

# Water Resources Monitoring for the Implementation of Nitrates Directive (91/676/EEC) in Turkey

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## Abstract

Statistical analysis was performed on 7,167 groundwater samples and 11,229 surface water samples originating from Turkey's nitrate monitoring network. Results showed significant spatial and temporal variation of nitrates among 81 provinces of the country. In general, surface and groundwater monitoring data have shown that nitrates concentration is relatively low compared to the corresponding values in several EU Member States. For the implementation of the Nitrates Directive (91/676/EEC), Nitrates Vulnerable Zones (NVZs) and Potential NVZs have been designated, the latter indicating an increased risk of nitrate pollution. Digital thematic maps were compiled and made available through a dedicated web platform, illustrating the spatial distribution of nitrates concentrations at the 25 river basins of Turkey. Statistical analysis of hydrochemical data from the groundwater monitoring stations showed strong increasing trends of nitrates in ten river basins. Results from the analysis of the respective surface water data have shown a stable situation in thirteen river basins of Turkey.

**Keywords:** monitoring; nitrates; pollution; water; vulnerable zone.

## 1. Introduction

The Council Directive 91/676/EEC [1] on the protection of waters against pollution caused by nitrates of agricultural origin was entered into force for the EU Member States in 1991. The implementation of nitrates directive in Turkey has entered into force in 2004 by law regarding protection of waters against nitrate pollution of agricultural origin.

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Middle East countries share some of the important Turkish river basins and this condition strongly influence the establishment of rational water management plans. Although the legislative background is of high importance, and improvements have been made in the environmental infrastructure of Turkey, considerable advancements are still required. Implementation of the Nitrates Directive (ND) requires the systematic collection and assessment of selected hydrochemical parameters, most importantly nitrates concentration. A climate condition where precipitation exceeds evapotranspiration favours both deep percolation to groundwater and runoff to surface water bodies [2].

Since 1961, the annual consumption of nutrients in Turkey (N,  $P_2O_5$  and  $K_2O$ ) from mineral fertilisers has increased by about 29 times. Nitrogenous fertilisers accounted for 63%, phosphorus fertilisers for 34% and potash fertilisers for 3% of the average consumption in the same period [3]. Nitrogen fertilization plans were compiled for the main crops of Turkey [4] in soils with various soil texture and indicative examples concerning inputs of nitrates from irrigation waters have also been prepared. Taking into account the aims of the Nitrates Directive (676/91/EEC) for minimizing nitrates content, nitrogen fertilization must introduce amounts of applied nitrogen in according to yields and special attention must be paid to the designated nitrates vulnerable zones (NVZ) of Turkey.

The main factors which affect the accumulation and leaching of nitrates from soils are closely related to intensive rainfall, irrigation, soil porosity, texture, excessive application of N fertilizer and manure, and land use changes i.e. from cereal crops to other which require increased amount of nitrogen (i.e. orchards). Irrigation of indigenous tree crops, such as olive and pistachio groves can increase both nitrate pollution and enhance soil erosion and disturbances in the hydrologic cycle [5,6,7]. It has been observed that several open marine waters of Turkey generally present conditions of oligotrophy; only in limited coastal areas which have been affected by either rivers' discharge, or industrial effluents, conditions of eutrophication are reported [8]. The impacts of fertilizers on water quality, create the following problems [9]: (i) heavy fertilization may lead to eutrophication, which can affect both inland and coastal waters; (ii) groundwater is being polluted mainly by nitrates including zones that are dedicated to domestic water production; (iii) in certain provinces of Turkey, the problem is particularly associated with increased quantities of applied manure, which increases the pollution risk of waters. A network of water quality monitoring stations was established in Turkey in 1979 to explicate both spatial patterns and temporal trends in water quality in an effort to elucidate mechanisms behind the recent ecological change [10]. One of the aims of this work is the assessment of the water resources monitoring network to study the distribution and changes of nitrate concentration for the study period. Also, to designate the NVZs with high certainty and to evaluate the nitrate trends in time and space in surface and groundwaters.

