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A Review of Water Pollution in Israel and Palestine

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Abstract

Water pollution is a daily risk with a major impact on both populations and ecosystems. An analysis of water pollution types is essential to determine the affected regions and the magnitude of its impact on various components of the geosystem. This study aims to conduct a thorough analysis of water pollution in the Israel and Palestine, focusing on the three main types of pollution: physical, chemical, and biological. The methodology of this article is based on the critical review of 22 scientific papers published between 1972 and 2023, addressing various aspects of water pollution in the analyzed region, from generating sources to their impact. Most studies are authored by researchers affiliated with institutions located in the conflict region, with many samples collected directly from the field and processed in laboratories or GIS environments. The study results highlight chemical pollution often exceeding recommended limits for various analyzed parameters. Biological pollution subjects aquatic ecosystems to significant pressures, including eutrophication and harmful algal blooms. Wastewater is discharged into watercourses in the region, affecting their physical properties. Areas subject to water pollution include the Gaza Strip, the coastal zone, the northern aquifer in Israel, and lakes in the western part of the analysis region, posing potential risks to the health of the populations in Israel and Palestine.

Keywords: Water pollution, Israel, Palestine, physicochemical parameters, eutrophication, wastewater

Introduction

Water is a resource that can bring both peace when managed rationally and sustainably, but it can also cause conflicts when access to it is limited or when it is polluted, thus creating disagreements between states. To raise awareness about the increasing tensions, the theme for World Water Day 2024 was chosen as Water for Peace.

Pollution represents one of the main problems of contemporary society, affecting not only the environment but also the lives of millions of people. One of the main types of pollution is water pollution. This is a phenomenon of contaminating water resources (rivers, lakes, seas, and oceans) with high toxicity organic and inorganic pollutants (Warren-Vega et al., 2023). Factors contributing to the pollution of water include industrial activities, agriculture, natural factors, biological factors, as well as inadequate water supply and the lack of wastewater treatment plants (Lin et al., 2022).

In recent years, water quality has become significantly affected in areas of military conflict. The Israel-Palestinian military warfare is one of the most complex and protracted conflicts in the world, with historical, religious, political, and territorial roots.

Subsequent wars between Israel and neighboring Arab countries have led to the expansion of territory controlled by Israel and the massive exodus of the Palestinian population. The Israeli occupancy of the West Bank, the Gaza Strip, and East Jerusalem succeeding the 1967 War intensified tensions (Feitelson, 2000).

According to Baalousha (2008), over the years, several international efforts have been made to reach a peaceful solution to the conflict, including the Oslo Accords in 1993. In accordance with the Oslo agreement between Palestine and Israel, the latter should provide the Gaza Strip with 5 million cubic meters of fresh water annually (El-Nakhal, 2004). Although this water is not provided for free, and the Palestinian Authority pays for it, Israel halved the volume of water from 1998 to 2004, in a clear violation of the Oslo Accords (Gray, 2006). However, the expansion of Jewish settlements in the occupied Palestinian territories, the blockade and siege of the Gaza Strip, and disputes over control of Jerusalem continue to fuel tensions and conflicts.

The study area, including both Israel and Palestine, is located at the border between Asia and Africa, in an area limited in continental water resources but rich in coastal water resources, due to its openness to the

Mediterranean Sea in the west and the Red Sea in the south (Figure 1.A). Israel is administratively divided into 6 districts, surrounded to the north by Lebanon, to the northeast by Syria, to the east by Jordan, to the southwest by Egypt, while Palestine is divided into two major territories: the West Bank east of Israel and the Gaza Strip on the Mediterranean coast (Figure 1.B). The study area presents four distinct regions: the Mediterranean coastal plain to the west, the Negev Desert in the central-southern part, the Jordan Valley in the east, and mountainous terrain in the north and center (Popa, 2012).

