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Anthropogenic Impacts on Groundwater Resources and Legal-Administrative Approach in Türkiye

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ABSTRACT

The main anthropogenic impacts on groundwater resources in Türkiye may be divided into four, overexploitation (excessive use), pollution, preventing recharge by covering it with impermeable materials, and destroying the aquifer by excavation. Excessive use of groundwater primarily causes a decrease in water level and quality deterioration. Industrialization, urbanization and agricultural activities are the biggest polluting threats. Most cities in Türkiye are located on valuable alluvial and limestone aquifers. Groundwater recharge is altered and reduced due to the covering with impermeable materials such as roofs, asphalt and concrete roads, parking lots, and pavements in urban areas. Sand-gravel and stone quarries are the other threats to groundwater resources.

There is comprehensive legislation on groundwater in Türkiye that started in 1960 and developed over time. However, significant problems still persist and are even growing. The gaps in the legislation against some anthropogenic impacts on groundwater and sometimes the failure to implement the legislation weaken the sustainable protection of groundwater resources. Groundwaters in Türkiye, which are already under the impact of drought and global climate change, should be evaluated as a strategic resource and protected for future generations. A new paradigm is needed to overcome the problems created by anthropogenic and natural impacts.

Keywords: Groundwater, overexploitation, pollution, urbanization, excavation, legislation

1. Introduction

Alluvial and carbonate formations constitute the most productive aquifers in Türkiye. Carbonates (mostly limestones) cover approximately one-third of the country. In areas where limestones are extensive and thick, they contain considerable groundwater and discharge large springs. Alluvial deposits particularly located in fault-controlled plains and wide valleys are the other valuable groundwater resources for the country. Basalts and tuffs are also

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aquifers that have local importance (Apaydın, 2018). According to DSI data (DSI, 2020), the total usable groundwater reserve of the country is 18 km3, of which 15 km3 is used. Almost three-quarters of the use is used in the irrigation sector (DSI, 2020; Yılmaz, 2021). As in many regions of the world, groundwater, the main source of which is precipitation, is under the influence of spatial and temporal changes in climate and also in anthropogenic effects in Türkiye. In the country, the annual average precipitation does not exceed 500 mm except in coastal areas and high mountain belts, and it falls below 400 mm in a wide area in the interior regions. In arid and semiarid regions, precipitation generally occurs mostly in winter and spring, but water is needed most in summer and early autumn. In Türkiye, where serious droughts have been experienced in the recent past and historical periods (Apaydın and Ocakoğlu 2020; Altındaş, 2018; Karademir, 2014; Uyanık and Sarı 2011; Erler, 1997), droughts have become more frequent, longer and more severe due to climate change, thus affecting life more.

The issue of climate change, global warming and drought has been a frequently discussed issue in Türkiye since the early years of the 21st century. In addition to drought and climate change, anthropogenic impacts are also very effective on water resources. Agricultural activities, urbanization and industrialization, especially due to population growth, threaten groundwater resources in terms of quantity and quality. Overuse and pollution are the two most important problems. In addition, urbanization and the deterioration of the groundwater balance, the threat of sand pits, stone and marble quarries, and unlicensed and uncontrolled use complicate the situation even more. In fact, the fundamental problem is that the public and decision-making authorities accept that the impact on water resources and aquatic environments is solely due to global climate change or highlight this factor. This mentality is actually a result of avoiding responsibility by ignoring anthropogenic impacts.

In this study, the anthropogenic impacts on groundwater in Türkiye are analysed, and related legal and administrative approaches are examined. Firstly, anthropogenic impacts are classified and defined, and then their effects and results are analysed. It is supported with examples from anywhere in the country. In the advanced stage, legal legislation aimed at preventing impacts on groundwater resources and thus protecting groundwater is examined. How legislation is implemented at the institutional level and how the process is managed is also examined. The rationale, purpose and approach in practice of legal provisions are questioned and interpreted.

2. Anthropogenic Impacts on Groundwater Resources in Türkiye

The anthropogenic impacts on groundwater in Türkiye may be divided into four overexploitation (overabstraction), pollution, preventing recharge by covering it, and reducing or destroying the aquifer by excavation. Most people may be familiar with the first two because there are many scientific publications, media and press reports on this subject. The other two, which are less frequently discussed, are more dangerous (Fig. 1).

