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EVALUATION OF GROUNDWATER QUALITY AND ITS SUITABILITY FOR DOMESTIC AND IRRIGATION USE IN PATOS-MARINZA REGION

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GENERAL CONSIDERATION

- The Patos - Marinza is one of the largest onshore heavy oil fields in Europe holding approximately 6 billion barrels of original-oil-in-place. (Bankers, 2009).
- It was discovered in 1928 by APOC (Anglo Persian Oil Co.) and the production began in 1939.
- The Patos-Marinez oilfield is located in south central Albania, approximately 20 kilometers in land from the Adriatic coast.
- The population is about 43 000 inhabitants.
- The main economic source is agronomy and agriculture.

ENVIRONMENTAL IMPACT

- Lack of investments in technology, infrastructure as well as up-to-date methods of management for 75 years had left Patos – Marinza field in a polluted environment with oil contamination surrounding wells.

- Municipal waste-water discharges.

- Lack of drinking water supply system.

- Fertilizer run-off from agricultural activities.

MATERIALS AND METHODS

The aim of the study:

The evaluation of the groundwater quality in Patos-Marinza region;

- **Drinking purpose** (based on the requirement of the Council Directive relating to the quality of water intended for human consumption [98/83/EC] as well as on Water Quality Index.).

- **Suitability for irrigation** (based on sodium adsorption ratio, sodium percentage, residual sodium carbonate, and permeability index).

WATER QUALITY INDEX

The Water Quality Index (WQI) integrates complex data to generate a score that describes the status of water quality to the public as well as decision and policy makers (Simoes et al., 2008; Fulazzaky et al., 2010).

Why a Water Quality Index?

✓*Incorporate data from multiple water quality parameters into a mathematical equation that rates the health of water body with number.*

✓*Less number of parameters required in comparison to all water quality parameters for particular use.*

✓*Useful for communication of overall water quality information to the concerned citizens and policy makers.*

✓*Reflects the composite influence of different parameters i.e. important for the assessment and management of water quality.*

✓*Describes the suitability of both surface and groundwater sources for human consumption.*

WATER QUALITY INDEX

Water quality is classified as excellent, good, poor, very poor and unfit for drinking purpose.

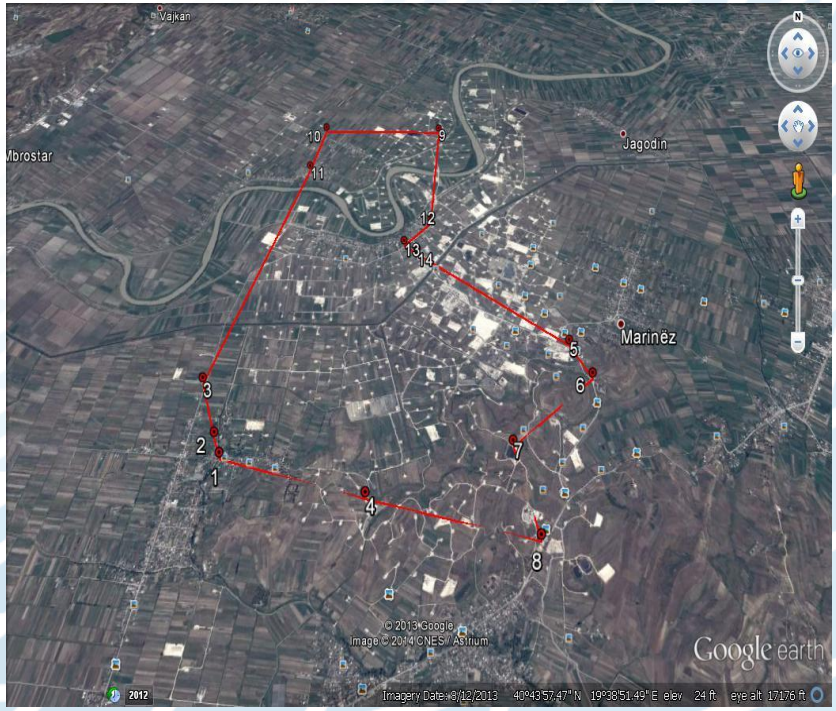
WQI Value	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

MATERIALS AND METHODS

Location of sampling stations of the study area

Station	*Latitude*	*Longitude*	*Depth (m)*
S_1	40°43'22.56"N	19°37'32.65"E	35
S_2	40°43'28.84"N	19°37'28.94"E	100
S_3	40°43'46.89"N	19°37'19.28"E	25
S_4	40°43'10.93"N	19°38'31.16"E	70
S_5	40°44'0.49"N	19°39'58.18"E	1900
S_6	40°43'47.74"N	19°40'5.60"E	1700
S_7	40°43'25.19"N	19°39'28.84"E	45
S_8	40°42'59.14"N	19°39'35.97"E	100
S_9	40°45'45.90"N	19°39'2.93"E	100
S_{10}	40°45'46.65"N	19°37'57.62"E	2000
S_{11}	40°45'22.90"N	19°37'51.45"E	25
S_{12}	40°44'54.07"N	19°38'57.37"E	35
S_{13}	40°44'43.22"N	19°38'44.03"E	1700
S_{14}	40°44'39.14"N	19°38'50.60"E	20
S_{15}	40°44'37.28"N	19°38'48.62"E	1300

Groundwater samples were collected from fifteen shallow and deep wells on the study area.



