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Quality assessment and hydrogeochemical status of potable water resources in a suburban area of northern Greece (Thermi Municipality, central Macedonia)

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ABSTRACT

Twenty-seven (27) tap water samples were collected during October 2012 from the supply network of Thermi Municipality (central Macedonia, northern Greece) in order to assess their hydrogeochemical signatures and the overall quality status according to the European legislation and international standards. Samples were analysed for a total of 25 environmentally significant parameters including physicochemical properties (pH, EC, colour, turbidity and hardness), major and minor ions (Ca^{2+}, Mg^{2+}, NO_3^-, NO_2^-, NH_4^+, Cl^-, SO_4^{2-}, F^-, and CN^-) and trace elements (B, Sb, As, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Mn). The vast majority of the parameters appeared in values below the maximum admissible concentration for potable waters. Individual elevated concentrations of B and NH_4^+ may be attributed to natural (geogenic) factors related with local lithology and anthropogenic influences possibly deriving from agricultural practices (excessive use of N-fertilizers). The assessments of the analytical results were validated with the use of PoS index, which classified nearly all samples of low to medium quality degradation and outlined the dominant triggering parameters affecting the hydrogeochemical status. These parameters included, apart from ammonium and boron, chromium, fluoride and nitrates. PoS index proved to be a versatile tool to communicate environmental information of groundwater quality characteristics, especially in environmental monitoring projects, since it abets to understand the overall evaluation of water quality. In addition, PoS application offers a valuable alternative for

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on-the-spot comprehensive and comparative analysis of all available water quality data, and may be used as a screening tool for environmental assessment applications.

Keywords: Groundwater quality; Hydrogeochemistry; Drinking water quality; Environmental monitoring; Thermi Municipality; PoS index

1. Introduction

Contamination of drinking water is a significant concern for public health throughout the world. Microbial hazards make the largest contribution to waterborne disease in developed and developing countries. Nevertheless, chemicals in water supplies can cause serious health problems [1–5]—whether the chemicals are naturally occurring or derived from sources of pollution [6–10].

Often, identification and assessment of risks to health from drinking water relies excessively on analysis of water samples. Effective preventive management of chemicals in drinking water requires simple tools for distinguishing the few chemicals of potential local or national concern from the unmanageably long list of chemicals of possible significance. The aim is to identify and prioritize the chemicals of concern, to overcome the limitations of direct analysis of water quality, and ensure that limited resources are allocated towards the monitoring, assessment and control of the chemicals that pose the greatest health risks.

Greece's water reserves depend mainly on groundwater resources [11,12]. In general, agricultural activities consume 86% of the national water resources; during the last decades, a great increase in the irrigated areas has taken place. The excessive use of fertilizers, pesticides and other similar products for agricultural causes and the existence of septic tanks for the temporary storage of municipal wastes (especially in suburban areas like the one being studied) led to groundwater quality deterioration by several contaminants and especially nitrogen compounds. Additionally, due to the excessive coastline of Greece and the ongoing overexploitation of groundwater resources, salinization has emerged as a critical problem [11,13–16].

The Municipality of Thermi is settled north-east of the city of Thessaloniki (Fig. 1) and is considered a suburban area. It consists of the Municipal Units of Thermi, Mikra and Vasilika and has a total area of about 385 km^2. The Municipal Water Supply Enterprise of Thermi serves a population of over 20,000 people with a total number of water flow indicators being over 12,000. The annual consumption of water was 1,861,100 m^3 during the year 2008. The water supply network has a total length of 214,621 m. The exploited water resources are abstracted by the local aquifers (mainly porous) through productive boreholes and are stored in tanks with a total capacity of 4,200 m^3 [17].

Supply of safe drinking water is considered as a high priority issue in the frame of the European Union as indicated by the Water Framework Directive [18]. Identifying and prioritizing chemical risks presents a challenge, because information on the presence of chemicals in water supplies is often lacking. In this direction, the Municipality of Thermi has developed an environmental monitoring programme of water resources, which is applied successfully the last years. The monitoring programme is implemented by the Greek legislation and is funded by the Municipality of Thermi. It includes a network of 27 sampling locations which are measured once every two months for a total of 19 basic parameters, whereas once in a year a more detailed analysis including 45 physicochemical parameters is made. The present study aims to evaluate the results of this monitoring programme, in respect to the quality of potable groundwater resources, and to identify the main hydrogeochemical processes controlling their hydrogeochemical status as indications of ongoing environmental pressures.

