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# The Water Quality of Devoll and Osum Rivers and Its Impact on the Agricultural Soils

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## Abstract:
**The Devoll River, one of the sources of Seman River, joins Osum River in the proximity of Kuçova. The above are both used for irrigation purposes. The studies performed (over a period of four years 2003-2006) were aimed at determining the water quality of the Devoll and Osum rivers together with their impact in agriculture. The maximal sodium values recorded in the Devoll and Osum rivers were 1 mg/L (2003) and 0.66 mg/L (2006) respectively. Magnesium levels ranged from 2.67 mg/L (2003) to 2.96 mg/L (2006) with a 4 year average of 2.79 for the Devoll river and 2.02 mg/L (2006) to 3.55 mg/L (2005) with a 4 year average value of 2.57 mg/L for the Osum river. The nutritious elements levels were generally low. The average value of N – $NO_3^-$ recorded in the Devoll waters reached 2.02 mg/L, with a maximal value of 5.88 mg/L (2006). The average value of N - $NH_4^+$ was calculated to be 1.12 mg/L, while the maximal value reached 2.1 mg/L (2006). $PO_4^{3-}$ and $K^+$ had a maximal value of 0.1 mg/L (2005) and 11 mg/L (2006) respectively. The last value was 5.5 times bigger than the allowed one. For the Osum River the maximal values of N - $NO_3^-$ and N – $NH_4^+$ were 9.02 mg/L (2006) and 3.22 mg/L (2006) respectively. The maximal values of $PO_4^{3-}$ and $K^+$ were recorded to be 0.228 mg/L (2004) and 12 mg/L (2006). This maximal value is six times bigger than the allowed value. On average nutrient concentrations were higher in 2006 compared to previously recorded values. These concentration levels, with the exception of $K^+$, were however within the FAO standard levels.**

**Keywords:** **irrigation, nutrients, parameters, soil, water quality**

## 1.0 Introduction:
The hydrographical territory of Albania is approximately 44,000 km$^2$ or 57% more than the national space of our country. The average altitude of this territory is over 700 m above the sea level. Rivers have always been the most important freshwater resources. They find multiple uses in agriculture, industry, transportation, aquaculture, public water supply etc. (Ravindra et.al, 2003). The multiannual average discharge of Albanian rivers is about 1,245 m$^3$/s. All the rivers flow in the sea direction with about 40 billion m$^3$ water/year (AKBN, 2010).

Devoll and Osum rivers are the main afluents of the Seman River. Their watershed areas are 3130 km$^2$ and 2150 km$^2$ respectively (Pano, 2008). With their geographic positions, both rivers have been used for irrigation purposes and have been a great part of agricultural and environmental strategies in our country.

The soil and water quality play a prominent role in the irrigation process. If they were not to be compatible with one another, the watering process might have a negative impact on the physical – chemical abilities of the soil. The estimation of water quality is based on salinity, sodium and toxicity of chemical elements (Goel 2006). Salinity is the most important criterion for evaluating irrigation water quality (Ghassemi, *et al.,* 1995). High salt concentrations prevent the uptake of water by plants causing crop–yield reductions. This occurs when salts accumulate in the root zone to such an extent that the crop is no longer able to extract sufficient water from the salty soil solution, resulting in water stress for a significant period (FAO, 1994).

Salt concentration can exert an effect or prohibit and delay plant growth. (Rhades, 1977; Raymond *et al.*, 1995). The irrigation process with low quality water generally does not represent an immediate damage to the plant. However, the damage is inflicted in the long run, as the salts or water sodium will be accumulated in the soil and lowers its productivity.
Regardless of the effects of the hydrochemistry of the Devoll and Osum Rivers, there are no previous studies analyzing the physico-chemical parameters, nutrients, salinity etc. of the water of the two rivers. Moreover, there exist no evaluations of the effects the latter can have on the soil and cultivated vegetation. The object of the study is to analyze the water quality of the Devoll and Osum rivers. The aim of the study is to assess their impact on agricultural lands and to recommend plants that are more suitable for cultivation.

## 2.0 Materials and Methods:

The Osum and Devoll rivers and the agricultural soils adjacent to them were monitored for a period of four years (2003 – 2006).