Physico-chemical determinations on the groundwater samples were carried out through standard methodologies of the American Public Health Association (APHA, 2005).

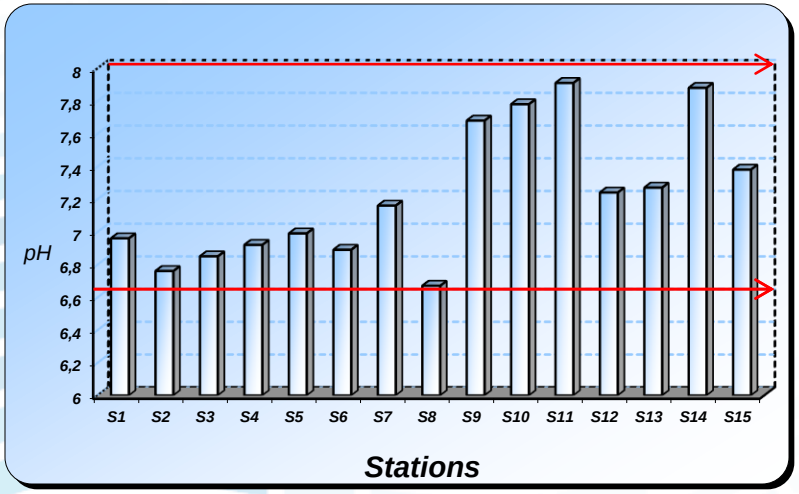
RESULTS AND DISCUSSION

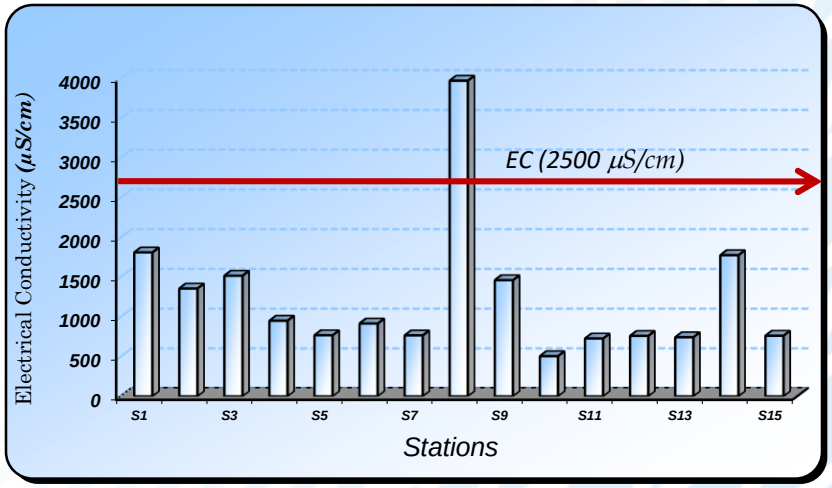
Results of measurements of physico-chemical parameters

Stations	pH	EC (us/cm)	TSS (mg/L)	TDS (mg/L)	DO (mg/L)	BOD (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	$N\text{-}NO_3^-$ (mg/L)
S1	6.96	1810	14.46	1346	1.46	0.16	623	945	199.5	99.4	168	146.5	17.14
S2	6.76	1356	1.23	1001	1.56	0.91	684	693	156.3	74.9	86	47.9	0.44
S3	6.85	1517	11.80	1123	1.87	1.35	857	816	151.1	92.4	72	17.8	1.67
S4	6.92	951	0.99	693	1.40	0.99	381	514	157.0	21.1	84	50.7	2.98
S5	6.99	768	0.69	554	1.77	0.03	381	414	109.9	29.5	44	14.0	0.63
S6	6.89	916	0.15	667	6.40	0.33	381	458	145.9	19.0	54	64.1	4.79
S7	7.16	766	0.99	553	6.50	0.52	390	414	121.7	30.0	47	16.9	2.42
S8	6.67	3970	2.50	2988	13.90	2.81	433	1453	507.2	108.7	956	136.9	2.66
S9	7.68	1461	3.40	1081	8.12	1.71	597	760	96.2	109.7	137	87.5	5.56
S10	7.78	505	0.70	354	2.91	0.23	268	257	23.7	33.2	44	11.3	0.18
S11	7.91	727	0.30	523	4.47	0.49	346	179	11.2	24.4	50	13.5	0.24
S12	7.24	760	0.20	548	6.81	0.49	372	425	124.3	32.8	46	12.0	2.27
S13	7.27	743	0.40	535	6.71	0.21	355	402	119.7	32.8	46	15.1	2.26
S14	7.88	1775	7.30	1319	5.56	0.97	667	771	94.2	107.6	213	81.1	1.77
S15	7.38	762	0.15	550	6.50	0.95	355	436	121.7	26.7	47	17.8	1.97
Min	6.67	505	0.15	354	1.4	0.03	268	179	11.2	19	44	11.3	0.18
Max	7.91	3970	14.46	2988	13.9	2.81	857	1453	507.2	109.7	956	146.5	17.14
Average	7.22	1252.5	3.02	922.3	5.1	0.8	472.7	595.8	142.6	56.2	139.6	48.9	3.1

