumping to factory location for bottling (commercial use). These springs are one of best Ethiopian waters that are fit for highland waters.

Sample Name: **Adolaye (Gargara) spring water**

Location	Gargara
Site	Adolaye (Gargara) spring water
Sampling Date	2006

Drinking Water Quality Regulations:

Element	Measured	Recommended	Maximum
EC	520	< 400	< 1250
Na	27	< 20	< 200
F	2.78		< 1.5
Cl	44	< 25	
SO4	33	< 25	< 250

Irrigation water assessment:

Conductivity	520 uS
Sodium Adsorption Ratio (SAR)	0.84
Exchangeable sodium ratio (ESR)	0.30
Magnesium hazard (MH)	21.01

1.4. Irrigation water quality assessment in Assimba areas

Standards of ground water quality for irrigation purpose is determined based on sodium Adsorption ratio (SAR), total dissolved solids and united states salinity criteria (USSC).

1. SAR

To study the suitability of groundwater for irrigation purposes the use of sodium Adsorption ratio (SAR) is used.

Sodium concentration is important in classifying irrigation water because sodium reacts with soil to reduce its permeability. The salinity laboratory of the U.S. department of agriculture recommends the sodium adsorption ratio (SAR) because of its direct relation to the adsorption of sodium by soil.

It is defined by

$SAR = Na/\sqrt{[(Ca+Mg)/2]}$ where all concentrations are expressed in mg/l.

SAR	**Water class**
<10	excellent
10-18	good
18-26	fair
>26	poor

A soil high in exchangeable sodium tends to have a relatively impermeable crust, which is very undesirable for agriculture and waters of high SAR promote this condition. Water with SAR value less than 10 is good and greater than 18 is high to use for irrigation. Sodium Adsorption ratio greater than 26 is very high to use for agriculture. Sodium Amendments to reduce high SAR values by using gypsum on

lime may correct the situation or using waters containing a high proportion of calcium and magnesium may reverse the condition.
The SAR value of the total samples analyzed from the study area varies from 0.18 to 2.00. Therefore, the tested water samples of the study area are excellently suitable for agriculture from the point of view of their SAR value.

2. **Total dissolved solids (TDS) criteria**
The Raghunath (1987) criteria have been used to classify water samples for irrigation use/purpose.

TDS	Water class
<1000 mg/l	Suitable for irrigation use
1000-1700 mg/l	fit for irrigation
>1700 mg/l	Unfit for irrigation

In general, since the TDS value of all water samples is less than 1700mg/l, with average value of 304 mg/l, they are suitable for irrigation purposes.

3) **USSC (United States salinity criteria = EC criteria)**
United States salinity criteria of irrigation water is based on electrical conductivity (EC) classification

EC (µs/cm)	Water class	Remark
0-250	Law salinity water	Good for irrigation of most crops
250-750	Medium salinity water	Satisfactory for plants having moderate salt tolerance on soils of moderate permeability with leaching.
.750-2250	High salinity water	Satisfactory for plants with good salt tolerance.
2250-4000	High salinity water	Satisfactory for salt tolerant crops on soils of good permeability with special leaching
>4000	Excessive (very high) Salty water	unfit for irrigation.

According to the above classification, since the EC values range from 165-562 mg/l, all water samples are fit for irrigation purposes, satisfactory for all crops up to moderate salt tolerant plants on soils of moderate permeability with leaching. Waters of the study area ranges b/n law salinity water and medium salinity waters.
For further information, details of same water point samples of Asimba area is analyzed below for agricultural suitability and drinking purposes.

Sample name	**Hundub Laye, Asimba**
Location	Assimba
Site	Hundub laye
Sampling Date	2006

Drinking Water Quality Regulations:

Element	Measured	Recommended
F	2.12	< 1.5

Irrigation water:	**Values**
Conductivity	311 uS
Sodium Adsorption Ratio (SAR)	0.58
Exchangeable sodium ratio (ESR)	0.27
Magnesium hazard (MH)	25.91

Sample name	**Bulo spring water**
Location	Assimba
Site	Bulo
Sampling Date	2006

Drinking Water Quality Regulations:

Element	Measured	Recommended	Maximum
Cond	895	< 400	< 1250
Na	40	< 20	< 200
Ca	103	< 100	
F	3.01		< 1.5
Cl	72	< 25	
SO4	52	< 25	< 250
NO3	33.62	< 25	<50

Irrigation water	**Values**
Conductivity	895 uS
Sodium Adsorption Ratio (SAR)	0.92
Exchangeable sodium ratio (ESR)	0.24
Magnesium hazard (MH)	27.75