### *2.1 The Investigated Area*

Albania has a mediterranean climate, with a relatively short and soft winter and with a hot and very dry summer. Albania's climate is very different depending on the region with contrasts in temperature, precipitation, sunshine, air humidity, etc. Albania comprises a very concetrated river network. The upper flow has a mountanous character, is fast and erosive, whereas the lower flows have a field character. The Devoll River (196 km) has its sourse at the foundations of the Gramoz Mountain. It continues its flow north to the city of Bilisht, returning then west through the valley between the Dry Mountain north and that of Morava in the south, where it joins river Osum (which flows too from the Gramoz Mountain). Together they form the Seman River. The water gathering surface of the Devoll River is 3.130 km². The average discharge is around 49.5 m³/s. The Osum River is 161 km, with a water gathering surface of 2.150 $km^2$, average altitude of 828 m and average multiannual discharge of 32.5 $m^3$/s. Both rivers have an important impact on agriculture.


Figure 1. Map of area under investigation

Figures 2 and 3. Areas of samples collection

Figure 4. Devoll River, sampling place

Figure 5. Devoll River, sampling place

Figure 6. Osum River, sampling place

Figure 7. Osum River, sampling place

## *2.3 Samples and Analytical Methods*

The locations used for sampling are located in: Murras – Elbasan, Fushë – Devoll, Devoll – Korçë dhe Berat. The collection of water samples has been done conforming to standard methods ISO 5667 - 3:200. The collection of soil samples has been done conforming to standard methods ISO 10381-1993. Concerning the measurements, contemporary methods were used: spectrometric and standard classical methods. The determination of the exchange cation capacity has been done with the employment of the methodics ISO 11260-94. Nitrate, ammonium, phosphate etc., levels were analyzed according to the standard methods described by APHA, 1998 & Rodier 1984. Samples for cations (calcium, magnesium) were analyzed by atomic absorbance spectrophotometry, while sodium was measured by flame photometry. Bicarbonate level was determined by the acid titration method while the organic matter was determined by the permanganate oxidation method (Golterman, 1978). The physico-chemical parameters such as pH and temperature were measured in the field using a pH meter while the conductivity of water was measured by a conductivity meter.

The soil samples tested were implemented according to ISO 10381-1993 method standard. For parameter measures, the contemporary methods of determination such as: Spectroscopy of Atomic Absorption method and interfrequently classical standard methods of analysis were used. The determination of effective cathion exchange, capacity and base saturation level was achieved via the usage of a barium chloride solution ISO 11260-94. The soil quality sampling was implemented according to ISO 5667 -1-1980. The water samples were analyzed according to the salt contents, pH, electrical conductivity, kations, anions ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $CO_3^{2-}$, $HCO_3^{-}$, $Cl^{-}$, $SO_4^{2-}$), nutritious elements ($NO_3^{-}$ , $NH_4^{+}$, $PO_4^{3-}$, $K^{+}$), acidity, ratio of sodium absorption, dry residue and heavy metals (Zn, Pb, Mn, Fe, Cu, Cr).

The SAR (Sodium Absorption Ratio) parameter evaluates the sodium hazard in relation to calcium and magnesium concentrations (Richards 1954). SAR was calculated using the following formula:

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

$[Na^{+}]$, $[Ca^{2+}]$, dhe $[Mg^{2+}]$ are the concentrations in mmol/L of sodium, calcium dhe magnezium ions in the soil solution. The $Na^{+}$, $Ca^{2+}$ dhe $Mg^{2+}$ ion concentrations were determined by extracting the ions from the soil in the solution and using the Spectroscopy of Atomic Absorption. When SAR increases over 12 – 15, there are serious physical problems and furthermore plants show difficulties in the absorption of water.

## 3.0 Results and Discussion

The results of the parameters are presented on Tables (1 - 7) and Graphics (1 – 9).

### *3.1 The pH Measurement*

For Devoll and Osum Rivers, the analyzed water samples had pH values of 7.2 – 7.7 and 7.1-7.9 respectively (Table 1 and 2). Conforming to the FAO specifications, the most adequate pH intervals on irrigation waters are 6.0-8.5, (Ayers *et.al.* 1976, 1885, 1994) whereas conforming to the *Irrigation water quality criteria* pH = 5 - 7 (Bradli 1998, 2000) intervals are recommended.

### *3.2 Electric Conductivity (EC)*

The average electric conductivity of the water samples collected in the Devoll River in the monitored years 2003-2006 has been 0.48-0.65 $dSm^{-1}$ while for the Osum river 0.45-0.53 $dSm^{-1}$ (Table 1 and 2). The salinity tolerance of plants is related to the salinity of the soil, described as EC. EC is directly related to the concentration of ions dissolved in the water. All the collected water samples (Figures 3 and 4, Devoll River and Figures 5 and 6, Osum River) were of no salinity, i.e. have no negative effect on the agricultural soil and its cultivated plants.