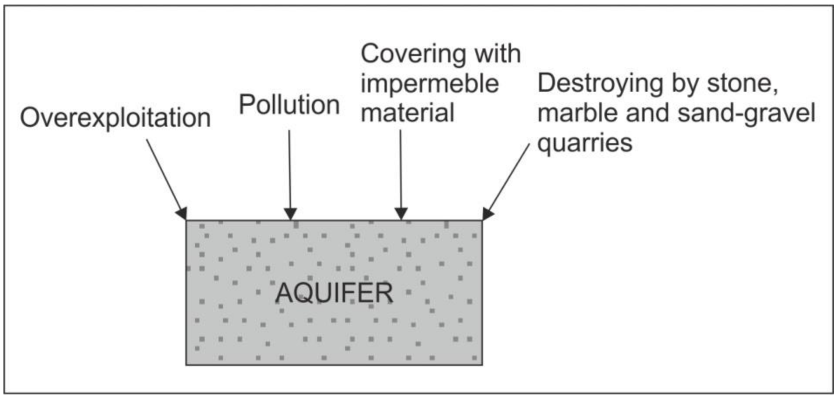

Fig. 1. Schematic presentation of the main anthropogenic impacts on groundwater resources in Türkiye (The damage increases to the right)

2.1. Groundwater Overexploitation

Excessive use of groundwater primarily causes a decrease in water level, sometimes quality deterioration, negative effects on the ecosystem related to the aquifer, and subsidence (sinkhole formation in carbonate aquifers) (Fig. 2). The situation becomes more complicated when several of these negative factors are present in a region. If there is also a withdrawal due to drought and climate change, the situation becomes even more complicated.

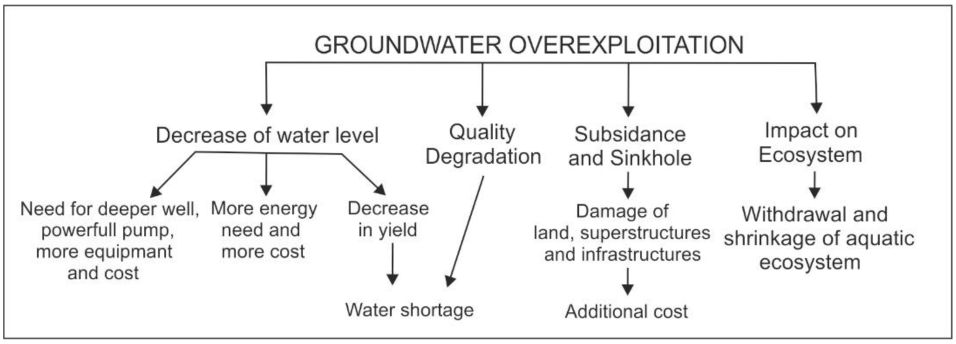

Fig. 2. Hierarchical expression of undesired consequences of excessive groundwater use in Türkiye

The most common negative effect of excessive extraction in Türkiye is the decrease in the groundwater level. This means that it is necessary to drill deeper wells and draw water from deeper depths compared to the past. In other words, it means an increase in construction and operating costs. Moreover, as the water level drops and the saturated thickness of the aquifer decreases, well yields also decrease. As the level and yield decrease, neighbouring wells affect each other more, which causes disagreements among water users.

In various regions of Türkiye, the groundwater level has fallen in a way that it cannot easily rise again due to excessive withdrawal, and the most famous site in this regard is the Konya Closed Basin (Fig. 3). This basin has semi-arid climate characteristics in the central region of Türkiye, and irrigated agriculture, especially sugar beet, is widespread. Irrigated agriculture is carried out on one-third of the 18.5 million decares agricultural area in the Konya Plain, known as the 'granary of Türkiye'. It supplies approximately 10 percent of Türkiye's total agricultural production (URL-1). Irrigation has mostly been done by withdrawal from wells since the 1960s. Excessive withdrawal and falling water levels have been on the country's agenda for at least 30 years. Many scientific papers, books and reports have been published on this subject. It also remains on the agenda with frequent news in the media and press (URL-1, URL-2, URL-3, URL-4). As of 2021, the number of licensed wells in the basin is around 20 thousand (Gedik, 2021). The number of unlicensed wells is at least four times this number. More than twice the annual recharge is used (SYGM 2018a). 60% of the groundwater used is illegal. Borehole depth varies between 70-250 m (SYGM 2018b). In some parts of the region, new sinkholes are formed due to the decrease in groundwater level (Ateş 2003; Yılmaz, 2010). The sinkholes formed in the last 5 years (Fig. 4) are narrower in diameter (45-50 m) and deeper (90-95 m) than the old ones. This is because groundwater has now fallen to very deep levels. In addition to local pollution, there is also pollution caused by agriculture and animal husbandry in the groundwater in the basin (SYGM 2018b). However, no evidence of quality deterioration due to the decrease in water level has been found. The groundwater level has decreased to 170-200 meters (URL-5). Some studies have been carried out in order to control the groundwater level and withdrawals in the region (Tunçok and Bozkurt 2015; SYGM, 2018b, 2023; Yıldız, 2022). In addition, some water is discharged from the water channel taken from the Mavi Tunnel to the Gökhöyük (Timraş) Sinkhole, one of the large sinkholes in that region, by the State Hydraulic Works (DSİ) and transferred to the Hotamış storage for artificial recharge of the groundwater (Fig. 5).