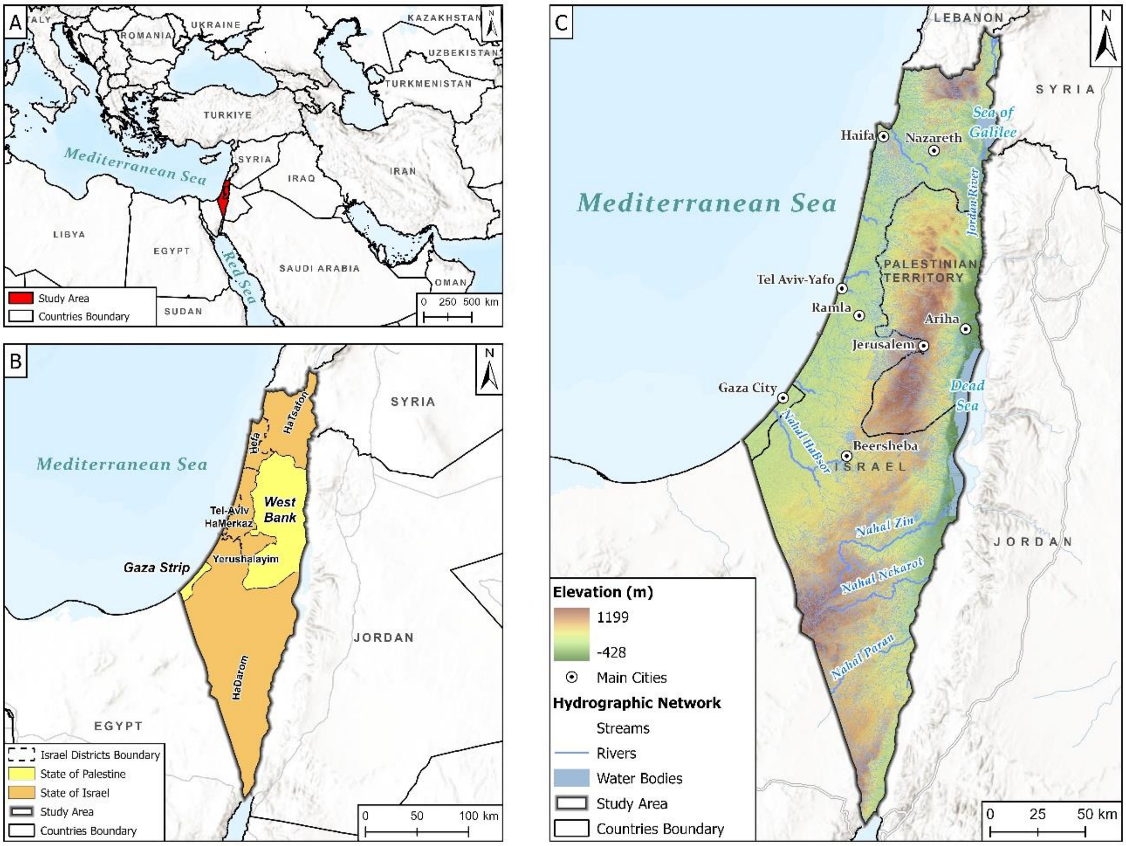

Figure 1. The study area: A) Continental scale; B) Regional scale; C) Physical and geographical scale

The hydrographic network has played a significant role over time in delimiting the borders of neighboring states, especially concerning the Jordan River (Srebro, 2018). In the region, due to the semi-arid and arid climate, there are springs, streams, and rivers, but many of them are small temporary water bodies (called wadis) that integrate only a small part of the water stocks (Laronne et al., 2004). In Figure 1 C, some of these are represented, such as Nehal Nakarot, Nehal Paran, Nehal HaBsor or Gaza, Nahal Zin, Yarkon.

However, the major water source for Israelis is the Sea of Galilee, or the Kinneret Lake, positioned in the northern part of Israel, neighboring the cities of Safed, Haifa, and close to the Golan Heights. This is the exclusive source of fresh surface water and has approximately 21 km in length, 12 km in width, and an average depth of 25 meters. Kinneret collects water from the upper basin of the Jordan River, the Hermon River, the Golan River, and natural groundwater (Maimon, 2014).

In the Middle East and North Africa region, water wealth has increasingly been utilized due to urbanization and agricultural expansion. Only 1% of freshwater is reused for 6% of the total population residing here (Haddaoui and Mateo-Sagasta, 2021). Furthermore, in the Jordan River basin, the main water source for Israel, Jordan, and the Palestinian population, it had already reached its maximum capacity by 1990 (Wiczyk, 2003) due to overexploitation of the shallow aquifer and increased salinity in the lower basin (Isaac, 2000).

Therefore, we can say that the main challenges facing the hydrographic basins in the Middle East are represented by the accelerated impact of climate change and extreme weather events, which exert greater pressure on water availability, provoking water-related conflicts and affecting the most defenseless groups. There is a severe decline in the availability of drinking water and for agricultural purposes, particularly pollution and contamination of surface and groundwater resources, giving rise to a high number of illnesses and deaths caused by waterborne diseases (Mohammed et al., 2021; Salameh et al., 2021).