### *3.3 The Dry Residue*

The values of dry residue for the waters of the Devoll River are 0.189 g/L (2005) in 0.508 g/L (2003) with an average value of 0.324 g/L and for Osum River are 0.106 g/L (2005) in 0.316 g/L with an average value of 0.241 g/L, (Table 1 and 2).

**Table 1.** Physico-Chemical Parameters of Devoll River in the samples collected during 2003 - 2006.

| Parameters | Units | Intervals | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| pH | - log [ H+] | 6.0 - 8.5 | 7.2 | 7.7 | 7.4 | 7.5 |
| Conductivity (ECW) | (dS/m) | 0 – 3 | 0.65 | 0.48 | 0.52 | 0.57 |
| Dry residue | g/l | | 0.25 | 0.32 | 0.11 | 0.29 |
| SAR | m.e/l | 0 – 15 | 0.64 | 0.39 | 0.23 | 0.30 |

**Table 2.** Physico-Chemical Parameters of Osum River in the samples collected during 2003 - 2006.

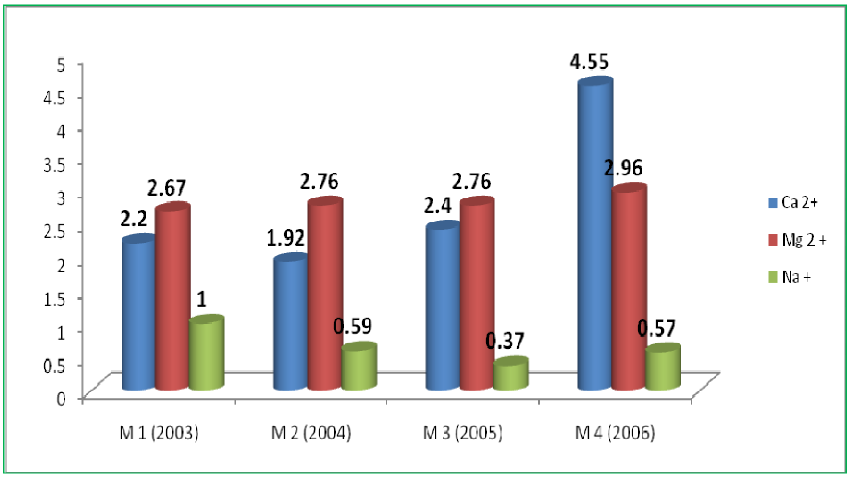
| Parameters | Units | Intervals | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| pH | - log [ H+] | 6.0 - 8.5 | 7.1 | 7.9 | 7.1 | 7.1 |
| Conductivity (ECW) | (dS/m) | 0 – 3 | 0.47 | 0.45 | 0.46 | 0.53 |
| Dry residue | gr/l | | 0.25 | 0.32 | 0.11 | 0.29 |
| SAR | m.e/l | 0 – 15 | 0.44 | 0.39 | 0.25 | 0.38 |

**Table 3.** Nutrient Levels in the Devoll River Samples 2003 – 2006.

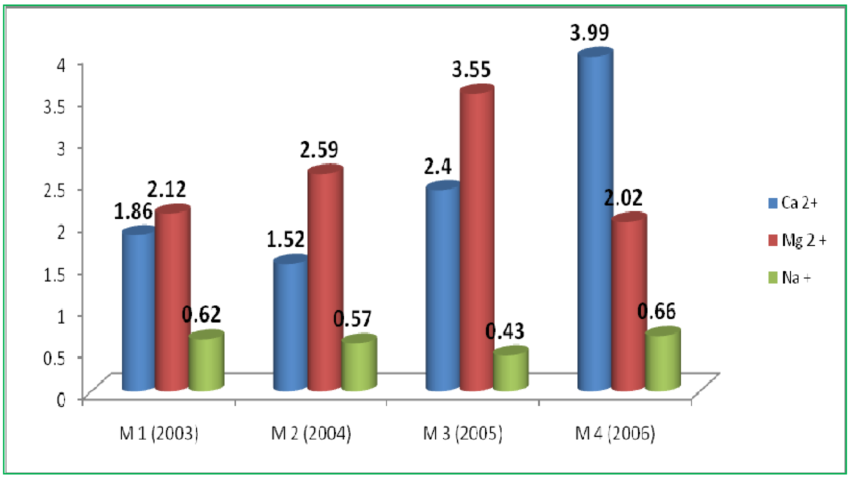
| Nutrients | Units | Intervals | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| N- $NO_3^-$ | mg/l | 0-10 | 0.28 | 0.56 | 1.34 | 5.88 |
| N- $NH_4^+$ | mg/l | 0-5 | 0.7 | 0.28 | 1.4 | 2.1 |
| $PO_4^{3-}$ | mg/l | 0-2 | 0.066 | 0.074 | 0.100 | 0.042 |
| $K^+$ | mg/l | 0-2 | 5.42 | 2.761 | 1.668 | 11 |