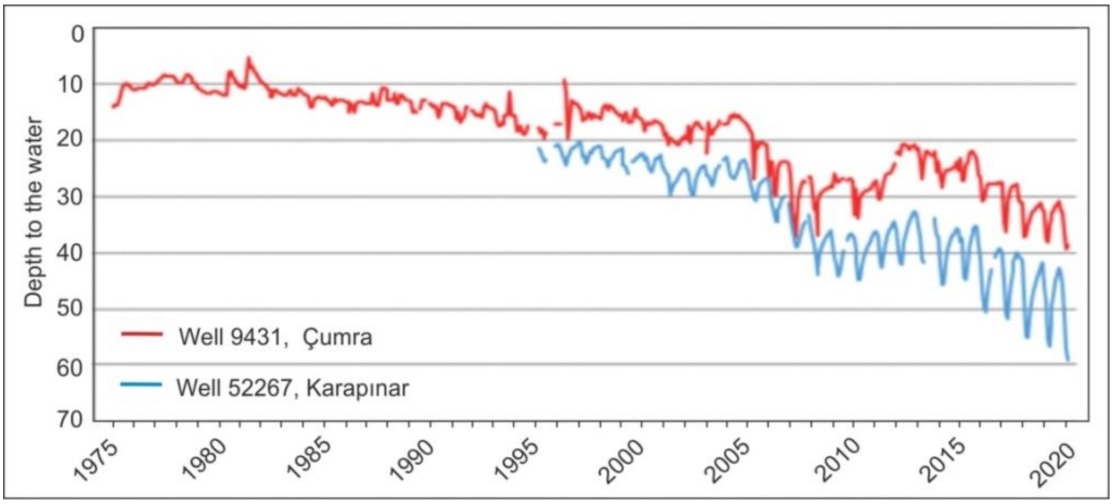

Fig. 3. Long-term permanent groundwater level change in some wells in Konya Closed Basin (URL-6)

Fig. 4. New sinkhole formations in Konya Karapınar region (URL-7, 8, 9)

Fig. 5. Artificial groundwater recharge with water flowing from the channel to the Gökhöyük (Timraş) sinkhole (URL-10, 11)

2.2. Pollution of Groundwaters

Pollution is one of the most important threats to water resources. Although groundwater is slightly more resistant to pollution than surface water, it is exposed to pollutants because it is associated with surface water. The biggest threat to groundwater pollution in Türkiye is industrialization and urbanization. The use of agricultural pesticides and fertilizers is also an important source of pollution (Fig. 6). The Ergene Basin in the northwest, and the Büyük Menderes and Küçük Menderes Basins in the west are the most well-known regions. Due to the industrialization that started in the 1970s in the Ergene basin, streams (Tokatlı, 2015, 2020) and groundwater associated with it have been polluted. Today, industrial facilities discharge their wastes, especially into Çorlu Creek, a tributary of Ergene, without treatment, and therefore the Ergene aquifer, which is in contact with the creek, has been polluted (Arkoç and Erdoğan 2006; Arkoç, 2012; Orta, 2010). Other examples of nitrate pollution from agricultural sources are Ankara (Ataseven, 2011), Antalya (Kaplan and others, 1996), Bursa (Yahşi 1981), Eskişehir (Kaçaroğlu and Günay 1997).