2. Materials and methods

Twenty-seven (27) water samples were collected during October 2012 from taps of the water supply network of Thermi Municipality. The network is exclusively supplied by groundwater resources that exploit local aquifer systems. The samples were analysed by a combination of suitable methods (photometry, titration, calculation, ph-meter and atomic absorption spectrometry) for a total of 25 environmentally significant parameters including physicochemical properties (pH, EC, colour, turbidity and hardness), major and minor ions (Ca^{2+}, Mg^{2+}, NO^{3-}, NO^{2-}, NH_4^+, Cl^-, SO_4^{2-}, F^- and CN^-) and trace elements (B, Sb, As, Cd, Cr, Cu, Pb, Hg, Ni, Se and Mn).

Quality assessment of water samples was performed with the aid of PoS index [20], which depicts the footprint of a water sample's environmental quality due to the presence of its various parameters (each of which may have the potential to cause adverse

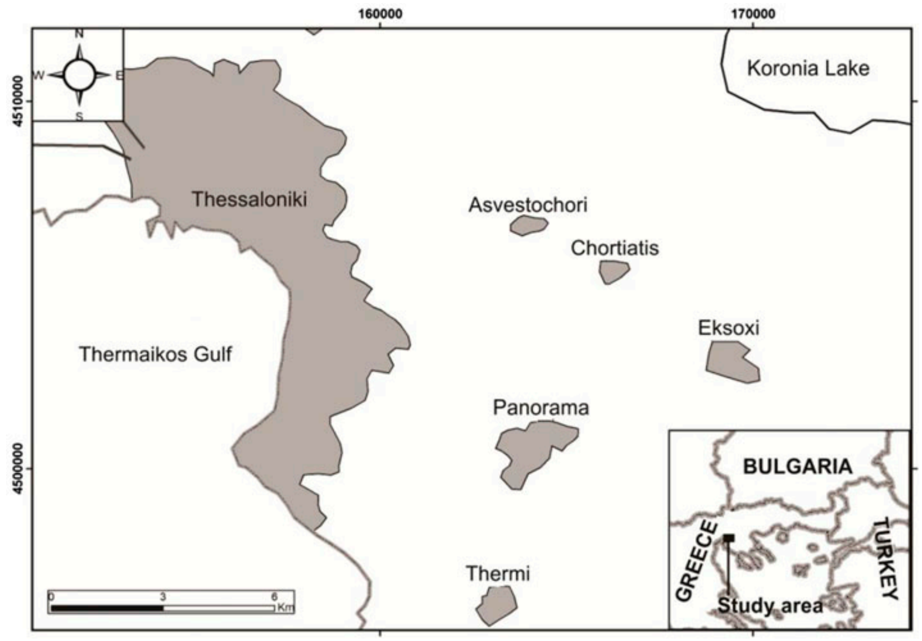

Fig. 1. Simplified map of the study area (modified after [19]).

effects to humans and the natural systems) and their potential cumulative effect. It is an alternative approach for the assessment and characterization of water quality that allows temporal comparisons between different periods of time at the same basin, but also enables assessments between basins that are subject to different pressures and controlled by diverse mechanisms. Classification according to PoS index includes the initial sample characterization through a common ranking system of six classes referring to quality degradation level (Table 1).

The detailed description of PoS index may be found on relative literature (e.g. [20]). Below follows a brief description of the methodology. Initially, the 13 parameters (As, Pb, F, NH_4^+, NO_2^-, NO_3^-, Cr, B, Ca, Cl^-, Mg, SO_4^{2+}, and EC) which appeared concentrations above the detection limit were chosen for further processing. Subsequently, they were classified (Table 2)

Table 1
Characterization of PoS index classes according to their quality degradation level

Class	Quality degradation level
1	none–minimum
2	low
3	medium
4	high
5	very high
6	severe

according to their toxicity and overall environmental adverse effects which is related with the "*P*-class", based on the original PoS method. The basis of their classification was founded on the "Priority List of Hazardous Substances" [21] but it was further modified by data obtained from various sources [22–27] so as to consider also additional aspects of water quality (e.g. ecosystem functioning).