**Table 4.** Nutrient Levels in the Osum River Samples 2003 – 2006.

| Nutrients | Units | Intervals | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| N- $NO_3^-$ | mg/l | 0-10 | 0.14 | 0.56 | 2.8 | 9.02 |
| N- $NH_4^+$ | mg/l | 0-5 | - | 0.28 | 1.26 | 3.22 |
| $PO_4^{3-}$ | mg/l | 0-2 | 0.108 | 0.228 | 0.154 | 0.015 |
| $K^+$ | mg/l | 0-2 | 2.63 | 1.881 | 1.356 | 12 |




**Graph 1.** Cations in mg/L River Devoll (2003 – 2006)




**Graph 2.** Cations in mg/L River Osum (2003 – 2006)

## 3.4 Sodium

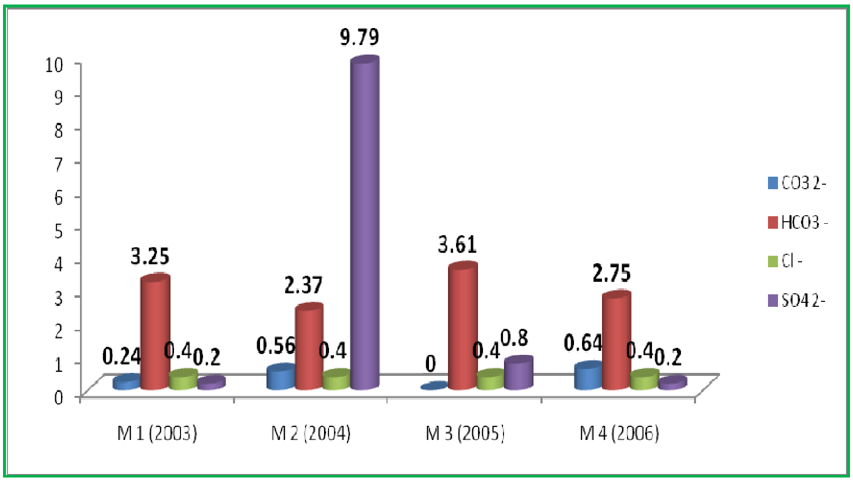
The sodium values wereas follows: minimal values of 0.37 mg/L (2005) in the Devoll River with a maximal value of 1 mg/L (2003). In the Osum River the minimal values were 0.43 mg/L (2005) and the maximal values 0.66 mg/L (2006). High concentration of ions $Na^+$ in water is undesirable because Na interferes with other ions absorption, destroying the soil structure, closing the soil pores and reducing the water flowing (Laze *et al.,* 2002). The medium and high levels of sodium in water could become toxic for some sensitive plants (fruit trees or ornamental plants).

## 3.5 Calcium and Magnezium

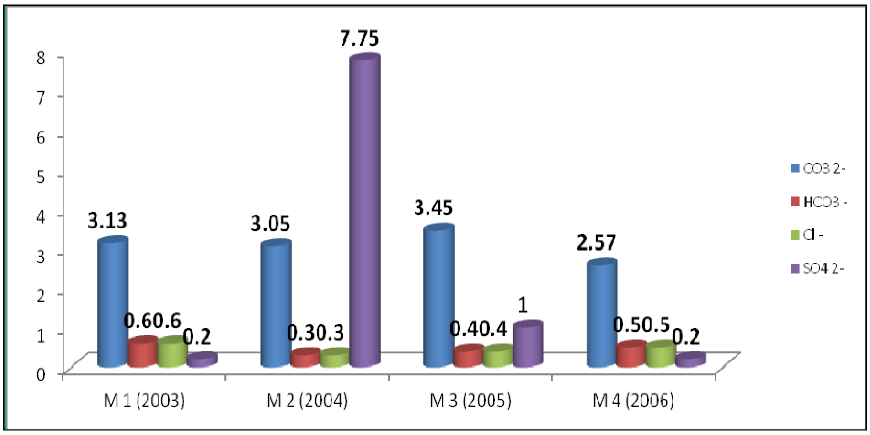
The calcium concentration in the Devoll waters was 1.92 mg/L (min value, 2004) and 4.55 mg/L (max value, 2006) (Graph.1). The average value for the 4 years duration was 2.77 mg/L. The calcium concentration in the Osum waters was 1.52 mg/L (min value, 2004) and 3.99 mg/L (max value, 2006), (Graph.2). The average value was 2.44 mg/L. For magnezium the concentration in the Devoll river varied from 2.67 mg/L (2003) to 2.96 mg/L (2006) with a 4 year average of 2.79; for the Osum River it varied from 2.02 mg/L (2006) to 3.55 mg/L (2005) (Graph.2) with a 4 year average value of 2.57 mg/L.
The values of SAR (Sodium Absorption Ratio) are shown in tables 1 and 2. They range from 0,23 – 0,64 m.e./L for Devoll River and from 0,25 – 0,44 m.e./L for Osum River. The medium and high levels of calcium and magnezium in water could become toxic for some sensitive plants.