## **2. Materials and Methods**

### ***2.1 Monitoring stations - hydro chemical data collection***

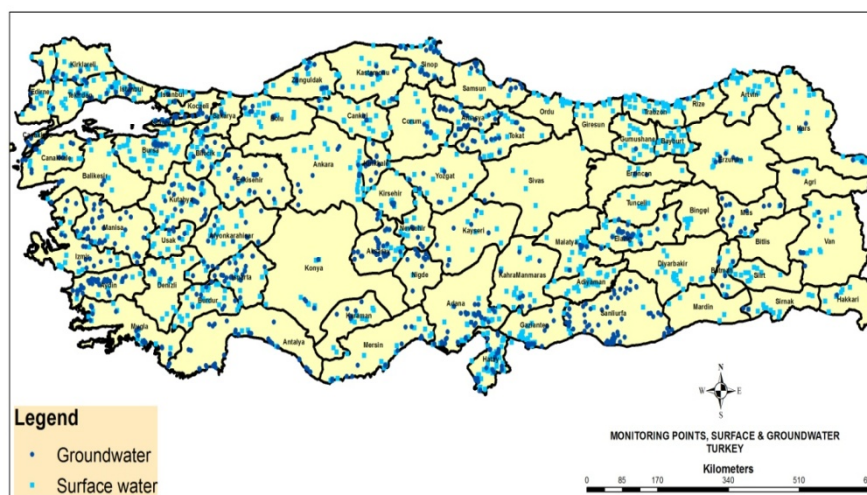
The data that was made available cover a period of 4 years, from 2008 to 2011. As a first step the datasets were received from the competent authorities of Turkey, checked for the accuracy of the coordinates for each monitoring point and where necessary appropriate corrections were imposed to have a uniform coordinate

system. Monitoring points were categorized in groundwater and surface water and the latter were distinguished in lakes, rivers, transitional and coastal monitoring points. A further categorization was performed to distinguish the monitoring points per province and river basin, following the official national scheme (81 provinces and 25 river basins). Both thematic layers (provinces and river basins) form the baseline geographical data upon which spatial, statistical analyses and results were elaborated, in order to be in line with the guidelines of the ND.

In total 1,939 monitoring stations were identified, out of which it was possible to check, correct and finally validate the coordinates and the category (i.e. groundwater or surface water) for only 1,630 stations. Out of the 1,630 monitoring stations, 711 refer to groundwater and 919 to surface water; separation in surface and groundwater was enabled on the basis of the descriptive information of each monitoring point. Based on the descriptive information of each monitoring point, the spatial distribution of each point and the conjunctive use of satellite imagery, it was possible to further split the surface monitoring points to water body categories. Hence, out of the 919 surface water monitoring points, 665 points relate to rivers, 223 points relate to lakes, 11 points relate to coastal water bodies and 20 points relate to transitional water bodies. The spatial distribution and the density of the monitoring stations is not ideal and needs to be reviewed. However, monitoring points were attributed to a specific province and a specific national river basin and statistical analysis was carried out for hydrochemical properties of 7,167 groundwater and 11,229 surface water samples, respectively.

## 2.2 Assessment of hydrochemical data

Figure 1, illustrates the spatial distribution of the existing monitoring network for surface and groundwaters. A series of statistical figures were calculated for each year, for the entire time series, per Province, per River Basin and for the entire country.



**Figure1:** Spatial distribution of monitoring points at Province level

Raw data and statistical figures have been classified in specific categories, in accordance with the ND and more specifically in line with the guidance document for the implementation and the reporting of the ND by Member States [11]. For surface waters the following 6 ranges of nitrate concentrations are distinguished ( $\text{mg l}^{-1}$ ): 0-2, 2-

10, 10-25, 25-40, 40-50, >50 mg l<sup>-1</sup>. For groundwaters the identified ranges of nitrate concentrations are the following 4 (mg l<sup>-1</sup>): 0-25, 25-40, 40-50, >50. Using as background information the spatial distribution of the Provinces and River Basins in a GIS environment, statistical analyses and then designation of NVZs at the aforementioned scales (Province, River Basins) were performed. It has to be stressed that the accuracy, representativeness and validity of the data from the national monitoring network is of paramount importance to the designation of the NVZs in a country. Regarding the representativeness, integrity and validity of the monitoring points, it is considered that this was adequate for the stage of Nitrate Vulnerable Zones (NVZ) elaboration, in the framework of Nitrates Directive implementation. Hard copies of geological maps 1:500,000 [12] for the entire country were used as reference material: they were scanned in high resolution and then geo-referenced. Furthermore, the monitoring points were plotted on the geological map of Turkey and polygons delineating the main aquifer units were designed, where monitoring points occurred. Based on the statistical analysis of available data sets compiled on individual thematic layers in GIS environment, it was possible to analyse specific elements that contribute to the definitive designation of NVZs. In fact, each thematic layer constitutes by itself an NVZ, as it meets one or more of the criteria set by the ND for NVZ inclusion. Hence, the individual thematic layers developed are:

$$HD_s + HD_g + DB_s + DB_g + TR + NU = NVZ$$

where:

**HD<sub>s</sub>** are the delineated NVZs based on the analysis of hydrochemical data available for surface waters

**HD<sub>g</sub>** are the delineated NVZs based on the analysis of hydrochemical data available for groundwaters

**DB<sub>s</sub>** are the delineated NVZs based on the analysis of slopes and sub-basins that drain into the designated surface water NVZs

**DB<sub>g</sub>** are the delineated NVZs based on the analysis of slopes and sub-basins that drain into the designated groundwater NVZs

**TR** are the basins delineated as NVZs based on the analysis of trophic conditions on coastal and inland water bodies (lakes-reservoirs)

**NU** are the areas delineated as NVZs based on the nutrient input analysis, (sum of bulk mineral fertilization used and manure produced per Province and hectare)

**NVZ** are the finally compiled NVZs of the country, superimposing afore-described thematic layers.

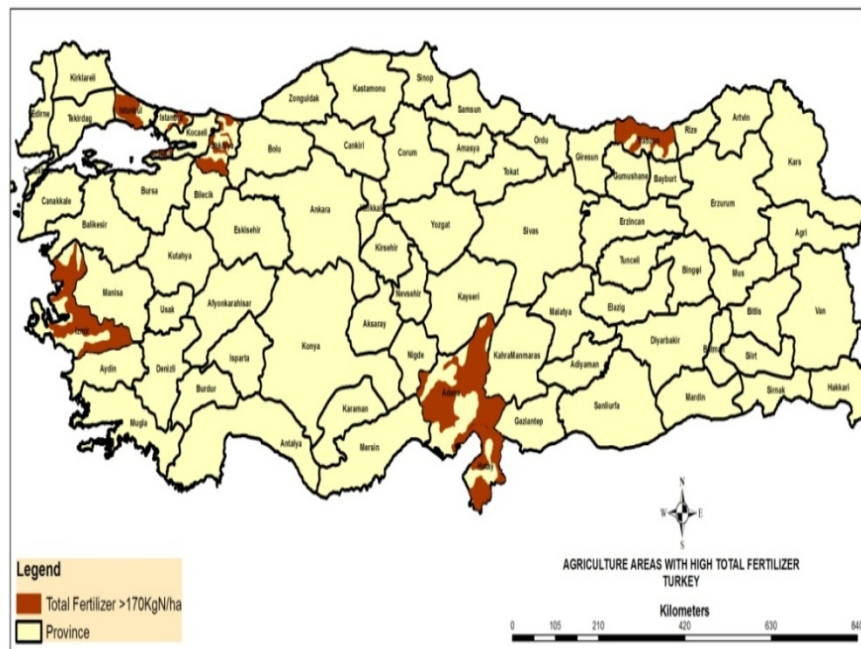
### 3. Results and Discussion

An important stage in the designation of the NVZs [1, 11] is the definition and delineation of zones where extensive use of inorganic fertilizers and/or manure takes place. Mineral fertilizers are a potential source of

pollution, and so is the production and use of manure. Acceptable threshold values (TVs) for fertilization application vary from 170-210 kg/ha. Adopting the stricter criterion of 170 kg/ha, that provides the worst-case scenario and in turn the most environmentally sensitive approach, seven Provinces (Figure 2) exhibit excessive nitrogen input, in the form of either mineral fertilization use and/or manure production (and/or use). Table 1 lists the spatial extent of agricultural land where excessive N-input occurs. According to the official national statistics of year 2010, seven provinces exhibit excessive use of N-fertilisers and manure. In total 32,697 km<sup>2</sup> are designated as NVZs due to the excessive N-input, and the identified areas are distributed in 11 river basins and represent 4.18% of the country.