RESULTS AND DISCUSSION

pH & Electrical Conductivity





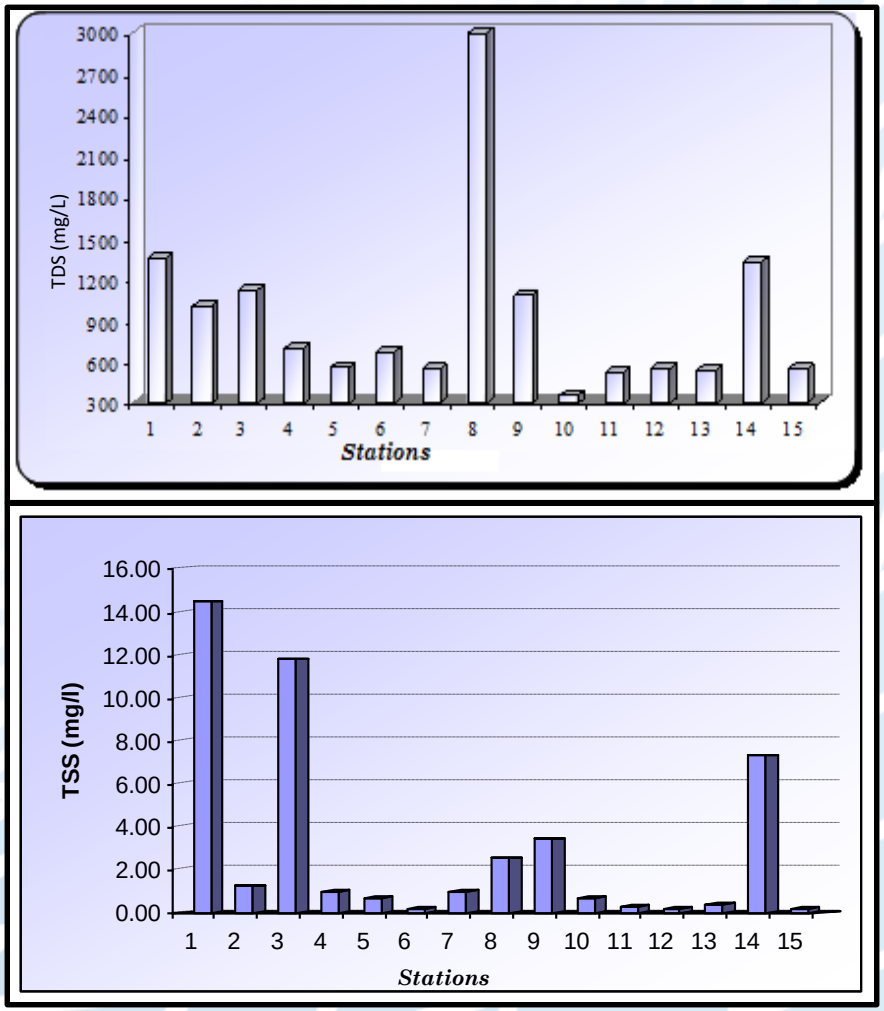
➢The pH values of water samples studied ranged around neutral pH values (6.67-7.91) and are within the limits recommended by the EU Directives for drinking water.

➢Conductivity value ranged from 505 µS/cm (S10) to 3970 µS/cm (S8). This fluctuation in EC is related to the geological nature of their water basins. However, with the exception of S8, all analyzed waters have conductivity within the limits recommended by the EU Directives for drinking water (2500 µS/cm).

RESULTS AND DISCUSSION

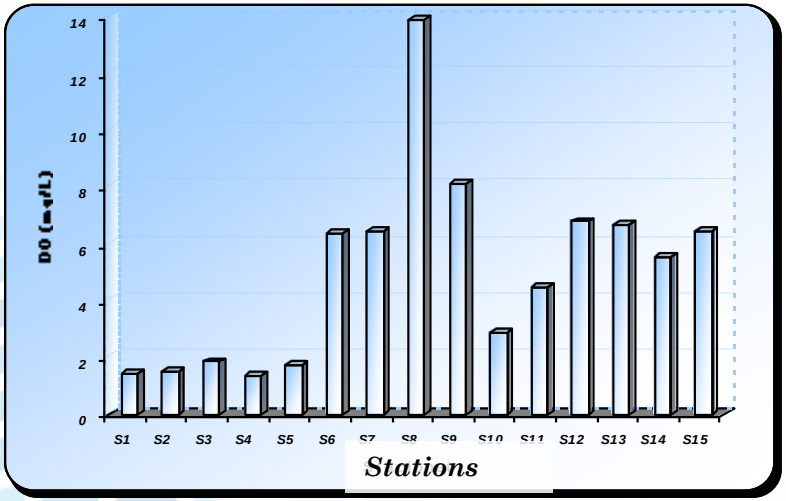
Total dissolved solids (TDS) & Total suspended solids (TSS)