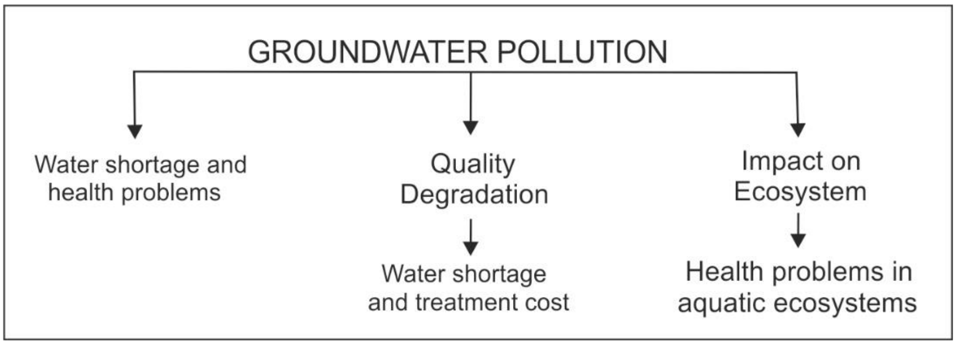

Fig. 6. Undesired consequences of groundwater pollution in Türkiye

2.3. Covering with Impermeable Materials in Urban Areas

Many studies (Craig and Anderson, 1979; Foster and others. 1997, 1998, Lerner, 2002; Morris and others 2003) indicate that urbanization affects the quantity and quality of groundwater (Fig. 7). These effects occur in the form of changes in the amount of recharge and circulation, changes in the withdrawal regime and groundwater level, and negative effects on groundwater quality (Foster and Chilton 1998). Recharge is altered due to the covering with impermeable materials such as roofs, asphalt and concrete roads, parking lots, and pavements. However, water collected from such areas, where groundwater recharge was previously widespread, is collected and drained in pipes or channels with narrower cross-sections (Lerner, 2002) and moves away from the region without infiltrating into the aquifers. As cities expand, impermeable areas also expand, but water infrastructure increasingly depends on surface water or groundwater brought from outside the urban area. In addition to the recharge from leakage from this expanding infrastructure, other sources of recharge are car washes and other cleaning activities, and recharge from irrigation in parks and sports areas (Morris and others, 2003). Thus, natural recharge in urban areas decreases; but new recharge mechanisms are created. As a result, urban development alters the natural hydrological cycle. These alterations disrupt the balance of surface water and groundwater interactions, leading to lowered water tables and diminished recharge rates (URL-12).

Most cities in Türkiye are located on or at the edge of alluvial plains. 52 out of 81 cities in Türkiye are partially or completely located on large and highly productive aquifers (Apaydın, 2018). The development and expansion of some cities located at the foothills of mountains is towards the alluvial plains where there is abundant groundwater. 55% of the country's population lives in large cities (provincial centres) that completely or partially cover aquifers. This ratio reaches 63% when we include large district centres such as Akhisar, Nazilli, Ceyhan and Tarsus. In addition, many smaller cities are located on highly productive aquifers. The potential for groundwater withdrawal in Türkiye has been estimated by the DSI as approximately 18 billion m3/year. Approximately three-quarters of this amount is in aquifers where cities are located or in close contact. In other words, 13.5 million m3 of groundwater is under the impact of urbanization. The aquifers most affected by urbanization in Türkiye are alluviums. Urbanization affects groundwater resources in terms of both quantity and quality. This situation is also the case in other parts of the world. For example, in a study conducted for some megacities in Asia (Haque and others, 2013), groundwater levels in Delhi (India) and

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Dhaka (Bangladesh) cities decreased due to excessive urban expansion, and groundwater was polluted in Delhi due to the pressure of dense population. In the coastal areas of Karachi and Mumbai, groundwater pollution has increased even more due to seawater intrusion and dense population.

There are few current studies in Türkiye on the impact of urbanization on groundwater resources. Apaydın (2018) examined the impact of urbanization on groundwater recharge in Türkiye, especially in terms of quantity, by addressing the issue of urbanization-groundwater recharge. Baba and Yazdani (2017) concluded in their study on the city of Izmir that the recharge rate from precipitation in the Izmir-Bornova region, which was 25% in 1925, decreased to 13% in 2012, and it was predicted that recharge would decrease to 1% in 2030 as a result of the continuation of the urbanization effect. Baba and Yazdani (2019) concluded that the groundwater dynamics were disrupted by urbanization in the Izmir-Bornova plain and that the construction of high-rise buildings with deep foundations prevented the natural discharge of groundwater towards the sea.

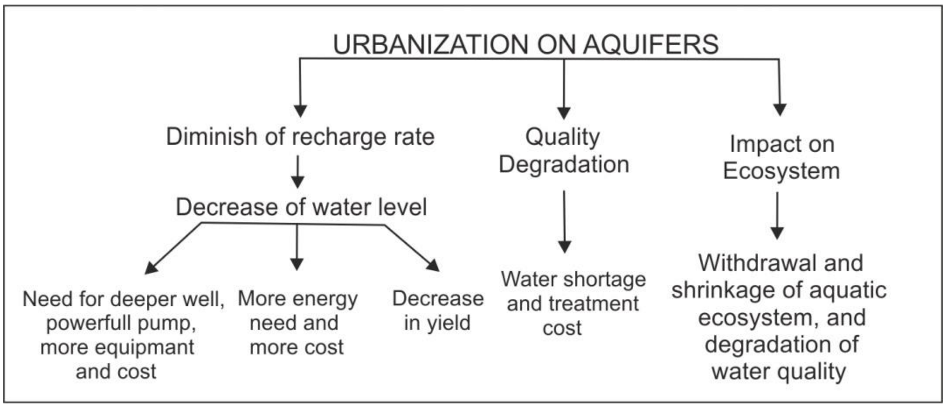

Fig. 7. Undesired results of covering aquifers with impermeable material in urban areas