**Table 1:** Spatial distribution of agricultural land receiving N above TV of 170 kg/ha

| (Province) | Agricultural area (km <sup>2</sup> ) | N (kg/ha) |
|------------|--------------------------------------|-----------|
| Adana      | 11684                                | 260.2     |
| Sakarya    | 1920                                 | 229.8     |
| Tabzon     | 3132                                 | 217.7     |
| Hatay      | 3870                                 | 215.4     |
| Izmir      | 7705                                 | 183.6     |
| Istanbul   | 2227                                 | 174.4     |
| Osmaniye   | 2159                                 | 187.5     |



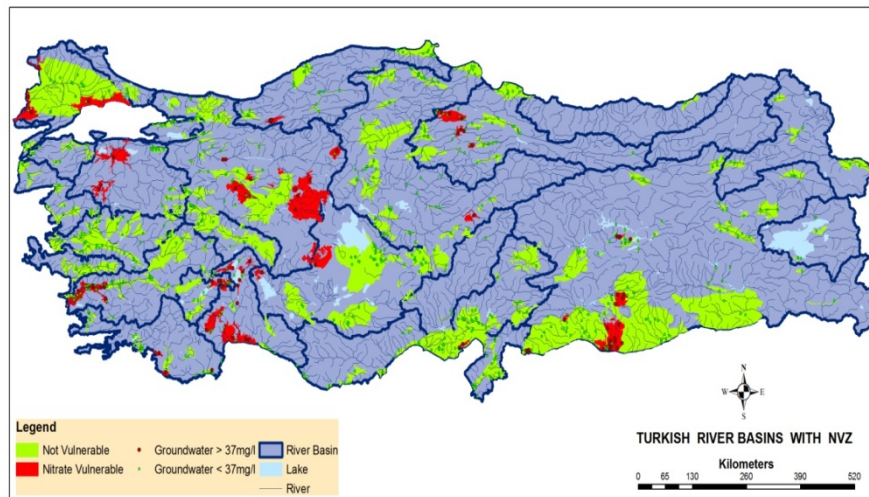
**Figure 2:** Delineation of agricultural areas receiving excessive nitrogen (kg ha<sup>-1</sup>)

The sum statistics and spatial distribution of the compiled NVZs per province, list the river basins (Table 2) in which the identified groundwater bodies were characterized as NVZ.

**Table 2:** Areas covered by designated groundwater bodies' NVZs

| Province      | NVZ (Km <sup>2</sup> ) | % NVZ |
|---------------|------------------------|-------|
| Merin-Erhone  | 1009                   | 7.0   |
| Marmara       | 1037                   | 4.5   |
| Susurluk      | 1656                   | 6.8   |
| BoyukMenderes | 1308                   | 5.0   |
| BatuAkdeniz   | 178                    | 0.8   |
| Antalya       | 2767                   | 13.6  |
| Burdur        | 348                    | 5.5   |
| Sakarya       | 5714                   | 9.0   |
| BatuKaradeniz | 216                    | 0.7   |
| Yeilurmak     | 1154                   | 2.9   |
| Kuzulurmak    | 268                    | 0.3   |
| Konya         | 1376                   | 2.7   |
| Ceyhan        | 116                    | 0.5   |
| Furat-Dide    | 2776                   | 1.6   |

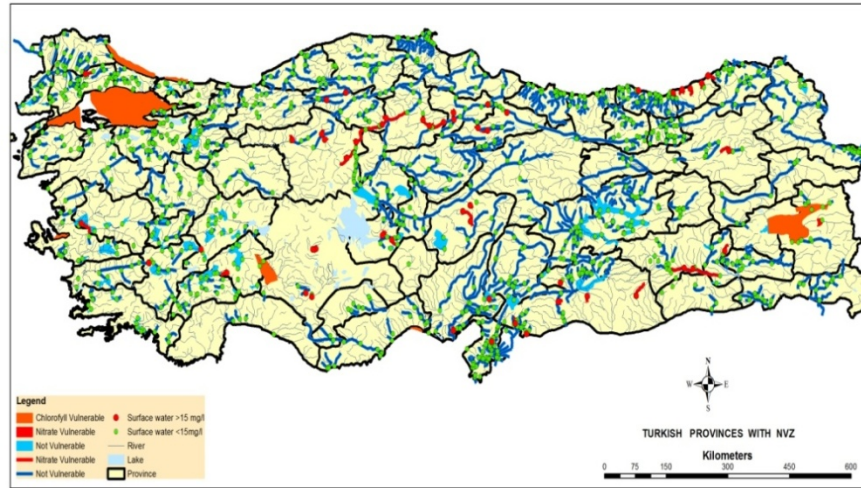
In whole, the groundwater NVZs are distributed in 14 river basins or 21 provinces that cover a spatial extent of 19,982 km<sup>2</sup>, i.e. 2.6% of the national area. Results are illustrated in Figure 3, where apart from the designated groundwater NVZs the non-NVZs are also depicted.