## 3.6 Anion Concentration

The anion levels in water were as follows: the sulphate ions concentration in the Devoll river was 0.2 (min values) and 9.79 mg/L (max value) for 2003 and 2004 respectively. The measured minimal and maximal values are shown Graph 3. In the Osum River, the concentrations of the carbonate ions, hidrogen carbonates and chlorine are presented in Graph 4. A high value of hydrogen carbonates in water value leads to an increase in the adsorption of sodium on soil. Irrigation water having hydrogen carbonates values greater than 5 has been considered harmful to the growth of plants. Water with hydrogen carbonates values above 2.5 is not considered suitable for irrigation purposes, and water with hydrogen carbonates values less than 1.25 is considered safe. (Yang *et.al* 2012). Chlorides are important inorganic anions which contain varying concentrations in natural waters (Makhoukh *et. al* 2011). Chlorides are troublesome in irrigation water and also harmful to aquatic life (Rajkumar *et.al* 2004).




**Graph. 3.** Anions in mg/L River Devoll (2003 – 2006)




**Graph 4**. Anions in mg/L River Osum (2003 – 2006)

### *3.7 Nutritious Elements*

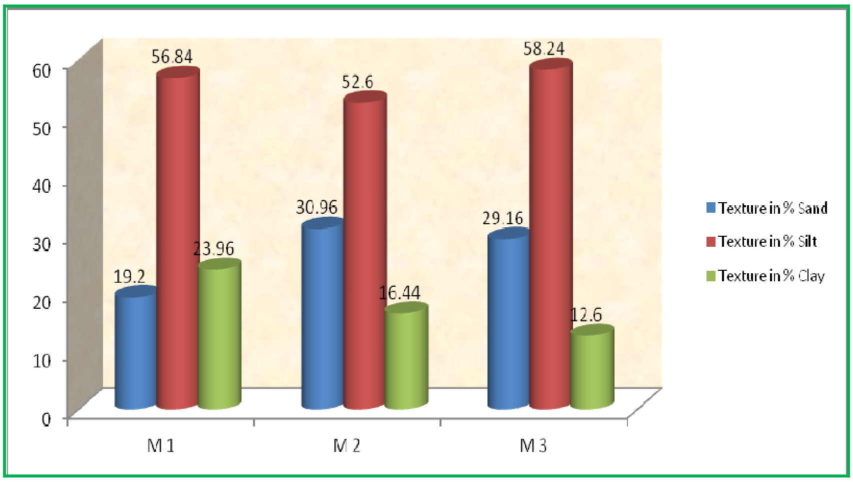
The nutritious element levels are generally low for N - $NO_3^-$ in the Devoll waters with the average value being 2.02 mg/L. The minimal measured value was 0.28 mg/L (2003) and the maximal one was 5.88 mg/L (2006). All the water samples had higher $NO_3^-$ levels, but less than the 10 mg/L limit calculated as N. Nitrate is an acute contaminant, which means that a single exposure can affect the health of people. (Fraser and Chilvers 1981). For N - $NH_4^+$, the average value was 1.12 mg/L, the minimal value 0.28 mg/L (2004) and the maximal value was 2.1 (2006). The average value for $PO_4^{3-}$ was 0.071 mg/L, the minimal value was 0.042 mg/L (2006) and the maximal value 0.1 mg/L (2005). For $K^+$ the average value was 5.11mg/L, the minimal value 1.67 mg/L (2005) and the maximal value 11 mg/L (2006). This maximal value is 5.5 times bigger than the allowed value