In the next step, the influence of each parameter to the overall assessment of sample's quality is assigned by means of the individual quality contribution factors (Qf), calculated by Eq. (1):

Table 2
Characterization of PoS index classes according to their quality degradation level

Parameter	*P*-class	Toxicity characterization
As	VI	Severely toxic
Pb	V	Highly toxic
F	V	
NH_4^+	IV	Moderately toxic
NO_2^-	IV	
Cr tot	III	Non-toxic
NO_3^-	III	
B	II	Non-toxic
Ca	I	Non-toxic
Cl^-	I	
Mg	I	
SO_4^{2+}	I	
EC	I	

$$\mathrm{Qfi} = [(\mathrm{Ci} \times \mathrm{Wi})/\mathrm{MACi}] \times 1,000 \quad (1)$$

where Qfi: the quality contribution factor of i-th parameter, Ci: the concentration of i-th parameter (units according to the studied parameter), Wi: the weight factor of i-th parameter, MACi: the maximum parametric value of i-th parameter.

The weight factor which is considered as critical in Eq. (1) reflects the magnitude of impact for each parameter in terms of human toxicity. It is based on previously mentioned "*P*-class" classifications following a trial-and-error approach in order to obtain the optimal results, which were verified in terms of environmental significance. The reliability of the final extracted weight factors was validated with multivariate techniques (item analysis) by calculating the Cronbach's alpha (a) which accounts for the internal consistency of the examined values.

The maximum admissible concentration (MAC) is introduced solely to normalize the concentration of a parameter against a well-established threshold or trigger value, and does not by any means relate the concluded water quality assessment to a particular use, nor does it create any dependency to use specific characterizations. The MAC values used in this case followed the thresholds imposed by the potable water directive [28].

The final step of PoS index calculation consists of summing up all the individual Qf factors (Eq. (2)). The derived score is a dimensionless number which may be used for the qualitative assessment of a sample.

$$\mathrm{PoS} = \Sigma \mathrm{Qf} \quad (2)$$

For the final evaluation, a reference water sample (R-sample) is assumed, which reflects the mean typical concentrations of the focal parameters as expected in natural groundwater [1], according to the original PoS method. Based on this, collected samples were classified accordingly into the categories of Table 1.

3. Results and discussion

3.1. Hydrogeochemical evaluation

Table 3 presents the outline of the descriptive statistics for the examined parameters, whilst Table 4 depicts the analytical results of the collected samples. Seven of the parameters (TOC, CN^-, Sb, Cd, Cu, Hg, Se, Ni, and Mn) had values below the detection limit in all samples; hence practically their concentrations are negligible. With respect to the remaining, the vast majority of the parameters had values below the MAC as imposed by the relative legislation [28] for nearly all samples. Based on the analyses performed, the main assessments may be summarized to the following:

Nitrogen compounds in general appear in low concentrations. Nitrates (NO_3^-) vary from below detection limit (0.05 mg/L) to 39.00 mg/L having a median value of <15.81 mg/L. The maximum value of 39 mg/L was found in the only sample having NO_3^- concentration above the triggering threshold (75% of MAC, 37.50 mg/L for NO_3^-), imposing an indication for a potential environmental pressure.

Nitrite (NO_2^-) concentrations were found very low (below the detection limit in twenty-five samples) as expected due to the unstable nature which is characterized by short time of existence before being converted to NO_3^-. The concentration of the samples varies from below detection limit (0.03 mg/L) to 0.06 mg/L having a median value below detection limit.