In the Middle East, there is significant concern regarding water resource management, with a focus on the continuous increase in water demand and the need for cooperation between Israel and stakeholders like Jordan and Palestine (Feitelson, 2002; Gvirtzman, 2012). The acute water conflict between Israel and Palestine is determined by disputes over the water distribution from common aquifers and the Jordan River (Ide and Fröhlich, 2014). Moreover, the use of fertilizers has induced an accumulation of nitrates in the coastal aquifers within the territories of both states, reducing agricultural areas (Brooks, 2003). Furthermore, in Israel, excessive pumping of groundwater beyond its natural recharge rate has led to its contamination, inducing a net loss in the annual quantity of reusable water for the population (Yoffe and Wolf, 1999).

In the Gaza Strip, environmental pollution has led to constant pressure on hydrographic resources, with freshwater available for human use and many agricultural crops falling below acceptable quality standards (Ahiram and Siniora, 1994). Following repeated invasions in the region, sewage systems have been damaged or destroyed, putting pressure on water resources and wastewater treatment plants. Thus, along the Gaza coast, samples have been collected, highlighting the microbial contamination of seawater, leading to hygiene-related infections (Mojabi et al., 2010).

Considering the importance of water resource in the region and how it has been affected by numerous conflicts, this study aims to quantify water pollution issues in this warfare-affected region.

Methods

For this study, scientific materials focusing on pollution in the Israel and Palestine were used. Using platforms like Google Scholar and Science Direct, scientific works (books, articles, and reports) based on the addressed topic were downloaded and analyzed. For the initial search, keywords such as "water pollution on Israel and Palestine rivers", "water pollution in Israeli-Palestinian conflict" or "water pollution in Israel and Palestine GIS" were used, resulting in 32,400 results. Of these, 92 scientific works were chosen for rigorous analysis, many of which provided general information on politics and legislation. However, some of these were retained for the introductory part of this article. After the second selection, 22 core articles remained, providing raw data on pollution in the region, which were then subjected to review. The entire workflow can be observed in Figure 2.

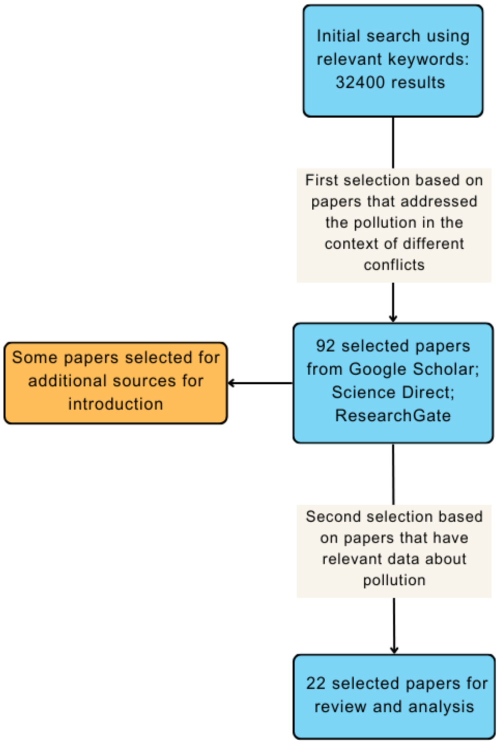

Figure 2. Workflow of the analysis

As for the publication years of the selected scientific papers (Table 1), they span from 1972 to 2023. In the years 2000, 2011, 2019, 2022, and 2023, the most papers were published, with 2 each, while in the other years, only one paper was published.

Table 1. Publication years of the selected papers

Publication year	Number of papers
1972	1 [8]
1976	1[30]
2000	2[23,24]
2001	1[15]
2004	1[33]
2006	1[20]
2008	1[3]
2010	1[6]
2011	2[4,7]
2012	1[21]
2013	1[9]
2016	1[18]
2019	2[11,12]
2020	1[34]
2021	1[17]
2022	2[27,41]
2023	2[2,42]

In Figure 3, the distribution of the types of scientific works analyzed in this article can be noticed. Analyzing the graph, it is remarked that the largest distribution of scientific works was represented by articles (17), while book chapters and books had a total of 2 works each. The smallest number is represented by reflection papers, which numbered only 1.