(Table 3). For the Osum River, the average value for N - $NO_3^-$ was 2.93 mg/L, the minimal measured value 0.14 mg/L (2003) and the maximal value was 9.02 mg/L (2006). For N - $NH_4^+$, the average value was 1.57 mg/L, the minimal value 0.28 mg/L (2004) and the maximal value was 3.22 (2006). For $PO_4^{3-}$ the average value was 0.126 mg/L, the minimal value 0.015 mg/L (2006) and the maximal value 0.228 mg/L (2004). The average value for K+ was 4.47 mg/L, the minimal value reached 1.88 mg/L (2004) and the maximal value was 12 mg/L (2006). This maximal value is 6 times bigger than the allowed value (Table 4). Nutrients can play a role in toughening up the plant to make it more resistant to dry conditions, disease and wear. For example, sufficient potassium encourages the thickening of cell walls in turf leaves, toughening the plant so it becomes more wear resistant (Handreck and Black 2002). With the only expection of Potasium, the nutrient levels in the waters of Osum and Devoll in all samples taken during 2004 – 2006 result in the status "bad" or "very bad" conforming to the NIVA classification. (Bratli, 1998 and 2000).

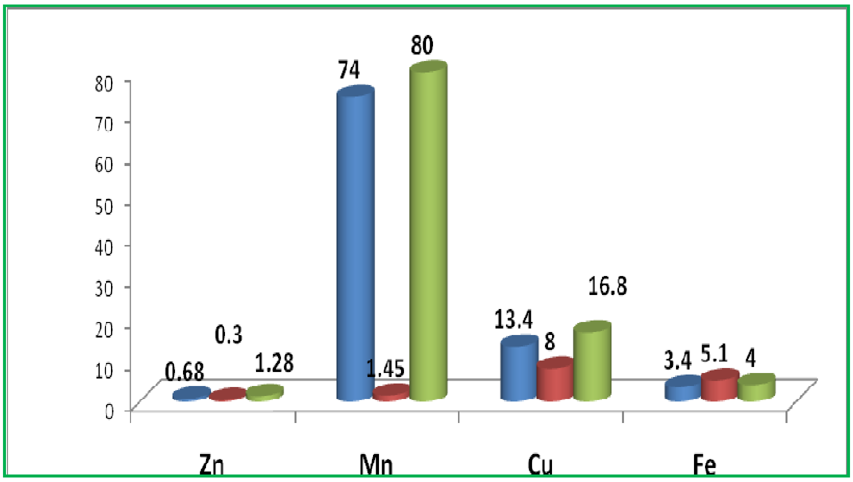
### *3.8 Soil Samples*

The soil texture results are presented in Graph 5, for the soil adjacent to the Devoll River, and in Graph 8, for those adjacent to River Osum. It can be noticed from the charts, that the texture of these soils is respectively silty – sandy – clay and silty – clay – sandy. Referring to the conductivity EC (ds/m), Tables 1 and 2, plants that should be cultivated in these areas are recommended for salinity ranging from "low" to "averagely sensitive plants" according to Table 8.

The heavy metals and microelements in both rivers have not reached disturbing levels (Graph 6, 7 and 9). Magnesium, an essential nutrient for plants as well as for animals, is washed from rocks (dolomite, magnesite, etc.) and subsequently ends up in water, being also responsible for water hardness. (Trivedi et. al 2009). Such soils tend to have a relatively high pH (approximately 7–10), as sodium carbonate is much more soluble than calcium or magnesium carbonates; As a result, higher concentrations of carbonate and bicarbonate are maintained in sodic soil solutions (Rengasamy and Olsson 1991, Brady and Weil 1999). Rivers contain approximately 4 mg/L of magnesium and a concentration of 30 and 50 mg/L is recommended for drinking waters in EPA (U.S. EPA) 2002.