**Figure 3:** Distribution of identified groundwater NVZs at River Basin scale, on the basis of data availability

Based on the surface water hydrochemical data distribution and analysis, the river stretches that are designated as NVZs are distributed in 27 Provinces and have a total length of some 1013 km. Figure 4, illustrates the spatial distribution of the characterized surface water bodies. On the same map, the areas that exhibit eutrophication signs are illustrated, on the basis of the processed satellite imagery used for the summer period of year 2011. Based on available nitrate concentrations and provisional standards [13] all river basins were assessed. In 12 of



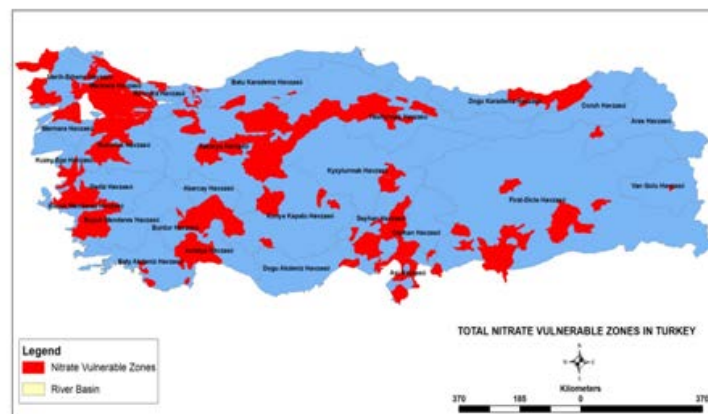
the 25 river basins the risk on eutrophication is low both for rivers and lakes. In 9 river basins rivers have a moderate risk on eutrophication and in 4 river basins lakes have a moderate risk. The rivers in Konya and the lakes in Seyhan have high risks on eutrophication.



**Figure 4:** Characterisation of surface water bodies for which data are available, and NVZs distribution at Province scale

However, it has to be stressed that aforementioned characterisations are based solely on the available data that were analysed. Future review of recent and/or spatially expanded data sets is necessary and may lead to drastically altered distribution of the identified NVZs.

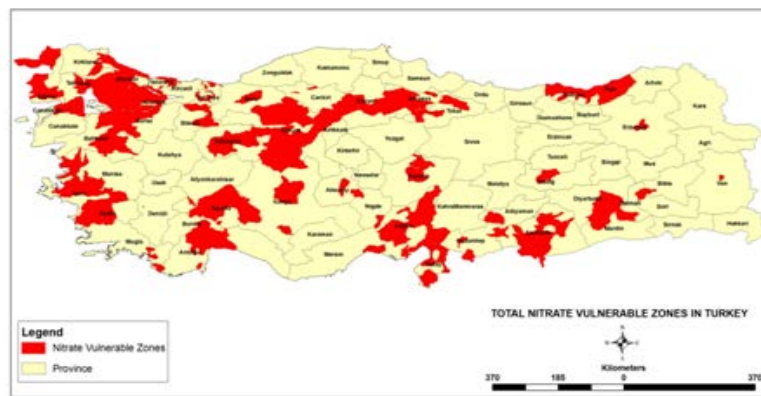
Having concluded the analysis of each separate thematic layer, the final distribution of the NVZs was calculated. The designated NVZs distributed at river basin scale are presented in Figure 5, and the respective NVZs distributed at province scale is depicted in Figure 6. In total, the designated NVZs are distributed in 53 of the 81 Provinces or 24 of the 25 River Basins of the country. The total areal extent is 148,669.76 km<sup>2</sup>, which represents 19.02% of the country[14].