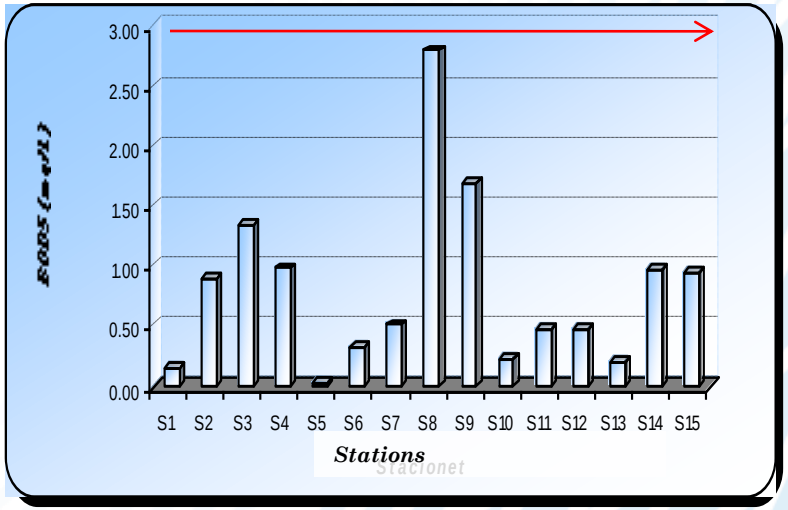
- TDS values of water samples varied from 354.28 mg/L to 2987.68 mg/L.
- Water containing more than 500 mg/L of TDS is not considered desirable for drinking water supplies, but in unavoidable cases 1500 mg/L is also allowed. Approximately 93.3 % of the analysed samples had shown TDS values lower than this value.
- TSS values ranged from 0.15 mg/L to 14.46 mg/L and are classified in the A1 category according to the recommended value (25 mg / L) of the EU Directive.



RESULTS AND DISCUSSION

Dissolved oxygen & Biological oxygen demand

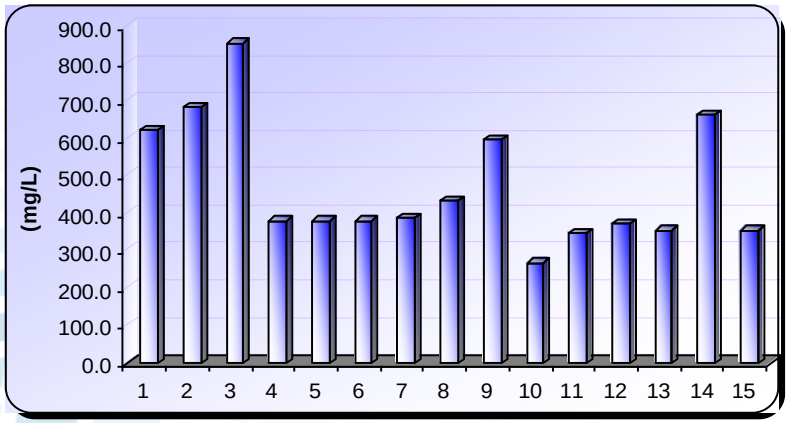


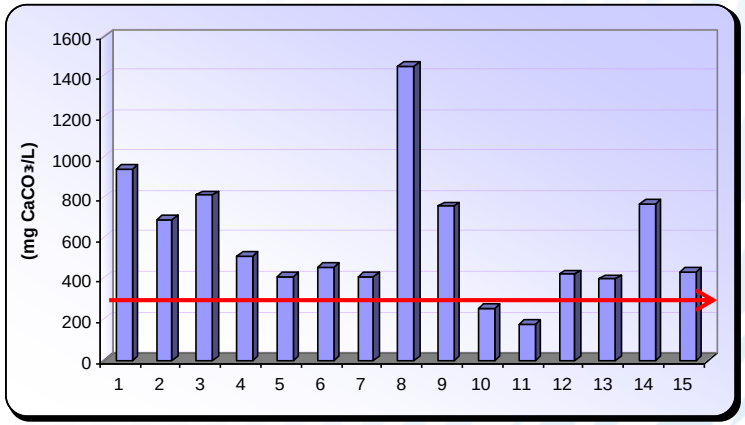


- The dissolved oxygen content ranged from 1.4 mg/L (S 4) to 13.9 mg/L (S 8).
- Biological oxygen demand for all water samples varied from 0.03 mg/L (S5) to 2.81 mg/L O_2 (S8).
- Based on the requirement of the EU Drinking Water Directive, all waters are classified under the A1 (<3 mg / L) quality.

RESULTS AND DISCUSSION

Alkalinity & Hardness



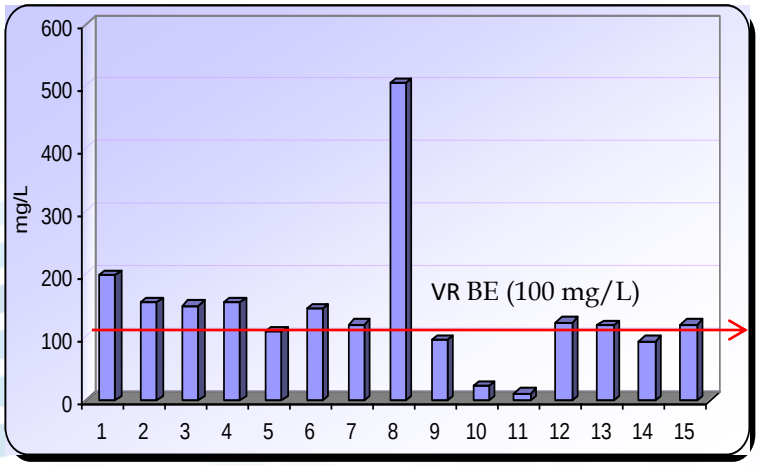


❑ Alkalinity of water samples ranged from 268 mg/L to 857 mg/L CaCO3 , and were within the WHO standards (1000 mg / L).