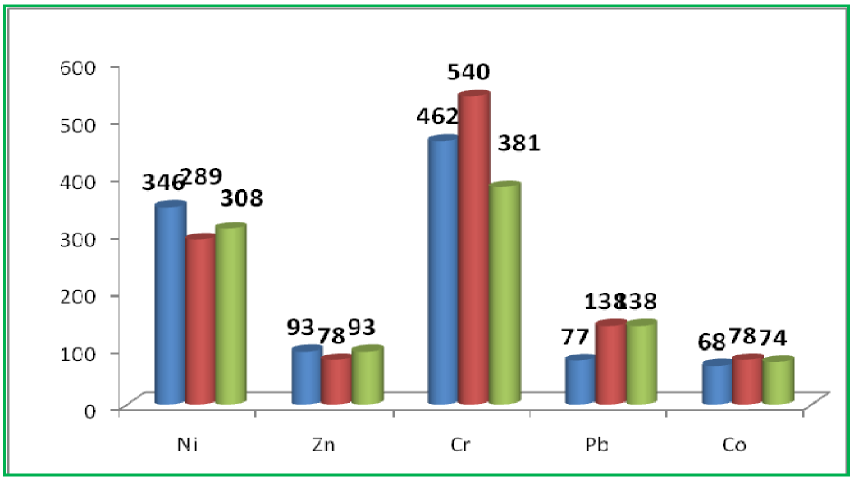

**Graph 5.** Texture analysis of adjacent soil to River Devoll.



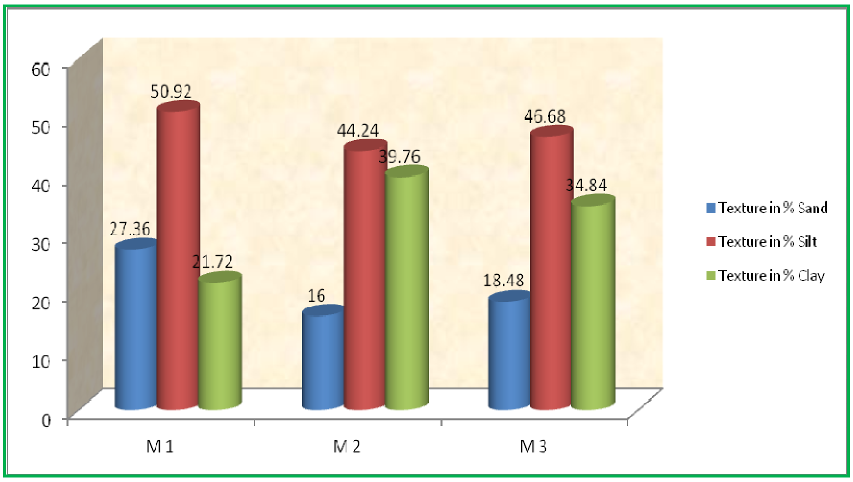

**Graph 6.** Microelements in the adjacent soils to River Devoll.

**Table 5.** Monitored parameters in the adjacent soils to River Devoll – Korcë

| Samples | pH | K | Humus | N | P | K | Ca | Mg | Na | KKK |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ppm | % | | ppm | m.e/100 gr Soil | | | | |
| P 1 | 6.5 | 133 | 2.6 | 0.133 | 38.4 | 0.34 | 16 | 6.5 | 0.74 | 36.07 |
| P 2 | 7.9 | 95 | 1.9 | 0.098 | 32.2 | 0.24 | 21.9 | 2.5 | 0.73 | 26.56 |
| P 3 | 7.2 | 143 | 4.5 | 0.217 | 45.0 | 0.37 | 20.4 | 5.8 | 1.25 | 32.23 |