2.4. Destroying the Aquifer by Excavation

The extraction of sand-gravel (Sonak and others 2006; Kondolf, 1994, 1997) and stone and marble (Marzouk, 2018; Sharma and others 2024) resources has a number of adverse environmental impacts. One of the most important environmental changes caused by sand–gravel pits occurs in groundwater aquifers. Sand–gravel pits affect groundwater systems in terms of quality and quantity. The potential impacts of sand–gravel pits include lowering groundwater levels due to excavations and mine dewatering, changes in turbidity levels in groundwater due to operation, temperature change (thermal impacts) in groundwater due to cropping out to the surface and contamination (Kondolf 1994, 1997; Sonak and others, 2006; Marquez and others, 2007; Navarro and Carbonel 2007; Peckenham and others, 2009). The most significant environmental impact of sand–gravel pits includes the reduction and destruction of the aquifer volume.

In most regions of Türkiye, Quaternary sand–gravel aquifers are under the threat of sand–gravel pits, and also some aquifers have already been damaged or completely excavated in the last decade. Hundreds of pits continue to destroy productive aquifers. Kazan Plain near the capital Ankara is a striking example of both the effects of sand-gravel mining and overexploitation on fresh groundwater (Apaydin and others, 2021, Apaydin 2012).

Natural stone is an important material used for construction, sculpting and decorative purposes. Thanks to the various geological formations found in various parts of the world, natural stones such as granite, marble, travertine, onyx, basalt and quartzite can be obtained. Türkiye carries out 33% of the world's marble exports and 40% of the world's travertine exports. There are more than two thousand marble and travertine quarries in Türkiye and more than 10,000 facilities processing natural stone. The main countries to which natural stone is exported from Türkiye are China, Italy, the USA, Germany, Japan, Russia, Poland, Spain and the United Arab Emirates (STSO 2023). According to the data of the General Directorate of Mineral Research and Exploration (MTA), Türkiye's natural stone potential is approximately 5 billion cubic meters (Adıgüzel and Şengüler 2019). Almost 40% of the operating quarry licenses are in Burdur, Isparta, Antalya, Muğla, Denizli and Afyonkarahisar located in the Western Taurus and the vicinity. These licenses were mostly granted in carbonate aquifer areas containing abundant groundwater. These aquifers and the large springs are under threat from the quarries. Aquifers are being destroyed and reduced in size by excavation every passing day. As a result, the groundwater level is falling, the springs are withdrawn and pollution is inevitable (Fig. 8).

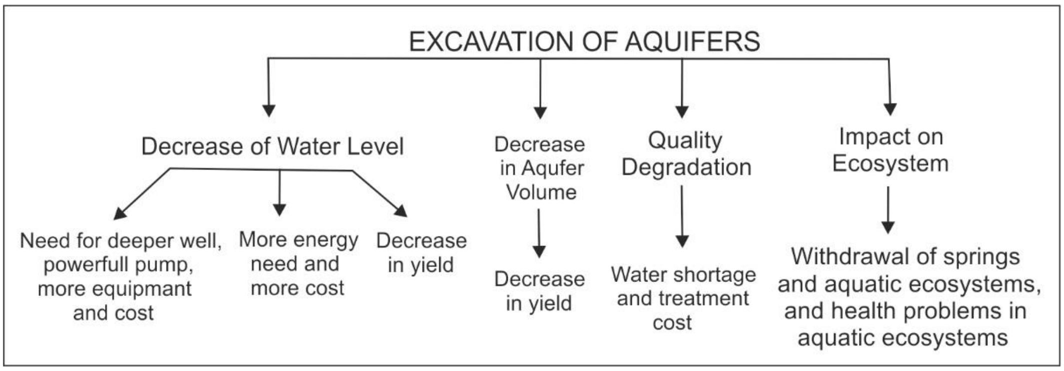

Fig. 8. Undesirable results of stone, marble and sand-gravel mining in Türkiye

3. LEGAL AND ADMINISTRATIVE APPROACH TO THE IMPACTS

There is no direct provision regarding water in the 1982 Constitution of the Republic of Türkiye. However, there is a provision that can be indirectly related to water in Article 168. Article 168 states that natural resources are under the sovereignty and control of the state and that the right to explore and operate these resources belongs to the state.