❑In this study, values of hardness of all samples ranged from 179 mg $CaCO_3$/L (S11) to 1453 mg $CaCO_3$/L (S8). Generally, hardness in the study area could be described as hard to very hard (ccording to McGoowan (2000), as approximately 87% of the samples had shown values >300 mg $CaCO_3$/L.

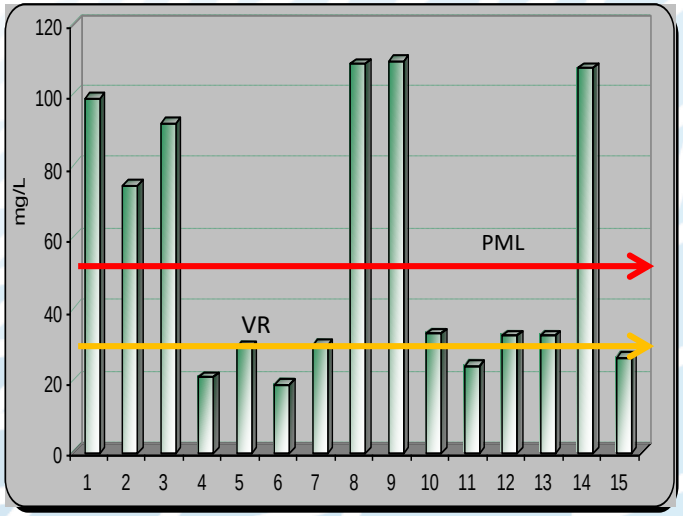
❑In general, deepwater wells present lower alkalinity and hardness compared to shallow well waters.

RESULTS AND DISCUSSION
Ca^{2+} & Mg^{2+}

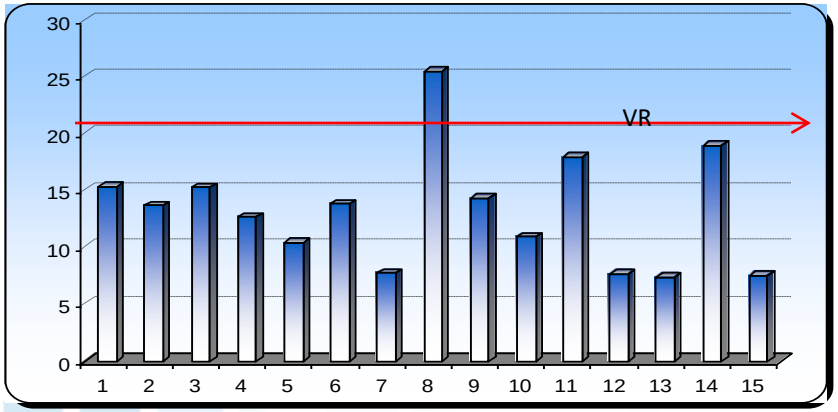


❑Concentrations of calcium ranged between 11.2 mg/L (S11) to 507.2 mg/L (S8).

✓The magnesium level recommended by the EU Directive is 30 mg / L. Only wells S4, S6 and S11 meet the EU standard recommendation, while PMLs exceed 40% of the samples.



RESULTS AND DISCUSSION
Na^+ & K^+



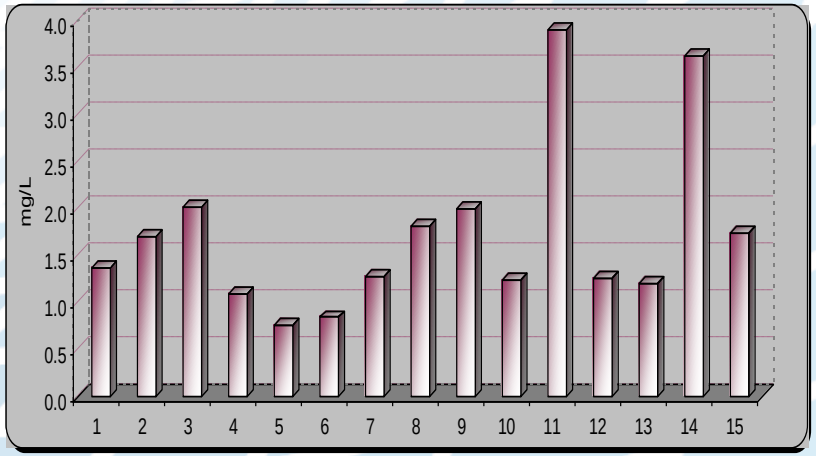
➢Sodium concentration ranged from 7.4 mg / L (S 13) to 25.5 mg / L (S8).

➢ Based on the requirement of the EU, we can say that all samples analyzed, except S8, meet this requirement.

➢The concentration of potassium ranged from 0.8 mg / L (S 6) to 3.9 mg / L (S11).

