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WATER RESOURCES QUANTITY AND QUALITY INVESTIGATIONS IN HALKIDIKI PENINSULA

P. Latinopoulos¹ and N. Theodossiou²

Faculty of Civil Engineering, School of Technology
Aristotle University of Thessaloniki
E-mail : latin@civil.auth.gr¹, niktheo@vergina.eng.auth.gr²

ABSTRACT

In the paper the results of two research studies, concerning water resources management in the Halkidiki peninsula, are presented. Halkidiki is an area, where water availability and demand are greatly influenced by both touristic and agricultural development. The first study refers to a surface water resources investigation for the region of Sithonia, where up-to-now the sole source of potable water is groundwater. The second study deals mainly with groundwater pollution caused by agricultural activities in North-western Halkidiki. It is an integrated project, where field research was combined with desk studies, in order to investigate groundwater resources degradation with particular emphasis on the impact of nitrogen fertilisation on groundwater quality

ΠΟΣΟΤΙΚΗ ΚΑΙ ΠΟΙΟΤΙΚΗ ΔΙΕΡΕΥΝΗΣΗ ΤΩΝ ΥΔΑΤΙΚΩΝ ΠΟΡΩΝ ΤΗΣ ΧΕΡΣΟΝΗΣΟΥ ΤΗΣ ΧΑΛΚΙΔΙΚΗΣ

Π. Λατινόπουλος και Ν. Θεοδοσίου

Τμήμα Πολιτικών Μηχανικών, Πολυτεχνική Σχολή
Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης

ΠΕΡΙΛΗΨΗ

Στην εργασία παρουσιάζονται τα αποτελέσματα από δύο ερευνητικές μελέτες, σχετικές με τη διαχείριση των υδατικών πόρων στη χερσόνησο της Χαλκιδικής. Η Χαλκιδική αποτελεί μια περιοχή, όπου η διαθεσιμότητα και η ζήτηση νερού επηρεάζονται σημαντικά τόσο από την τουριστική όσο και από την αγροτική ανάπτυξη. Η πρώτη μελέτη αφορά στη διερεύνηση των επιφανειακών υδατικών πόρων στην περιοχή της Σιθωνίας, όπου προς το παρόν η μοναδική πηγή πόσιμου νερού είναι τα υπόγεια νερά. Η δεύτερη μελέτη αναφέρεται κυρίως στη ρύπανση των υπόγειων νερών εξαιτίας γεωργικών δραστηριοτήτων στη Βορειο-δυτική Χαλκιδική. Πρόκειται για ένα ολοκληρωμένο έργο, όπου έρευνα πεδίου συνδυάστηκε με μελέτη γραφείου με στόχο, τη διερεύνηση της υποβάθμισης των υπόγειων νερών με κύρια έμφαση στις επιπτώσεις της εφαρμογής αζωτούχων λιπασμάτων στην ποιότητα των υπόγειων νερών

1. INTRODUCTION

From the water resources point of view, the county of Halkidiki, situated in Northern Greece, is one of the most troublesome regions in the Central Macedonia Water District. This is because, compared to the average standards of Greece, it is considered poor, both in groundwater and surface water resources.

Water resources are considered to be essential not only for the development of every kind of activity but also for the conservation of the human and natural environment. The uncontrolled increase of the agricultural activities and the touristic development in Halkidiki in the past few decades, has led to an upright increase of the relevant water demand. Halkidiki is one of the most touristically attractive areas in Greece and every summer it is visited by thousands of tourists. Even though the permanent habitants do not exceed 100.000 people, during the summer the number of visitors reaches one million. The effort to meet with their demands led to an irrational exploitation of the available water resources. As a consequence of this, the water balance was disturbed, the groundwater level has dropped and sea water intrusion in the coastal aquifers begun.

The county of Halkidiki (fig. 1) due to its complex geomorphology and the especially long seacoast - because of the three peninsulas - is described, hydrologically, by a large number of small to medium size independent hydrologic basins. In addition it presents an intense hydrogeological heterogeneity. Along the seacoast there are a number of freshwater aquifers who have been intensely exploited through shallow and deep pumping wells. The quality and quantity of the groundwater of these aquifers, as it is derived from water level observations and groundwater analysis, has started to diminish dramatically. The main reason for this intense exploitation is that the high water demand period is rather short and coincides with the dry summer period. Unfortunately in Halkidiki, as in many other parts of Greece, water problems are, usually, tackled taking into consideration factors that are time-limited and have only local importance. As a result of this, intense problems of water shortage for domestic and agricultural use arise, especially during the summer.

The need for rational and overall water resources management in the county of Halkidiki, is a problem of major importance, and is expected to contribute to the touristic and agricultural development of the county.