In Türkiye, groundwater issues are handled by the State Hydraulic Works (DSI) in accordance with the provisions of the Groundwater Law No. 167. This law and related legislation cover the exploration, protection and licensing of groundwater. In accordance with this law, first the Groundwater Regulation (1960) and later the DSI Groundwater Technical Regulation (1972) were put into effect. Later, Solid Waste Control Regulation (1991), Regulation on Assessment of Environmental Impacts (1992), Medical Waste Control Regulation (1993), Toxic Chemical

Substances and Products Control Regulation (1993), Hazardous Waste Control Regulation (1993), Water Pollution Control Regulation (2004) and Regulation on the Protection of Groundwater Against Pollution and Deterioration (2012), Communiqué on Determination of Protection Areas of Aquifers and Resources Supplying Drinking Water (2012), General Directorate of State Hydraulic Works Groundwater Measurement Systems Regulation (2013), Regulation on Monitoring of Surface Waters and Groundwater (2014) were put into effect. Within the scope of this legislation, the provisions and implementation approach on anthropogenic impacts on groundwater are explained below.

3.1. Overexploitation

There is no provision in the main text of the Law of Groundwater regarding the groundwater level or the decrease in yield. Article 12 states that "According to the observations and researches made for the purpose of operating the groundwater reserve within the safe limit without depleting it, the amount of safe water to be withdrawn from the wells may be decreased or increased as necessary. In this case, the license holders are notified by DSI and the necessary revisions are made to the license. At the same time, the previously determined beneficial need of the land or well owners is also adjusted in accordance with the change in the groundwater storage capacity." Thus, a precaution is considered against excessive decrease in the water level indirectly. Article 15 states that "The amount of water to be allocated for beneficial need can never be higher than the safe yield of the groundwater reserve".

The "General Directorate of State Hydraulic Works Groundwater Measurement Systems Regulation" prepared based on the "Law on Groundwater" aims to control the amount of water to be withdrawn from wells, drainages, galleries, etc. constructed to obtain groundwater by obtaining a usage license. The main purpose of the regulation is to measure the amount of groundwater used and to prevent the use of more water than permitted. It states the installation of automatic meters in wells for industrial purposes in Türkiye, and the installation of meters in all wells in the Ergene basin (NW Türkiye) and Konya Closed basin (Central Türkiye). The ultimate goal of this application is to prevent the water level in the aquifer from falling to undesirable levels and to protect the groundwater system.

There are no provisions in the legislation regarding the concepts of subsidence and sinkhole formation or any provisions related to them. However, the provisions regarding the prevention of excessive use and excessive fall in groundwater levels serve to prevent this subsidence event indirectly to some extent.

The Groundwater Law generally aims to protect the amount of groundwater and the rights of the people and to define the authority of the State. The provisions regarding the prevention of excessive use and excessive fall in groundwater levels are not sufficient to protect the ecosystem in which the groundwater is located or interacts.

The concept of "safe yield" in the legislation should be replaced by the concept of "sustainable yield" and "sustainable management". Safe yield refers to protecting the groundwater bodies, while sustainable yield and management refers to protecting both the groundwater and all water environments associated with it by affecting them the least. This issue is generally mentioned in the Regulation on the Protection of Wetlands. The Regulation states that "It is essential not to pollute wetlands and to protect their natural structures and ecological characters. The protection of the functions and values of wetlands will be ensured in all land and water use planning."

3.2. Groundwater Pollution and Quality Degradation

There are no direct preventive provisions in the Groundwater Law regarding quality degradation due to excessive drops in water levels or other reasons. While the protective provisions of the Groundwater Law are generally aimed at protecting the quantity, there is a provision regarding saltwater intrusion. The Groundwater Technical Regulation draws attention to the issue by stating that "If it is deemed necessary to open a well in coastal areas; the well location should be selected far enough from the coast to prevent seawater from mixing with the well water, taking into account the geological condition of the formation".

Provisions to prevent groundwater pollution were implemented for a while in the Water Pollution Control Regulation that came into force in 2004, and as of 2012, prohibitions and permits for direct and/or indirect discharges into groundwater bodies have been implemented within the framework of the Regulation on the Protection of Groundwater Against Pollution and Deterioration. Accordingly, pollution monitoring studies to be carried out in groundwater for all kinds of regular storage activities are carried out in reference and observation wells within the framework of Table 23 in the annex of this regulation. For this purpose, it has been stipulated that an observation network consisting of wells will be established (in fact, DSI has had a quality observation network since the 1960s). This law states that "In case any pollution is detected in groundwater as a result of activities; the Ministry shall take action in accordance with the Environmental Law and relevant legislation. Those causing pollution are obliged to eliminate the pollution they have created and to bring the quality of the groundwater to the quality determined before the activity begins in the reference monitoring well and to cover all expenses in this regard."