Table 3
Descriptive statistics of the analysed variables

Variable	Unit	Minimum	Mean	Median	Maximum	St. Dev	Q1 (25%)	Q3 (75%)
As	(μg/L)	0.10	0.29	0.10	3.10	0.60	0.10	0.10
B	(mg/L)	0.05	0.29	0.24	1.18	0.30	0.07	0.32
Ca	(mg/L)	9.60	51.69	43.20	136.00	32.92	35.40	54.20
Cl	(mg/L)	11.70	45.90	38.30	124.70	26.37	28.17	50.02
Cr	(μg/L)	0.10	12.01	7.56	35.70	11.84	1.08	22.78
EC	(μS/cm)	437.0	747.0	715.0	1,129.0	191.6	640.8	847.0
F	(mg/L)	0.05	0.16	0.13	0.41	0.08	0.11	0.20
Mg	(mg/L)	9.20	31.25	30.40	57.50	9.86	26.15	36.22
NH_4^+	(mg/L)	0.02	0.07	0.02	0.33	0.08	0.02	0.09
NO_2^-	(mg/L)	0.03	0.03	0.03	0.06	0.01	0.03	0.03
NO_3^-	(mg/L)	4.43	15.80	16.80	39.00	10.30	4.59	21.50
Pb	(μg/L)	0.10	0.18	0.10	1.13	0.24	0.10	0.10
SO_4^{2-}	(mg/L)	12.90	32.22	22.50	149.30	40.33	18.57	31.00

Table 4
Analytical results for the study area (Thermi Municipality)

	Locality	Agios Antonios	Agia Paraskevi	Ano Scholari	Filothei	Kardia	Kato Paristera	Kato Scholari	Lakkia	Livadi
Parameter (unit)	MAC									
Turbidity (NTU)	No unusual variation	0.62	0.22	0.34	0.15	0.46	0.11	0.01	0.26	1.09
Hardness (mg/L)		46.2	29.6	27.6	14.2	20.8	28.4	27.2	25.4	20.4
B (mg/L)	1	0.25	0.25	0.96	0.05	bdl	0.24	0.98	0.19	0.21
Ca (mg/L)		136.0	38.4	28.8	9.6	35.2	49.6	36.8	47.2	55.2
Mg (mg/L)		28.10	46.00	46.90	27.20	27.60	36.80	41.40	31.28	15.18
NO_3^-	50	4.43	13.50	16.90	4.43	5.08	39.00	4.43	5.30	29.20
NO_2^-	0.5	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.05
F^- (mg/L)	1,5	0.21	0.11	0.10	0.09	0.16	0.31	0.12	0.13	0.11
pH	6.5 < pH < 9.5	7.28	7.54	7.69	8.33	7.75	7.43	7.69	7.22	7.03
EC (μS/cm)	2,500	1,127	683	1,018	437	763	803	833	573	677
Cl^- (mg/L)	250	36.8	42.6	68.1	29.6	43.0	41.7	84.2	27.0	12.3
SO_4^{2-} (mg/L)	250	148.7	21.3	25.4	18.8	12.9	18.1	20.2	28.6	31.8
NH_4^+	0.5	0.24	0.16	0.07	0.02	0.1	0.13	0.02	0.02	0.02
As (μg/L)	10	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl
Cr (μg/L)	50	1.08	28.27	24.31	15.87	18.90	2.56	30.21	bdl	bdl
Pb (μg/L)	25	bdl	bdl	bdl	bdl	bdl	0.61	bdl	bdl	bdl
	Locality	Monopigado	Peristera Kato Deksameni	Peristera Ano Deksameni	Plagiari	Redestos Megali	Redestos Mikri	Rysio	Souroti	Tagarades
Parameter (unit)	MAC									
Turbidity (NTU)	No unusual variation	1.19	0.29	0.3	0.42	0.01	0.05	0.09	1.02	0.67
Hardness (mg/L)		41.6	23.2	26.4	31.2	17.2	18.4	28.0	34.0	23.2
B (mg/L)	1	0.30	0.21	0.32	0.35	0.05	0.05	0.32	0.31	0.23
Ca (mg/L)		133.6	76.8	56.0	36.8	16.0	20.8	48.0	36.0	32.8
Mg (mg/L)		18.90	9.20	28.52	28.52	30.40	30.40	36.80	57.50	34.50
NO_3^- (mg/L)	50	4.43	14.40	12.97	16.70	5.80	26.10	21.80	24.03	4.43
NO_2^-	0.5	0.03	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.03
F^- (mg/L)	1,5	0.21	0.09	0.05	0.41	0.10	0.13	0.25	0.16	0.13
pH	6.5 < pH < 9.5	7.08	6.98	7.08	7.79	8.05	7.95	7.55	7.48	7.67
EC (μS/cm)	2,500	1,129	653	626	1,109	485	637	742	773	652
Cl^- (mg/L)	250	36.7	13.4	11.7	124.7	27.7	41.0	51.8	44.7	35.4
SO_4^{2-} (mg/L)	250	149.3	27.8	26.9	56.6	14.5	17.2	19.5	26.6	15.1
NH_4^+	0.5	0.02	0.02	0.02	0.06	0.33	0.02	0.02	0.02	0.12
As (μg/L)	10	bdl	bdl	bdl	bdl	bdl	bdl	3.1	bdl	bdl
Cr (μg/L)	50	0.82	bdl	bdl	2.62	19.40	19.70	10.80	25.20	35.54
Pb (μg/L)	25	bdl	bdl	bdl	bdl	bdl	bdl	1.13	bdl	bdl