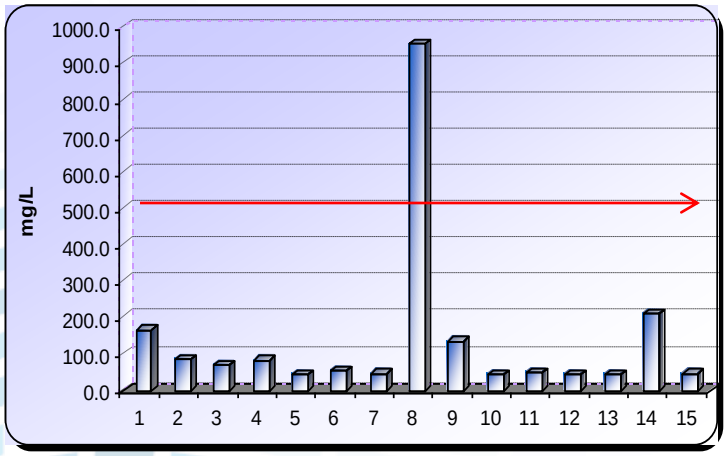
➢These values are much lower than the EU standards for drinking water quality (10mg / L).

➢The level of potassium in deep wells are generally lower than in shallow wells.



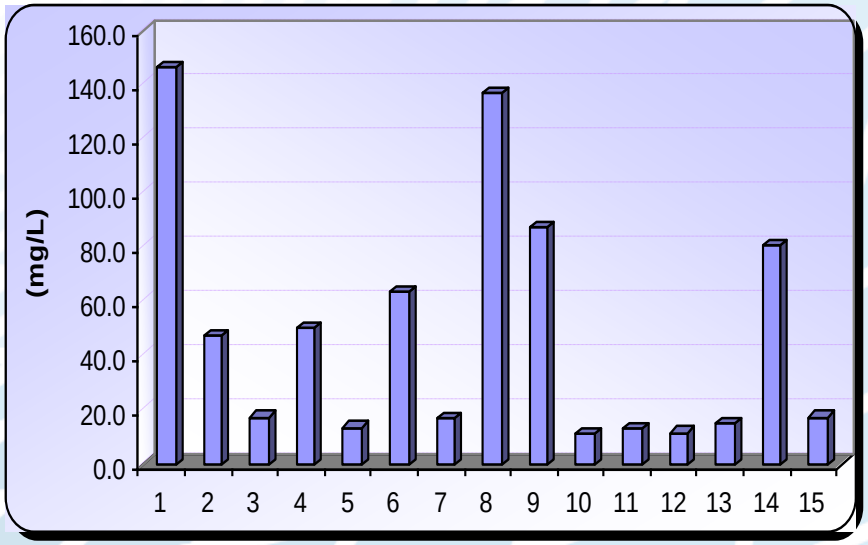
RESULTS AND DISCUSION

Chloride & sulfate



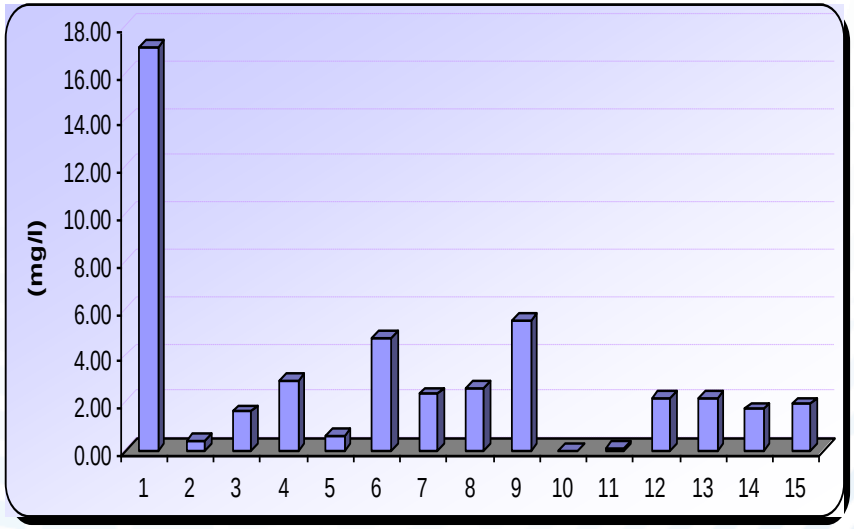
➢The chloride concentrations were within the limit prescribes by WHO (250 mg/L) except water sample collected from sites S8 and S14. The higher values of chloride in these sites may be due to the mixing of sewage and leaching from waste sites.

➢The sulfate concentrations in all the water samples were within the international standards for drinking water. This sulfate ion is generally harmless, except its effect on taste. The major physiological effects resulting from the ingestion of large quantities of sulfate are catharsis, dehydration and gastrointestinal irritation.



RESULTS AND DISCUSION

Nitrate



❑The nitrate content in the water ranged from 0.18 mg / L (S10) to 17.14 mg /L (S1). Concentrations of nitrate ion in water samples are below the international recommended values for drinking water.

WATER QUALITY INDEX

- The weighted arithmetic index method (Brown et al.,1970) has been used for the calculation of WQI.

$$WQI = \sum q_n W_n / \sum W_n$$

- The quality rating (qn) has been calculated using the following expression:

$$q_n = 100[V_n - V_{i0}]/[S_n - S_{i0}]$$

- Unit weight has been calculated by a value inversely proportional to the recommended standard value *Sn* of the corresponding parameter.

$$Wn = K/Sn \qquad K = 1/\Sigma 1/Sn$$

WATER QUALITY INDEX

- In the present study, for the calculation of water quality index thirteen parameters has been chosen and has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes.