**Figure 5:** Distribution of designated NVZs at River Basin scale

It is essential to note that the contribution of the areas draining into the identified NVZs and the areas where excessive N-input occurs are much larger than the actual groundwater and surface water bodies characterized as NVZs. This in turn signifies the importance of the agricultural management practices at river basin scale. Consequently, this stresses the fact that intervention measures in the framework of specific action plans to alleviate the documented problems need to be implemented at much larger scales than the boundaries of the affected water bodies, in order for them to be efficient and effective.

Surface and groundwater samples were classified according to the nitrates concentration into classes[11]. Hydrochemical data assessment at river basin level for the period 2008-2011 indicated that 59.5% of the surface water monitoring stations contain nitrates between 0.01 and 1.99 mg/l, 35.3% belong to the class 2.0-9.99 mg/l, 4.6% of the stations belong to the class 10.0-25.0 mg/l, 0.5% to the class 25.0-39.99 and only 0.1% of the stations has a mean content which ranges between 40.0-50.0 mg/l. None of the monitoring stations belongs to class with nitrates concentration higher than 50.0 mg/l. It was also observed that groundwater samples with an average nitrates concentration between 0.01-25.0 mg l<sup>-1</sup> represent 89.6% of the monitoring stations, which is the future target of European Union, regarding the maximum allowable concentration for drinking water[15]. Also, it has been recorded that 6.7% of the stations have a concentration 25.0-50.0 mg l<sup>-1</sup> and the rest 3.7 % was > 50.0 mg l<sup>-1</sup>. Statistical analysis on groundwater monitoring stations data showed strong increase trends of nitrates in ten river basins and weak increase in nine river basins for the period between 2008 and 2011. Results for the above mentioned period regarding the surface waters monitoring stations revealed a rather stable situation in thirteen river basins, and weak increase trends in five river basins.



**Figure 6:** Distribution of designated NVZs at Province scale

Concentrations of nitrates in surface and ground waters vary greatly among monitoring stations for the same sampling period. In general, higher concentrations in groundwaters were expected in drier areas and lower in wetter areas, due to the effect of dilution in wetter areas. These trends were not recorded for the monitoring stations, because are depended on fertilization and farming practices. Nitrate concentrations in groundwaters fluctuate less in comparison to surface waters, and variation in surface waters can be attributed to differences in climate conditions and the runoff conditions imposed by them. Groundwater protection from nitrates is of high priority and can be achieved through measures that are mostly focused on the reduction of pollutant inputs to the system. The required quantity of fertilizers in various crops, the number of fertilization doses and the applied



water quantity per year vary widely depending mainly on soil type and irrigation method. Also, application of proper tillage systems to minimize run-off and set-aside in conjunction with a proper rotation system are realistic and effective practices for minimizing pollution. Hydrochemical results of the monitoring network have shown that concentration of nitrates is relatively low in comparison to the corresponding values of Greece [16]. This can be attributed to less intensive agriculture in Turkey where farmers use lower quantities of nitrogenous fertilizers. It needs to be stressed however, that afore discussed results are expected to alter dramatically on the basis of spatial increase of the available data base to include large areas of the country that are now covered either insufficiently or not at all.

#### 4. Conclusions

The designation of NVZs in Turkey was based on the monitoring network of nitrates concentrations for ground and surface waters. Specific improvements need to be implemented in order to make the network more efficient, reliable and more representative. Distribution and location of the monitoring networks should be closely related to agricultural land use, hydrogeology, geomorphology and hydrologic features. Aquifer vulnerability mapping is essential in the designation of the NVZs, especially at a next stage, and analysis of aquifer vulnerability is perhaps the safest and most efficient measure for pollution prevention. The identified groundwater NVZs are distributed in 14 river basins or 21 provinces and the surface water bodies that are designated as NVZs are distributed in 27 Provinces. Hydrochemical data indicated a low eutrophication risk in twelve river basins both for rivers and lakes and this risk was moderate in nine river basins. Statistical analysis showed significant increase trends of groundwater nitrate concentrations in ten river basins and weak increase in nine river basins for the examined period. For the same period, nitrate concentrations in surface waters exhibit a stable situation in thirteen river basins, and a weak increase trend in five river basins. In certain provinces of Turkey, high nitrate concentrations in rivers could be attributed to industry rather than agriculture, whereas in other cases agriculture can be viewed as the most likely source of pollution.

#### Acknowledgment

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