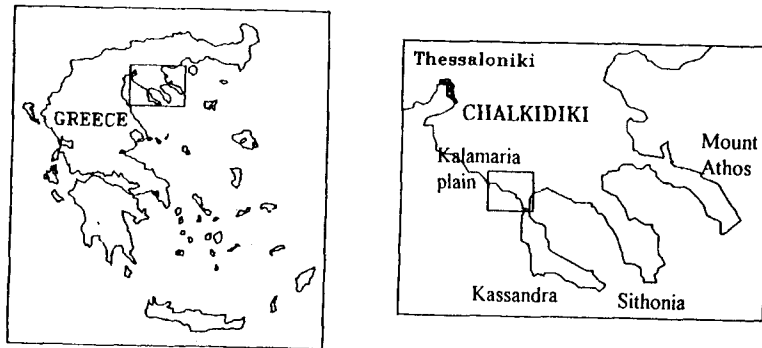


Figure 1. Halkidiki Peninsula

In this paper, the results of two research projects are combined to present the major issues of the water resources quantity and quality problems of Halkidiki. Both of these projects were conducted at the Division of Hydraulics and Environmental Engineering of the Faculty of Civil Engineering of the Aristotle University of Thessaloniki. The first study refers to the investigation of the surface water potential and the possibility of meeting with the high demands for potable water in the region of Sithonia [1]. The second study refers to the groundwater pollution caused from agricultural activities in the plain of Kalamaria in the south-western part of Halkidiki [2], [3], [4].

2. WATER QUANTITY INVESTIGATION IN SITHONIA

Sithonia is the central peninsula of Halkidiki, west of Kassandra and east of Mount Athos. It covers an area of 544.7 square kilometres which represents the 18.7 % of the area of the Halkidiki county. It consists of seven communities and a number of touristic resorts. The exceptionally scenic natural beaches of Sithonia, along with the development of the county of Halkidiki, led to a dramatic improvement of the touristic industry. Unfortunately this development had not only positive consequences - mainly economic - but also caused a number of problems, such as an environmental degradation in some areas, due to the irrational rate of development. Another severe problem caused by this situation, is that seasonal summer tourism led to an overexploitation of the available water resources.

At first an investigation was performed over the potable freshwater demand of the communities of Sithonia. This investigation was based mainly on a questionnaire completed in-situ by representatives of the communities. The aim of the questionnaire was to determine the water needs not only of the permanent residents but also of the tourists. The latter was not an easy task, considering that even the National Tourism Organisation of Greece estimates that the licensed accommodation (hotel rooms, rooms to let, camping) do not exceed half of the existing accommodation in Sithonia [5].

By combining the results of the questionnaire survey with water demand estimates based on population forecasting, we concluded to a total annual demand for drinking water equal to 4.0×10^6 m³ for the whole Sithonia peninsula. Local demand varies, due to different rates of urban and touristic development, and ranges from 0.1×10^6 m³ to 1.2×10^6 m³.

Up to now the sole source of potable water in Sithonia is groundwater, overexploitation of which has caused not only quantity but also quality problems, such as sea water intrusion. So the investigation for the solution of the water shortage problem was directed towards the development and use of surface water resources. The aim of this investigation was twofold: first to determine the surface water potential in the area and second to identify alternative water storage sites for dam construction.

It is obvious that from a surface water resources management point of view, there can be many combinations of water storage sites for dam construction, especially in the case of Sithonia where the surface water potential is many times greater than water demand. Thus, it was decided to propose a finite number of alternatives, based on the degree by which the communities of Sithonia could jointly use the water stored in some reservoirs. Thirty-six watersheds were examined in order to determine the best sites for the construction of the dams. The final selection was made after taking into consideration all the available physical, technical and social characteristics of the area [6].

Figure 2 presents four different water development schemes based on the above criteria. According to the first scheme, two dams (shown in figure 2 as small circles), one for the west and one for the

east side of Sithonia, could supply the water needed for all the communities. As opposed to the first, the fourth scheme, proposes the construction of seven dams, one for each community. Between these two, lie the second and third scheme, with a combination of conjunctively used dams and dams that serve the needs of one and only community. All four proposed alternatives include reservoirs that exactly meet or slightly exceed the total water storage requirements for the peninsula, as referred above. The final choice among these schemes is not easy to make because the economic advantage of constructing only a small number of dams is diminished by the cost of the pipe network needed for the conveyance of water to the communities.