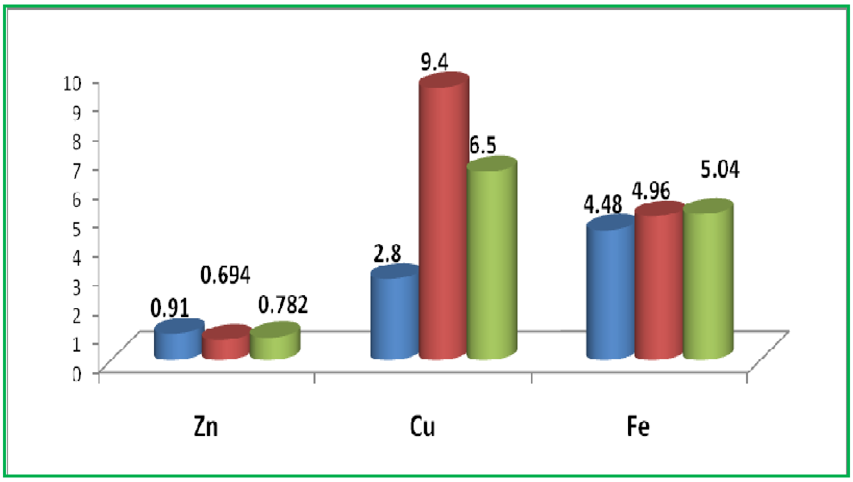

**Graph 7.** Heavy metals in the adjacent soils to River Devoll –Korcë (2003 – 2006) in mg/Kg




**Graph 8.** Analysis of the mechanical contents of the adjacent soils to River Osum in 3 points.

**Table 6.** Monitored parameters in the adjacent soils to River Osum

| Samples | pH | K | Humus | N | P | K | Ca | Mg | Na | KKK |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ppm | % | | Ppm | m.e/100 gr Soil | | | | |
| P 1 | 8.0 | 93 | 1.9 | 0.176 | 0.13 | 0.24 | 17. 3 | 3.2 | 0.13 | 21.46 |
| P 2 | 8.3 | 174 | 1.2 | 0.112 | 0.30 | 0.44 | 17. 6 | 4.7 | 0.30 | 24.35 |
| P 3 | 8.0 | 280 | 1.6 | 0.149 | 0.26 | 18.6 | 3.38 | 0.72 | 0.26 | 27.85 |




**Graph 9**. Microelements in the adjacent soils to River Osum. (2003-2006).

**Table 7.** General classification of water sodium hazard based on SAR values

| SAR values | Sodium hazard of water | Comments |
|---|---|---|
| 1-9 | Low | Use on sodium sensitive crops must be cautioned |
| 10-17 | Medium | Amendments (such as gypsum) and leaching needed |
| 18-25 | High | Generally unsuitable for continuous use |
| ≥26 | Very High | Generally unsuitable for use |

**Table 8.** Soil and water salinity criteria based on plant salt tolerance groupings

| Plant salt tolerance Grouping | Water or soil salinity rating | Average root zone s alinity EC (dS/m) |
|---|---|---|
| Sensitive crops | Very low | <0.95 |
| Moderately sensitive crops | Low | 0.95 – 1.9 |
| Moderately tolerant crops | Medium | 1.9 – 4.5 |
| Tolerant crops | High | 4.5 – 7.7 |
| Very tolerant crops | Very high | 7.7 – 12.2 |
| Generally too saline | Extreme | >12.2 |

## 4.0 Conclusion:

The water quality was assessed with respect to its suitability for irrigation activities. Based on the results, it can be concluded that the water quality is relatively good. Hydrogen carbonate was the dominant anion, while sodium and calcium were the dominant cations in most rivers samples. The main anion differences are that in river water $HCO_3^-$ has a much higher concentration than $Cl^-$ (which has the lowest concentration out of the major anions in river water). The chemical composition of the river water showed that $HCO_3^-$ and $SO_4^{2-}$ were the most abundant anions while $Ca^{2+}$ the most abundant cation. High content of bicarbonate and calcium in river sites confirm the fact that 98% of all river waters was of the calcium carbonate type (Ramesh, R. 1989). Calcium, Magnesium and Bicarbonate are contributed to river water mostly by rock weathering. Calcium is the main cation in river water, followed by Mg and Na, then K.
Water chemistry of the rivers can reflect changes in their watersheds, making rivers good indicators of land use (Meybeck and Helmer 1989). According to the Richards (1954), the low to medium SAR of rivers makes it suitable for irrigation of most crops with little danger of development of exchangeable sodium and salinity, although few of hard water can have high EC in the Devoll and Osum River. Referring to different guides and standards of FAO, EU and the U.S., not only the physical/chemical water conditions and their impact on land were determined, but also the required plants that can be grown in those characteristiced soils ca be recommended. Analysis performed (texture) in our land have shown a relatively light silt-sand soil (Hameed *et.al.*1966). In general these soils have deficiency in nourishing elements. Sulfate in water exists as negatively charged ions. It contributes to the total salt contents. The principal component regulating ion pH in natural waters is the carbonate, which comprises $CO_2$, $H_2CO_3$ (Larpent, 1997). Low values in pH are indicative of high acidity, which can be caused by the deposition of acid forming substances in precipitation. A high organic content will tend to decrease the pH because of the carbonate chemistry. A neutral pH in the interval (6.5–8.5) characterizes water where life develops in an optimal way (Bhatt, 1999). According to water analysis, the pH has resulted relatively neutral with a very slight tendency basic.

Physicochemical parameters were used to evaluate the quality of river water for determining its suitability for irrigation purposes. Calculated values of SAR indicate that most of river water is suitable for irrigation of most crops. Systematic monitoring programs are urgently needed in order to understand and evaluate the actual state and water quality of these rivers and also to determine the main pollution sources and the irrigation potential (Cuena 1989).

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