Parameters	Unit	WHO Standards	Unit Weight
pH	-	*6.5-8.5*	*0.1926*
Electrical Conductivity	*µS/cm*	*300*	*0.0055*
Total Dissolved Solids	*mg/L*	*500*	*0.0033*
Total alkalinity	*mg/L*	*120*	*0.0136*
Total hardness	*mg/L*	*300*	*0.0055*
Total suspended solids	*mg/L*	*500*	*0.0033*
Calcium	*mg/L*	*75*	*0.0218*
Magnesium	*mg/L*	*30*	*0.0546*
Chloride	*mg/L*	*250*	*0.0065*
Nitrate	*mg/L*	*45*	*0.0364*
Sulfate	*mg/L*	*150*	*0.0109*
Dissolved oxygen	*mg/L*	*5.00*	*0.3274*
Biological oxygen demand	*mg/L*	*5.00*	*0.3274*

WATER QUALITY INDEX

Parameters Station 1	*Observed values(Vn)*	*Standard Values(Sn)*	*1/Sn*	*Unit Weight(Wn)*	*Quality rating (qn)*	*Wnqn*
pH	6.96	6.5-8.5	0.117	0.1926	-2.67	-0.51
Electrical Conductivity	1810	300	0.003	0.0055	603.33	3.32
Total Dissolved Solids	1346	500	0.002	0.0033	269.20	0.89
Total alkalinity	623	120	0.008	0.0136	519.17	7.06
Total hardness	945	300	0.003	0.0055	315.00	1.73
Total suspended solids	14.46	500	0.002	0.0033	2.89	0.01
Calcium	199.5	75	0.013	0.0218	266.00	5.80
Magnesium	99.4	30	0.033	0.0546	331.33	18.09
Chlorides	168	250	0.004	0.0065	67.20	0.44
Nitrate	17.14	45	0.022	0.0364	38.09	1.39
Sulfate	146.5	150	0.004	0.0109	97.67	1.06
Dissolved oxygen	1.46	5	0.2	0.3274	137.26	44.94
Biological oxygen demand	0.16	5	0.2	0.3274	3.20	1.05
Water Quality Index =Σ qnWn/ΣWn= 84.5						

WATER QUALITY INDEX

Station	Latitude	Longitude	Location	Depth (m)	Water Quality Index	Water quality status
S1	40°43'22.56"N	19°37'32.65"E	Sheqisht	35	84.5	Very poor water quality
S2	40°43'28.84"N	19°37'28.94"E	Sheqisht	100	77.8	Very poor water quality
S3	40°43'46.89"N	19°37'19.28"E	Sheqisht	25	86.0	Very poor water quality
S4	40°43'10.93"N	19°38'31.16"E	Sheqisht	70	66.7	Poor water quality
S5	40°44'0.49"N	19°39'58.18"E	Marinëz	1900	59.1	Poor water quality
S6	40°43'47.74"N	19°40'5.60"E	Marinëz	1700	44.3	Good water quality
S7	40°43'25.19"N	19°39'28.84"E	Marinëz	45	49.0	Good water quality
S8	40°42'59.14"N	19°39'35.97"E	Zharrëz	100	70.7	Poor water quality
S9	40°45'45.90"N	19°39'2.93"E	Zharrëz	100	77.0	Very poor water quality
S10	40°45'46.65"N	19°37'57.62"E	Kallm	2000	62.5	Poor water quality
S11	40°45'22.90"N	19°37'51.45"E	Kallm	25	60.2	Poor water quality
S12	40°44'54.07"N	19°38'57.37"E	Kallm	35	49.1	Good water quality
S13	40°44'43.22"N	19°38'44.03"E	Belinë	1700	47.6	Good water quality
S14	40°44'39.14"N	19°38'50.60"E	Belinë	20	84.4	Very poor water quality
S15	40°44'37.28"N	19°38'48.62"E	Belinë	1300	53.6	Poor water quality

- WQI values of the study area ranges from 44.3 to 86.0.
- The minimum WQI has been recorded at site S6 , while maximum WQI has been recorded at site S3.

WATER QUALITY INDEX

WQI Classification of Groundwater in the Study Area

WQI Values	***Category Sample***	***Stations (%)***
0-25	Excellent water quality	-
26-50	Good water quality	6, 7, 12, 13 (26.7%)
51-75	Poor water quality	4, 5, 8, 10, 11, 15 (40%)
76-100	Very poor water quality	1, 2, 3, 9, 14 (33.3%)
100 and above	Unfit for drinking	-

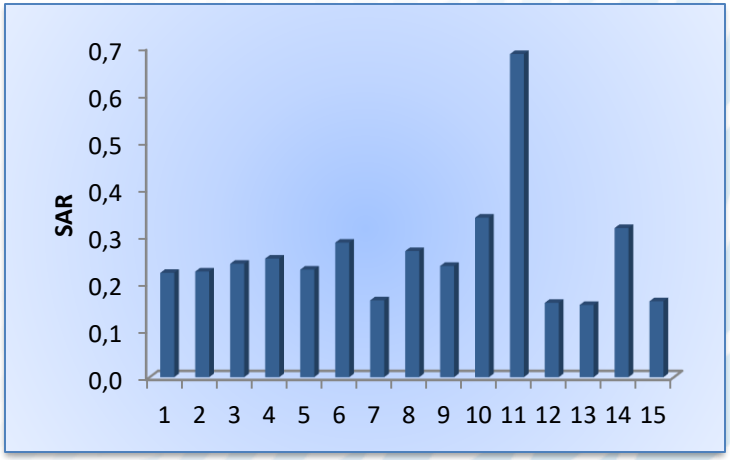
- It has been observed that the majority of groundwater samples classified in poor (40%) to very poor (34%) category indicating that groundwater was therefore not suitable for human consumption without adequate treatment.