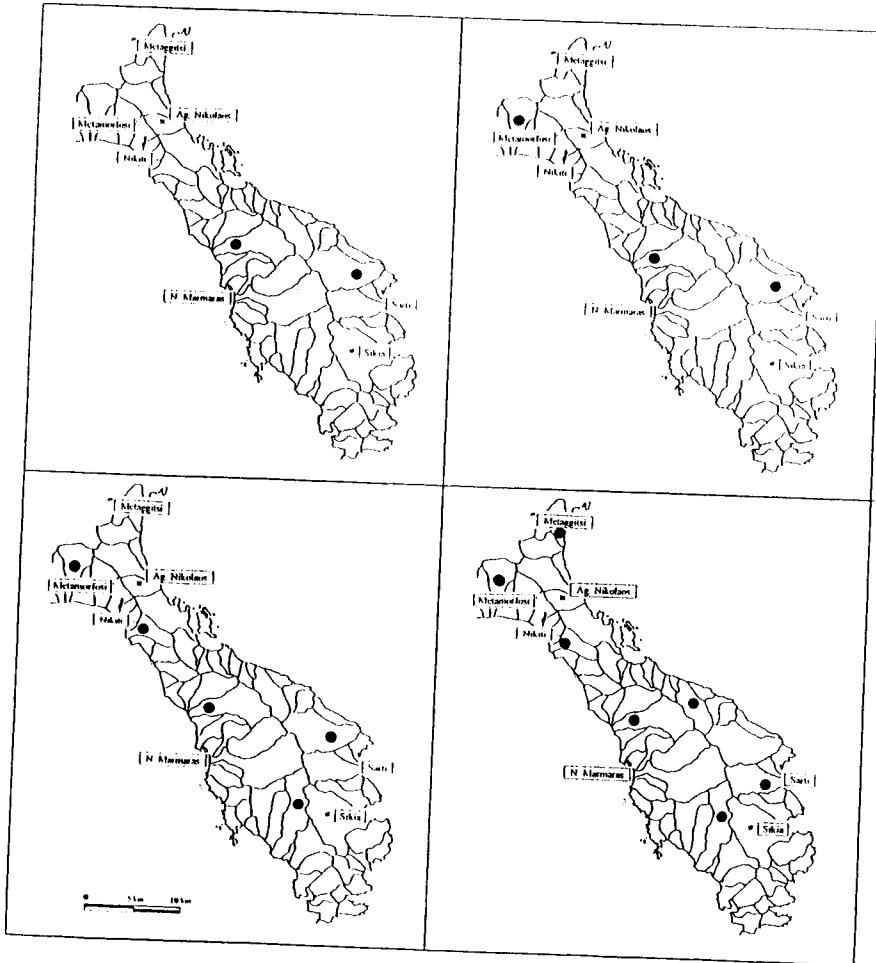


Figure 2. Alternative surface water management scenarios in Sithonia

3. WATER QUALITY INVESTIGATION IN THE PLAIN OF KALAMARIA

The plain of Kalamaria is located at the south-western part of the Halkidiki county, between the Kassandra peninsula and the town of Thessaloniki. It constitutes the main agricultural region in the Halkidiki county and, as a result of this, it is intensively cultivated and irrigated. During the summer a large number of tourists visit the area. Taking into consideration the high water demand for both domestic and agricultural use, the fact that a constant groundwater level decline is observed, is, at least, expected. Another factor that reduces, even more, the availability of water resources, especially for domestic use, is the fact that extensive groundwater nitrate pollution is observed - more clearly seen in shallow wells - as a result of the uncontrolled irrational use of nitrogen fertilisers.

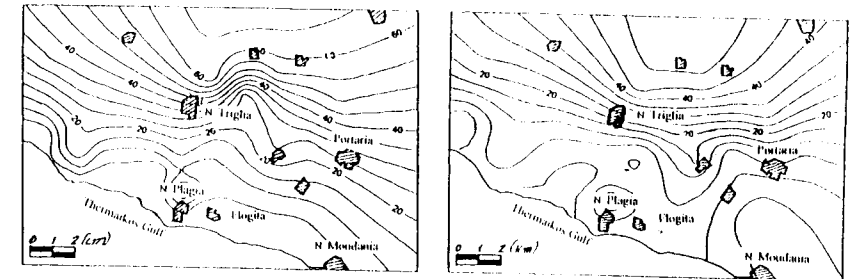


Figure 3. Groundwater level contours in Kalamaria (Left : in 1988, Right : in 1995)

Figure 3 shows the decline of groundwater levels in the study area, as occurred in the period 1988-1995. The two contour maps were produced by applying the kriging method using water-table altitudes from forty wells and boreholes, almost uniformly spread in the 182 square kilometer area. The overall analysis of the groundwater decline led to the following results : (a) A remarkable high rate of groundwater levels decline has been observed all over the area, with higher peaks in the western part where abstractions are high for domestic purposes. (b) Maximum decline has reached values over 20m, while its annual average value is about 2m/year. (c) Taking into account the current trends in the rates of water abstraction and its effect on groundwater levels, it is estimated that at least the shallow phreatic aquifer, which extends in the larger part of the area, is reaching depletion within the next 5 to 6 years.