With the entry into force of the 'Regulation on the Protection of Groundwater Against Pollution and Degradation' in 2012, in order to harmonize the implementation of the European Union Water Framework Directive with Turkish legislation, we have encountered some concepts. These are new concepts such as groundwater mass, quality and quantity monitoring assessments of masses, pressure-impact-risk, threshold value, trend analysis, measures program, and groundwater protection area. These concepts have started to take place in the works of DSI and the General Directorate of Water Management. The purpose of the regulation is to reveal the current status of groundwater, protect it, prevent its pollution and deterioration, and cover the principles of taking the necessary measures for the improvement of waters.

One of the most radical principles of this regulation is the one expressed in Article 5. This article states that "Direct discharge of wastewater into groundwater is prohibited regardless of its quality." This provision was transferred from the Water Pollution Control Regulation. Direct discharge into groundwater is prohibited even if the water is purified. The indirect discharge of purified wastewater into groundwater bodies is permitted by the Ministry of

Environment and Urbanization as a result of engineering studies to be carried out by taking into account the intended use of the groundwater, its quality, and the tolerance capacity of the groundwater in case the purified water to be given mixes with the groundwater, in accordance with the provisions of the Regulation on Permits and Licenses to be obtained by the Environmental Law that entered into force in 2009. However, what is meant by direct and indirect discharge is not explained.

The regulation also includes the determination of ecosystems that have hydraulic connections with groundwater. This is a new issue that has not been included in the legislation before. Another important innovation is the introduction of the concept of protection areas, especially for drinking water facilities and resources. Thereupon, the Communiqué on the Determination of Protection Areas of Aquifers and Resources Supplying Drinking Water was published by DSI in the same year (2012). The natural and anthropogenic impacts on the groundwater bodies defined in the regulation were determined, and the effects on the bodies were started to be monitored in quality and quantity. Quality monitoring is carried out in two ways observational and operational. The parameters of the groundwater body are first monitored in a surveillance manner, and after the surveillance monitoring is completed, operational monitoring is carried out for the parameters exceeding the threshold value.

The regulation also addresses important issues related to level changes, pollution and overdrafts. Accordingly; the analysis of the impacts on groundwater resulting from human activities and the effects resulting from these impacts is prepared by SYGM by obtaining all necessary information, documents and inventory from relevant institutions. The evaluation of the effects of changes in groundwater levels is carried out or commissioned by DSI and reported to SYGM once a year. The evaluation of the pollution effects on groundwater quality is carried out or commissioned by SYGM and DSI and according to this evaluation, the groundwater masses at risk are determined by the working groups to be established by SYGM and DSI. In groundwater uses, it is essential to maintain the balance of recharge and withdrawal and not to use more water than the allocated amount.

Another innovation brought by the regulation is that it brings a standard and a framework to the subject of monitoring. In this regard; in order to review the effects of human activities on groundwater, DSI determines the number and location of groundwater observation wells that will represent each aquifer and groundwater levels are monitored with sufficient frequency. A standard has been introduced stating that "Monitoring of the quantity and chemical status of groundwater bodies is carried out by DSI after the characterization of the groundwater bodies."

In addition, “harmful substances that can be carried by wastewater or rainwater and mixed into groundwater cannot be directly stored on the ground within the groundwater feeding basin. In order to take precautions to prevent groundwater pollution, storage tanks for all kinds of chemicals, process and treatment sludges, special wastes and similar substances are made leak-proof. When it is necessary to use radioactive tracers, substances that will not cause water pollution are selected and if irrigation is carried out with wastewater, the irrigation water quality, quantity and irrigation program are arranged in a way that minimizes the risk of these waters leaking into groundwater and causing permanent pollution" provisions have been put into effect.

The purpose of the Regulation on Monitoring of Surface Waters and Groundwater, which was put into effect in 2014, is to determine the quantity, quality and hydromorphological status of all surface waters and groundwaters in Türkiye, to determine the ways and methods for monitoring waters and ensuring coordination of institutions and organizations. The regulation also states that a groundwater monitoring network will be established by DSI after receiving the opinions of the relevant institutions and organizations. The monitoring network has been operating for 10 years.