Parameter	Locality MAC	Thermi Lida-Maria	Thermi Litsa Megali	Thermi Litsa Mikri	Thermi Toumpa	Triadi Kato Deksameni	Triadi Pano Deksameni	Trilofos 1	Trilofos 2	Vasilika
Turbidity (NTU)	No unusual variation	0.29	0.08	0.06	0.08	0.03	0.15	0.15	0.71	0.25
Hardness (mg/L)		33.0	23.6	24.8	23.6	23.4	22.8	23.8	18.6	29.0
B (mg/L)	1	0.05	0.07	0.05	0.07	0.07	0.05	1.18	0.67	0.28
Ca (mg/L)		76.0	51.2	45.6	51.2	39.2	46.4	40.8	29.6	37.6
Mg (mg/L)		32.20	24.80	30.80	24.80	31.28	25.80	31.28	25.76	45.08
NO_3^- (mg/L)	50	39.0	20.3	19.5	20.3	23.0	18.1	19.3	4.43	20.6
NO_2^- (mg/L)	0.5	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.06	0.03
F^- (mg/L)	1.5	0.15	0.14	0.12	0.14	0.11	0.09	0.13	0.34	0.14
pH	6.5 < pH < 9.5	7.59	7.68	7.98	7.68	7.89	7.9	7.91	7.69	7.61
EC (μS/cm)	2,500	851	698	578	698	659	623	835	907	732
Cl^- (mg/L)	250	96.3	38.3	39.0	38.3	31.1	23.5	83.3	72.4	27.6
SO_4^{2-} (mg/L)	250	31.9	22.5	22.5	22.5	18.5	16.3	20.2	38.1	21.6
NH_4^+ (mg/L)	0.5	0.02	0.02	0.02	0.02	0.02	0.06	0.02	0.59	0.02
As (μg/L)	10	bdl	bdl	bdl	bdl	0.62	0.87	bdl	1.09	bdl
Cr (μg/L)	50	4.47	6.17	bdl	6.17	7.84	7.28	23.80	8.11	35.70
Pb (μg/L)	25	0.76	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl

Note: MAC: Maximum admissible concentration; bdl: Below detection limit.

Ammonium (NH_4^+) concentration in the samples varies from below detection limit (0.02 mg/L) to 0.59 mg/L having a median value of <0.08 mg/L. The maximum value of 0.59 mg/L was found in a single sample having concentration above the MAC for potable waters (0.50 mg/L).

Based on dominant land use activities, the possible sources of NO_3^- and NH_4^+ should be related with the excessive use of nitrogen fertilizers; the local impact of septic tanks is probably not affecting groundwater quality, since the NO_3^- concentrations do not correlate positively with other compounds (e.g. HCO_3^-, Cl^-) related with sewage contamination [29].

With respect to heavy metals (Hg, Pb, Cr, Mn, Ni) and metalloids (As, Sb) whose significance is high due to their potential toxic effects, all parameters are below the MAC of relative legislation. Only exception to this fact is B concentrations in three particular samples: two of them have concentrations above the triggering threshold (0.75 mg/L) and one sample over MAC (1 mg/L). The values in those samples are 0.96, 0.98 and 1.18 mg/L, respectively. Nevertheless, boron's median concentration in the twenty-seven samples is <0.30 mg/L.