Sample name	**Hohoytilaye (spring water)**
Location	Assimba
Site	Hohoyte Laye
Sampling Date	2006

Drinking Water Quality Regulations:

Element	Measured	Recommended	Maximum
Cond	189	<400	<1250
Na	43	<20	<200
Mg	35	<30	
Ca	185	<100	
Cl	76	<25	
SO4	470	<25	<250

Irrigation water:	**Values**
Conductivity	189 uS
Sodium Adsorption Ratio (SAR)	0.76
Exchangeable sodium ratio (ESR)	0.15
Magnesium hazard (MH)	23.78

Sample name	**Sankiyayto: Assimba Spring water**
Location	Assimba
Site	Sankiyayto Asimba
Sampling Date	2006

Drinking Water Quality Regulations:

Element	Measured	Recommended	Maximum
Cond	445	< 400	< 1250
F	3.11		< 1.5
SO4	45	< 25	< 250

Irrigation water:	**Values**
Conductivity	445 uS
Sodium Adsorption Ratio (SAR)	0.59
Exchangeable sodium ratio (ESR)	0.23
Magnesium hazard (MH)	42.59

Sample name	**Bire (Undufe) Spring**
Location	Bire Undufe
Site	Undufe

Drinking Water Quality Regulations:

Element	Measured	Recommended	Maximum

Irrigation water:	**Values**
Conductivity	182 uS
Sodium Adsorption Ratio (SAR)	0.24
Exchangeable sodium ratio (ESR)	0.13
Magnesium hazard (MH)	19.93

1.5. The analysis of water chemistry in Assimba, with its ionic species (water quality indicators).

Sample name	**Hundub Laye (Assimba) spring water**
Location	Assimba
Site	Hundub Laye
Sampling Date	2006
Geology	Granite

Watertype	Ca-Na-HCO3

Sum of Anions (meq/l)	3.06
Sum of Cations (meq/l)	2.88
Balance:	3.0%

Total dissolved solids	5.9 meq/l	222.1 mg/l

Hardness	meq/l	°f	°g	mg/l CaCO3
Total hardness	2.22	11.11	6.22	111.1
Permanent hardness	0.12	0.62	0.35	6.2
Temporary hardness	2.1	10.49	5.87	104.9
Alkalinity	2.1	10.49	5.87	104.9

(1 °f = 10 mg/l CaCO3/l 1 °g = 10 mg/l CaO)

Major ion composition

	mg/l	mmol/l	meq/l	meq%
Na+	14.0	0.609	0.609	10.263
K +	1.8	0.046	0.046	0.775
Ca++	33.0	0.823	1.647	27.755
Mg++	7.0	0.288	0.576	9.707
Cl-	14.0	0.395	0.395	6.656
SO4--	20.0	0.208	0.416	7.01
HCO3-	128.0	2.098	2.098	35.355

Ratios			Comparison to Seawater	
	mg/l	mmol/l	mg/l	mmol/l
Ca/Mg	4.714	2.859	0.319	0.194
Ca/SO4	1.65	3.954	0.152	0.364
Na/Cl	1.0	1.542	0.556	0.858

Gas composition			Air saturated water (0.0°C, p=1 bar)	
mg/l	mmol/l	mmol%	mg/l	mmol/l

	mg/l	mmol/l	mmol%	mg/l	mmol/l
CO2	25.0	0.568	99.945		

Dissolved Minerals:	mg/l	mmol/l
Halite (NaCl)	0.652	0.0111
Carbonate (CaCo3)	32.752	0.3275
Dolomite (CaMg(CO3)2)	53.011	0.288
Anhydrite (CaSO4)	28.358	0.208

Sample name	**Bulo (Assimba) Spring water**
Location	Assimba
Site	Bulo
Sampling Date	2006
Geology	Granite
Watertype	Ca-Mg-HCO3-Cl

Sum of Anions (meq/l)	9.67
Sum of Cations (meq/l)	8.88
Balance:	4.2%

Total dissolved solids 18.6 meq/l 685.8 mg/l

Hardness	meq/l	°f	°g	mg/l CaCO3
Total hardness	7.11	35.57	19.92	355.7
Permanent hardness	1.26	6.31	3.54	63.1
Temporary hardness	5.85	29.26	16.38	292.6
Alkalinity	5.85	29.26	16.38	292.6

(1 °f = 10 mg/l CaCO3/l 1 °g = 10 mg/l CaO)

Major ion composition

	mg/l	mmol/l	meq/l	meq%
Na+	40.0	1.74	1.74	9.38
K +	1.2	0.031	0.031	0.167
Ca++	103.0	2.57	5.14	27.708
Mg++	24.0	0.987	1.974	10.641
Cl-	72.0	2.031	2.031	10.948
SO4--	52.0	0.541	1.083	5.838
HCO3-	357.0	5.852	5.852	31.546