3.3. Urbanization on the Aquifers

There is no provision in Groundwater Law No. 167, the Groundwater Regulation and the DSI Groundwater Technical Regulation regarding the zoning application in aquifer areas, and their protection by keeping them away from construction and industrialization. Until 2012, DSI experts who were asked for their opinions on groundwater in areas where zoning applications will be made were giving their opinions based on the general protection provisions of the legislation at that time. The provision that 'It is necessary to obtain a positive opinion from DSI for zoning application in groundwater recharge areas' was included in the measures program section of the 'Regulation on the Protection of Groundwater Against Pollution and Deterioration' that entered into force in 2012. This statement means that if DSI's opinion is negative, zoning will not be permitted.

According to the "Circular on Streambeds and Floods" published by the Prime Ministry in 2010, there is a provision stating that "the measures and recommendations of DSI shall be meticulously followed during the preparation of zoning plans for large and medium-scale planned settlements such as provinces, districts and towns, and all kinds of small-scale settlements made according to local plans." However, this provision is only intended to prevent construction in areas with flood risk. It can be used for aquifers entering the flood area, but it is not intended to directly protect aquifer areas.

3.4. Excavation of Aquifer Formations

There is no provision on this subject in the Groundwater Law, the Groundwater Regulation and the DSI Groundwater Technical Regulation. In the Measures Program section of the Regulation on the Protection of Groundwater Against Pollution and Deterioration, it is stated that "It is prohibited to obtain material from any formation with aquifer character that contains groundwater reserves. However, DSI may permit the collection of material from groundwater recharge basins on condition that the groundwater bodies are not damaged." This provision was previously included in the Water Pollution Control Regulation.

There are some restrictions and prohibitions in the Regulation on the Collection, Operation and Control of Sand, Gravel and Similar Materials. In summary, there is a provision that states, "It is not permitted to open and operate sand and gravel quarries in the continental surface water resources that provide drinking and utility water and in the flowing and dry streams that feed them, and in any formations with aquifer characteristics that contain groundwater reserves." The Circular on Stream Beds and Floods includes the provision that "Sand, gravel and stabilized material quarries operating activities within stream beds or in areas adjacent to stream beds shall be carried out in accordance with the opinions of DSI. In cases of irregular practices, the permits of the quarries shall be cancelled by the administrations that issue the licenses." Similar provisions of these two legislations aim to protect aquifers against sand and gravel mining, but there is no provision in the legislation regarding marble and stone quarries.

4. Conclusion

In Türkiye, the main anthropogenic impacts on groundwater resources are overuse, pollution, urbanization, reduction of recharge and destruction by excavation. In addition to these, there are other impacts such as reducing recharge by building reservoirs on rivers and water use from streams. Reduction in stream flow rates, either through direct use from streams or storage in reservoirs, reduces recharge to the aquifer, but four main impacts are the most effective and destructive. Even if the abstraction is completely stopped in an aquifer whose water level has extremely decreased due to excessive water withdrawal, it takes a very long time for the aquifer to be completely renewed. This period can take decades, centuries or even millennia depending on factors such as the type, type, thickness and distribution area of the aquifer, and its hydraulic conductivity. Natural cleaning of polluted aquifers requires an even longer period or it is not possible to return to its original fresh state at all. In aquifers that are covered with impermeable material by urbanization or damaged by excavation due to mining, it is too late to return.

The administrators of the big cities, especially in the arid and semi-arid regions of Türkiye, obtain their water from large dams, but when there is not enough water in the reservoirs during long-term droughts; groundwater resources in the city and its vicinity are needed. For this reason, the protection of water resources in terms of both quantity and quality should not be ignored when making city development plans. Unfortunately, while cities, which are becoming increasingly industrialized and whose populations are increasing, are trying to find more costly drinking water resources from far away in order to meet their water needs, it is a great contradiction that the development plans of the cities are directed towards areas with groundwater.

The gaps in the legislation against anthropogenic impacts on groundwater and sometimes the failure to implement the legislation weaken the sustainable protection of groundwater resources. Groundwater in Türkiye, which is already under the impact of drought and global climate change, should be evaluated as a strategic resource and must be protected for future generations by preserving its original state and even improving it if possible, as stated in the European Union Water Framework Directive.

As stated in the introduction section, the perception of the public and decision-making authorities that the impact on groundwater resources is largely due to global climate change is an obstacle to the solution of the problems. First of all, a new paradigm is needed that focuses on anthropogenic impacts that humans can prevent or control. However, this may not be enough, because for success it must be supported by the determined and sustainable implementation. Some restrictive decisions may be temporarily painful, but it should be comprehended that they will benefit humanity in the long term.

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