The investigation of the groundwater quality deterioration due to the increased concentrations of nitrates especially in the shallow and medium depth wells, started in 1991. That first survey [2] was quite indicative as nitrate concentration from raw water from 54 sampled wells exceeded the target concentration of 50 mg/l in more than 20 of the wells (fig. 4). In the following period and up to 1996 a systematic sampling was performed by analyzing 218 water samples from 111 wells. The initially (in 1991) estimated percentage of 40% contaminated wells was eventually reconfirmed after completing the 5-year investigation.

A series of statistical analyses revealed an inherent structure of nitrate concentrations evolution in both space and time, that is rather typical for the types of soils, aquifers and land development as those in the plain of Kalamaria [4]. The boxplots in figure 5 are representative as summary statistics for the major part of the nitrates database. Central values, distributions and seasonal variations are indicative of the phenomenon and have given proper explanations [4].

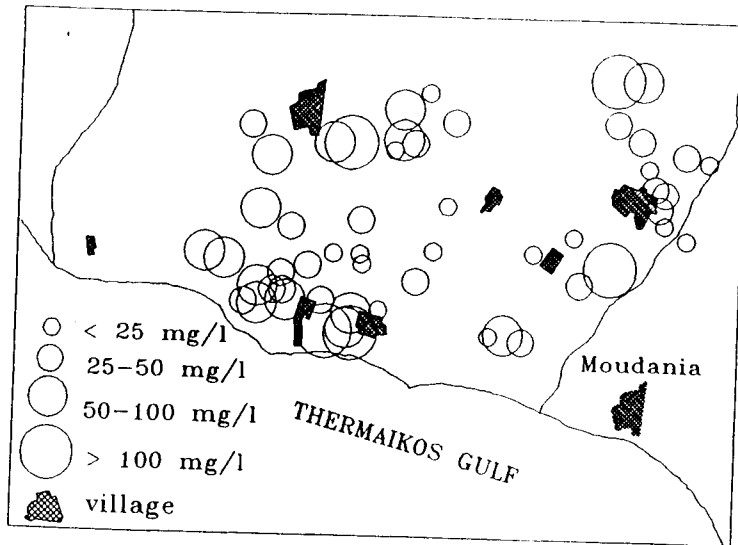


Figure 4. Nitrate concentration in selected sampling wells.

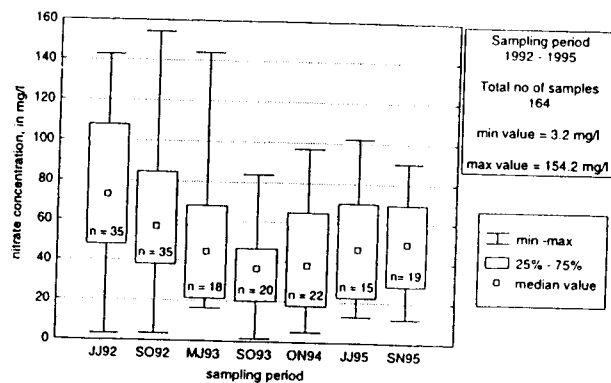


Figure 5. Nitrate concentration boxplots (n is sample size; JJ92 is June-July 1992 etc)

4. CONCLUSIONS

The major issue that is inferred from the two studies described above is that in Halkidiki water resources management is practiced at a very slow pace and with no strategic plan at all. It is only local demands that tend to be satisfied with short-term measures and individual actions, that often

lead to adverse effects, as far as the medium and long-term development of the resources is concerned.

The complete lack of surface water exploitation and use in the whole Halkidiki peninsula and the consequent over-exploitation of the groundwater resources has caused many serious problems in areas of high water demand, either for domestic, or agricultural use, or both.

In Sithonia, where agricultural activities are sparse, the main concern is the shift towards a rational development of the surface water resources to ensure a sufficient drinking water supply. The geomorphology and hydrology of the area favor such a policy and the study described above can be efficiently used to implement a conjunctive use of ground and surface waters. Short, medium and long term strategies should be adopted by seriously considering the availability of many suitable locations for dam construction. Decision making has to be focused on the relative merits of each potential site by considering the full range of the relevant economic, technical, social and development criteria, when selecting among the four proposed types of water exploitation schemes.

The situation in the plain of Kalamaria is more complex, due to the existing various types of development. As far as water resources management is concerned the use of water for urban and touristic development is, more or less, competitive to that for agricultural practices. Although the water quantity aspect of the problem, i.e. adequacy of water potential for all uses, is not a minor issue, the major threat to both quantity and quality of the groundwater reserves comes from the agriculture. The significant decline of groundwater levels and the deterioration of the quality of groundwater, caused by the intensive and irrational agricultural practices, as detected and studied in the second research project described above, have to be recovered in the very near future. Among the proposed measures towards this task are the conjunctive use of surface and subsurface water resources, a strategically planned change in land use and agricultural activities and the implementation of efficient farmers practices, including the use of modern irrigation systems.

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