Ratios Comparison to Seawater

	mg/l	mmol/l	mg/l	mmol/l
Ca/Mg	4.292	2.603	0.319	0.194
Ca/SO4	1.981	4.747	0.152	0.364
Na/Cl	0.556	0.857	0.556	0.858

Gas composition Air saturated water (0.0°C, p=1 bar)

	mg/l	mmol/l	mmol%	mg/l	mmol/l
CO2	20.0	0.455	100.077		

Dissolved Minerals:	mg/l	mmol/l

Halite (NaCl)	101.783	1.7399
Carbonate (CaCo3)	104.23	1.0423
Dolomite (CaMg(CO3)2)	181.752	0.987
Anhydrite (CaSO4)	73.732	0.541

Sample name **Sankiyayto Assimba Spring water**

Location	
Site	Sankiyayto Assimba
Sampling Date	2006
Geology	Granite
Watertype	Ca-Mg-HCO3-SO4

Sum of Anions (meq/l)	4.81
Sum of Cations (meq/l)	4.32
Balance:	5.4%

Total dissolved solids 9.1 meq/l 336.2 mg/l

Hardness	meq/l	°f	°g	mg/l CaCO3
Total hardness	3.48	17.38	9.74	173.8
Permanent hardness	0.43	2.14	1.20	21.4
Temporary hardness	3.05	15.24	8.54	152.4
Alkalinity	3.05	15.24	8.54	152.4

(1 °f = 10 mg/l CaCO3/l 1 °g = 10 mg/l CaO)

Major ion composition

	mg/l	mmol/l	meq/l	meq%
Na+	18.0	0.783	0.783	8.577
K +	2.2	0.056	0.056	0.613
Ca++	40.0	0.998	1.996	21.865
Mg++	18.0	0.740	1.481	16.224
Cl-	23.0	0.649	0.649	7.11
SO4--	45.0	0.468	0.937	10.264
HCO3-	186.0	3.049	3.049	33.4

Ratios			Comparison to Seawater	
	mg/l	mmol/l	mg/l	mmol/l
Ca/Mg	2.222	1.348	0.319	0.194
Ca/SO4	0.889	2.13	0.152	0.364
Na/Cl	0.783	1.207	0.556	0.858

Gas composition			Air saturated water (0.0°C, p=1 bar)	
mg/l	mmol/l	mmol%	mg/l	mmol/l

CO2	5.0	0.114	100.297

Dissolved Minerals:

	mg/l	mmol/l
Halite (NaCl)	1.07	0.0183
Dolomite (CaMg(CO3)2)	136.314	0.74
Anhydrite (CaSO4)	63.807	0.468

Sample name	**Harade, Elal Daga spring water**
Location	Elal daga, haraze
Site	Elal Daga
Sampling Date	2006
Geology	Tsaliet group
Watertype	Ca-HCO3

Sum of Anions (meq/l)	5.78
Sum of Cations (meq/l)	5.53
Balance:	2.2%

Total dissolved solids	11.3 meq/l	433.5 mg/l

Hardness	meq/l	°f	°g	mg/l CaCO3
Total hardness	4.65	23.24	13.01	232.4
Permanent hardness	0.3	1.52	0.85	15.2
Temporary hardness	4.34	21.72	12.16	217.2
Alkalinity	4.34	21.72	12.16	217.2

(1 °f = 10 mg/l CaCO3/l 1 °g = 10 mg/l CaO)

Major ion composition

	mg/l	mmol/l	meq/l	meq%
Na+	19.0	0.826	0.826	7.302
K +	2.2	0.056	0.056	0.495
Ca++	75.0	1.871	3.743	33.088
Mg++	11.0	0.452	0.905	8.0
Cl-	28.0	0.79	0.79	6.984
SO4--	23.0	0.239	0.479	4.234
HCO3-	265.0	4.344	4.344	38.401

Ratios			Comparison to Seawater	
	mg/l	mmol/l	mg/l	mmol/l
Ca/Mg	6.818	4.135	0.319	0.194
Ca/SO4	3.261	7.815	0.152	0.364
Na/Cl	0.679	1.046	0.556	0.858

Gas composition Air saturated water (0.0°C, p=1 bar)

	mg/l	mmol/l	mmol%	mg/l	mmol/l
CO2	10.0	0.227	99.857		

Dissolved Minerals:	mg/l	mmol/l
Halite (NaCl)	1.303	0.0223
Carbonate (CaCo3)	118.05	1.1805
Dolomite (CaMg(CO3)2)	83.303	0.452
Anhydrite (CaSO4)	32.612	0.239