SUITABILITY FOR IRRIGATION

- ***Sodium adsorption ratio (SAR)***

Sodium adsorption ratio can indicate the degree to which irrigation water tends to enter into cation exchange reactions in soil. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure and becomes compact and impervious.

$$SAR = \frac{[Na^+]}{\sqrt{\frac{1}{2}([Ca^{2+}]+[Mg^{2+}])}}$$



In the study area, SAR values ranged from 0.153 meq/L to 0.685 meq/L, indicating that all samples are suitable for irrigation purposes.

Criteria:

<10 excellent (S1),
10–18 good (S2),
18–26 doubtful (S3),
>26 unsuitable (S4)

SUITABILITY FOR IRRIGATION

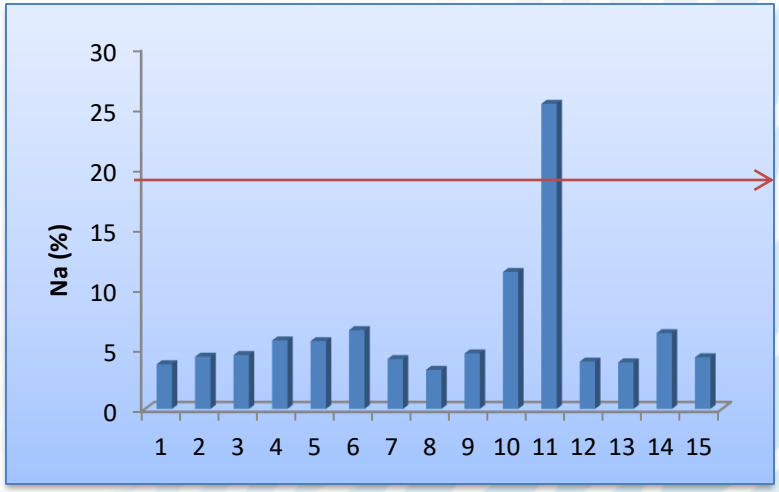
- ***Sodium percentage (%Na)***

Sodium concentration plays an important role in evaluating the groundwater quality for irrigation because sodium causes an increase in the hardness of the soil as well as a reduction in its permeability.

$$Na\% = \frac{(Na^{+} + K^{+}) \cdot 100}{(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})}$$

Criteria:

<20	**excellent,**
20–40	**good,**
40–60	**permissible,**
60–80	**doubtful,**
>80	**unsuitable**



Based on this classification, all of groundwater samples belong to the **excellent** category.

SUITABILITY FOR IRRIGATION

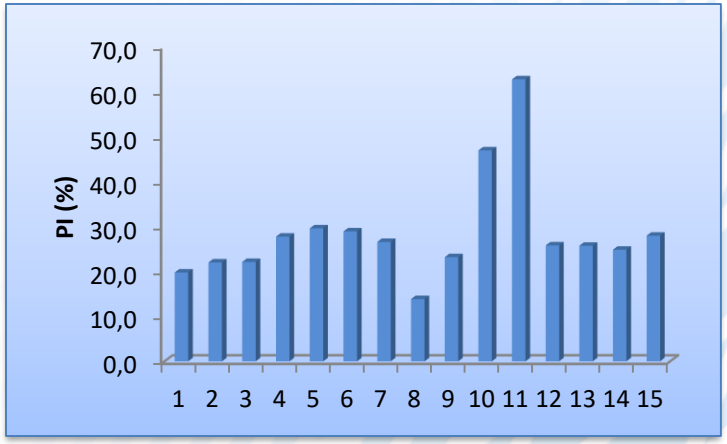
- ***Permeability index (PI)***

The soil permeability is affected by long term use of irrigation water as it influenced by sodium, calcium, magnesium, and bicarbonate content of the soil.

$$PI(\%) = \frac{(Na^{+} + \sqrt{HCO_3^{-}})}{(Ca^{2+} + Mg^{2+} + Na^{+})} 100$$

Criteria:

<25 (Class III)	**Unsuitable**
25-75 (Class II)	**Good**
> 75 (Class I)	**Excellent**



The PI values range from 13.9 to 62.8 % and indicate that 60% of the water samples of the study area fall within class II which make the water suitable for irrigation purposes.

CONCLUSIONS

- The evaluation of the groundwater quality in Patos-Marinza region presents a special importance because of unauthorized use as drinking water.

- Quality assessment is based on the requirement of the Council Directive relating to the quality of water intended for human consumption [98/83/EC] as well as on Water Quality Index.

- Water from these resources meets the A1 category requirements (according to 75/440/EEC) for the measured parameters and may be used as drinking water after the necessary treatments, with the exception of well S8, which is mainly categorized as A2.

- The water quality based on WQI indicated that 27 % of sampling wells are fit for drinking purpose, while 40% and 33 % of wells fall in poor and very poor status respectively.

- The physico-chemical analysis revealed that the groundwater in the study area is better for irrigation rather than for drinking purpose.

Thank you!