Boron is present in aqueous solutions as $B(OH)_4^-$ and/or boric acid (H_3BO_3) [30] and may be found in water systems as a result of natural or anthropogenic sources. Natural boron is derived from geothermal activity, leaching from a large variety of rocks, mixing of groundwater with oil field water, connate water or fossil brines [31]. On the other hand, anthropogenic boron sources include: boron-containing washing powders, municipal wastewaters, industrial residues, pesticides and fertilizers [32,33]. In the studied area, boron's origin is likely to be geogenic and should be attributed to the geothermal activity of the wider region [34]. The selective spatial distribution of boron's elevated values as well as their wide contrast from the area's average boron concentrations (<0.30 mg/L) is probably an indication of hydrothermal fluids impact, as a result of preferential flow through conduits and tectonic discontinuities which influences only a part of the aquifer system. However, due to main land use activities related with agriculture, the synergetic action of B-rich fertilizers and soil amendments could not be excluded.

For the purpose of this study, a comparison was made between the analytical results of the collected samples and those of relevant studies concerning other rural areas of Greece (Table 2). According to the results, it is notable that the potable groundwater of Thermi area presents the highest average value (<12.07 mg/L) of Cr concentrations between the compared areas. Nevertheless, Cr concentrations of all twenty-seven (27) samples are lower than the highest accepted value according to legislation (50 mg/L). Also, the presence of Ni in the analysed samples (average value <0.71 mg/L) is the second lowest comparing with the areas of Table 2. The lowest value can be found at the nearby rural area of Hortiatis [19].

3.2. PoS index evaluation

The application of PoS index to the collected drinking water samples classified them according to their overall quality degradation (Table 6). It has to be mentioned, that PoS classification is not intended for use characterization (e.g. potability) but for generic quality assessments (Table 5).

Based on PoS results, the 27 samples are classified into three categories, namely class 1 (no-minimum quality degradation) with 14 samples, class 2 (low quality degradation) with 12 samples, and finally class 3 with only one sample (medium quality degradation). Hence, it is evident that the overall quality status of

Table 5
Comparison of selected parameters (mean values) between study and other Greek suburban areas

Parameter	Hortiatis [19] a	Hortiatis [19] b	Korinthos [35]	Thessaly [36]	Thessaly [37]	Mesologgi [38]	Study area
pH	7.9	8.1	7.2	na	7.0	7.4	7.6
EC (μS/cm)	584	618	1,564	na	654	1,661	747
SO_4^{2-} (mg/L)	41.2	44.6	232	33.6	4.9	75.2	32.2
NO_3^- (mg/L)	18.6	17.6	74.0	32.5	1.9	6.3	15.8
Cl^- (mg/L)	27.1	30.5	112.0	14.3	12.8	111.0	45.9
B (μg/L)	0.1	0.1	na	25	na	73.2	0.3
Cr (μg/L)	7.0	na	na	5	na	9.0	22.8

Note: na: not available.

Table 6
Characterization of samples according to PoS index

Number of samples	PoS class	Quality degradation
14	1	none–low
12	2	low–medium
1	3	medium–high
0	4	high–very high
0	5	very high–severe
0	6	severe

samples is good, with minor individual expectations as discussed above.

PoS results also revealed the relevant contribution of each parameter to the overall hydrogeochemical signature of the collected samples (Fig. 2). Based on the significance of their percentages, there are four groups of parameters which can be distinguished, two dominant and two trivial ones.

The dominant groups include parameters with percentage of contribution over than 10% which is regarded as a critical threshold of significant contribution to hydrogeochemistry and water quality. These parameters should be screened by the environmental monitoring programme for further investigations, as having direct impact on water quality and possibly triggering adverse environmental pressures. The first group includes individually the parameter of ammonium which seems to be the dominant parameter that drives water quality with a percentage of 17.6%; accordingly follows the second group with nearly similar contributions the parameters of Cr (13.7%), F (13.4%), B (13.1%) and NO_3. These results are in line with the values highlighted by the hydrogeochemical analyses, which showed individual elevated values mainly for NH_4^+, Cr and B. The impact assessment of the above parameters should be made in relation with the PoS classes of the samples, which for their majority are characterized by low to medium quality degradation.