Sample name	**Adolaye (spring water)**
Location	Gargara
Site	Adolaye, Gargara
Sampling Date	2006
Geology	Granite
Watertype	Ca-Na-HCO3-Cl

Sum of Anions (meq/l)	5.37
Sum of Cations (meq/l)	5.11
Balance:	2.5%

Total dissolved solids 10.5 meq/l 380.6 mg/l

Hardness	meq/l	°f	°g	mg/l CaCO3
Total hardness	3.92	19.58	10.97	195.8
Permanent hardness	0.65	3.27	1.83	32.7
Temporary hardness	3.26	16.31	9.13	163.1
Alkalinity	3.26	16.31	9.13	163.1

(1 °f = 10 mg/l CaCO3/l 1 °g = 10 mg/l CaO)

Major ion composition

	mg/l	mmol/l	meq/l	meq%
Na+	27.0	1.174	1.174	11.204
K +	0.6	0.015	0.015	0.143
Ca++	62.0	1.547	3.094	29.527
Mg++	10.0	0.411	0.823	7.854
Cl-	44.0	1.241	1.241	11.843
SO4--	33.0	0.344	0.687	6.556
HCO3-	199.0	3.262	3.262	31.131

Ratios / Comparison to Seawater

Ratios	mg/l	mmol/l	Seawater mg/l	Seawater mmol/l
Ca/Mg	6.2	3.761	0.319	0.194
Ca/SO4	1.879	4.503	0.152	0.364
Na/Cl	0.614	0.946	0.556	0.858

Gas composition / Air saturated water (0.0°C, p=1 bar)

Gas	mg/l	mmol/l	mmol%	Air saturated water mg/l	Air saturated water mmol/l
CO2	30.0	0.682	100.004		

Dissolved Minerals:	mg/l	mmol/l
Halite (NaCl)	68.704	1.1744
Carbonate (CaCo3)	79.28	0.7928
Dolomite (CaMg(CO3)2)	75.73	0.411
Anhydrite (CaSO4)	46.791	0.344

Sample name	**Bire Spring water**
Location	Undufe
Site	Bire (Undufe)
Sampling Date	2006
Geology	Tsaliet group
Watertype	Ca-HCO3

Sum of Anions (meq/l)	1.90
Sum of Cations (meq/l)	1.92
Balance:	0.5%

Total dissolved solids	3.8 meq/l	145.8 mg/l

Hardness	meq/l	°f	°g	mg/l CaCO3
Total hardness	1.65	8.26	4.62	82.6
Permanent hardness	0.21	1.05	0.59	10.5
Temporary hardness	1.44	7.21	4.04	72.1
Alkalinity	1.44	7.21	4.04	72.1

(1 °f = 10 mg/l CaCO3/l 1 °g = 10 mg/l CaO)

Major ion composition

	mg/l	mmol/l	meq/l	meq%
Na+	5.0	0.217	0.217	5.686
K +	1.9	0.049	0.049	1.284
Ca++	26.5	0.661	1.322	34.637
Mg++	4.0	0.165	0.329	8.62
Cl-	5.0	0.141	0.141	3.694
SO4--	13.0	0.135	0.271	7.1
HCO3-	88.0	1.442	1.442	37.781

Ratios			Comparison to Seawater	
	mg/l	mmol/l	mg/l	mmol/l
Ca/Mg	6.625	4.018	0.319	0.194
Ca/SO4	2.038	4.885	0.152	0.364
Na/Cl	1.0	1.542	0.556	0.858

Gas composition				Air saturated water (0.0°C, p=1 bar)	
	mg/l	mmol/l	mmol%	mg/l	mmol/l
CO2	20.0	0.455	100.077		

Dissolved Minerals:	**mg/l**	**mmol/l**
Halite (NaCl)	0.233	0.004
Carbonate (CaCo3)	36.166	0.3617
Dolomite (CaMg(CO3)2)	30.292	0.165
Anhydrite (CaSO4)	18.433	0.135

As everybody can see in the above water chemistry analysis, water quality indicators (Ionic species) of Assimba water makes it to be classified as one of the Ethiopian best waters that can easily be developed for commercial purposes. The Assimba waters can be tapped at the eye of several springs and collected in scientific way, introducing local factory that can bottle and prepare these highest quality waters for sale.

By this way, Irob youth can be employed in their homeland instead of risking dangerous journeys and abusive situations in foreign countries.

To be continued………..

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The Author can be reached at alematesfaye@yahoo.com