This fact proves that the exploited groundwater resources used for drinking purposes are chiefly regarded as having a good quality without any significant problem. However, the distinguished parameters reveal notable trends and therefore special attention should be given in order to avoid potential environmental problems in future.

The trivial groups, include the individual parameter of magnesium, with a percentage of contribution slightly under the critical threshold (9.6%) Finally, the fourth group includes all those parameters whose significance in hydrogeochemistry is negligible (<4.3%).

Nevertheless, we should bear in mind that the percentage of contribution of each parameter is directly related with its toxicity; hence a parameter may have significant abundance in terms of absolute concentration in samples, but may be insignificant in terms of quality degradation. This advantageous approach is a valuable tool for environmental assessment investigations, where the crucial point is the identification of hazardous substances based on their impact and not only on their relative analytical concentrations.

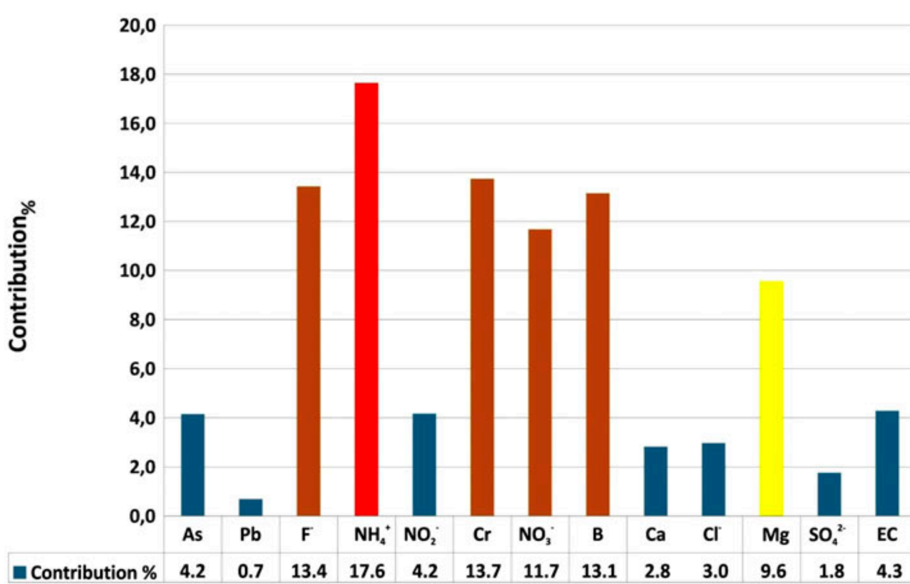

Fig. 2. Contribution of the examined parameters to the overall quality of water samples.

4. Conclusions

Twenty-seven tap water samples that exploit local groundwater resources of Thermi sub-urban area where analysed for significant environmental parameters, in order to evaluate their overall quality status. Results revealed that nearly all samples are suitable for human consumption. However, further hydrogeochemical processing highlighted NH_4^+ and B as critical parameters of quality degradation in individual samples. The presence of ammonium is attributed to the dominant land use activities related with agriculture, whilst the presence of boron to the geothermal field of the wider area.

The assessments of the analytical results were validated with the use of PoS index, which classified chiefly all samples of low to medium quality degradation and outlined the dominant triggering parameters affecting the hydrogeochemical status. These parameters included ammonium and boron as stated above and additionally chromium, fluoride and nitrates.

PoS index proved to be a versatile tool to communicate environmental information of groundwater quality characteristics, especially in environmental monitoring projects, since it abets to understand the overall evaluation of water quality and may serve as a versatile tool for decision-makers regardless of their scientific background. However, this methodological approach does not substitute an in-depth analysis of the groundwater quality characterization, which in every case should be performed depending on the specific needs of the assessment and the compliance requirements to existing legislation. Nevertheless, it offers a valuable alternative for on-the-spot comprehensive and comparative analysis of all available water quality data, since it may be used as a screening tool for environmental assessment applications.

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