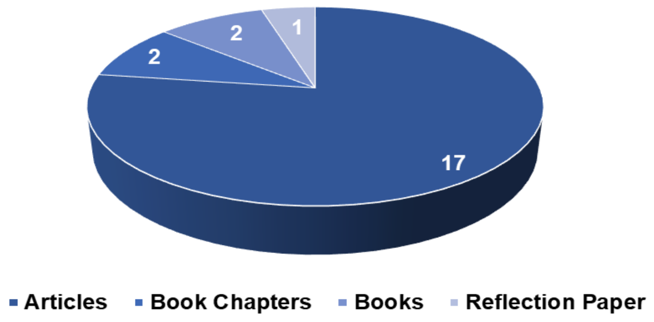

Figure 3. Distribution of the scientific paper type

Figure 4 illustrates the affiliation of the first author of the 22 scientific papers, represented in the form of a Sankey diagram. Upon analysis of this diagram, it emerges that the majority of papers originate from the Asian continent (18). Among these, 10 belong to researchers from Israel, predominantly from Haifa (4), Jerusalem (3), Tiberias (2), and Tel Aviv (1); 6 belong to those from Palestine, specifically Birzeit (3), Gaza (2), and Khan Younis (1), while from Malaysia, 2 articles belong to the same researcher affiliated with Banji. From the European continent, only 3 articles were considered representative for the current study, with 2 originating from Germany and 1 from the Netherlands. From Oceania, specifically from New Zealand, from the city of Napier, only one article was suggestive for this analysis.

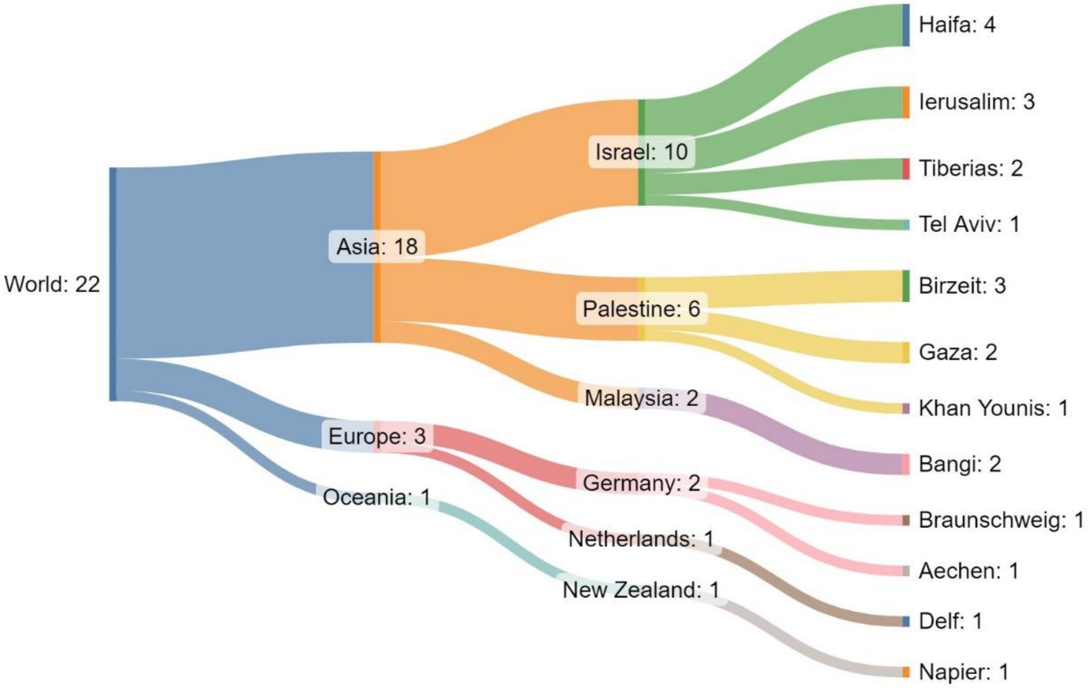

Figure 4. Affiliation of the first author of the papers

For a better understanding of the topics and types of pollution addressed in each scientific paper, a Word Cloud was created (Figure 5), showing the recurrence of keywords found in each article. Out of the 22 basic scientific papers, only 14 of them had keywords, classifying them as articles. Therefore, the most commonly encountered keywords in these sources were Israel, GIS, water quality, and groundwater, each appearing 3 times. These signify the study area, the topic, and the methods used. Keywords like West Bank, Gaza Strip, diversity, and nitrate appeared twice, representing the two regions of the Palestinian state and the main pollutant. The remaining keywords appeared only once, indicating locations of analysis, parameters, and various types of pollution. Additionally, in this article, the names of the territories presented by authors from the basic scientific papers were used.

Figure 5. Word Cloud of the main keywords of the articles

Results

In this paper, based on the 22 articles, water pollution in the Israel and Palestine was analyzed in terms of its types: physical, chemical and biological. Figure 6 illustrates the classification of articles according to the types of pollution addressed. Thus, chemical pollution was the subject of 17 sources, followed by 10 sources that analyzed physical pollution, and biological pollution was investigated in 9 sources.

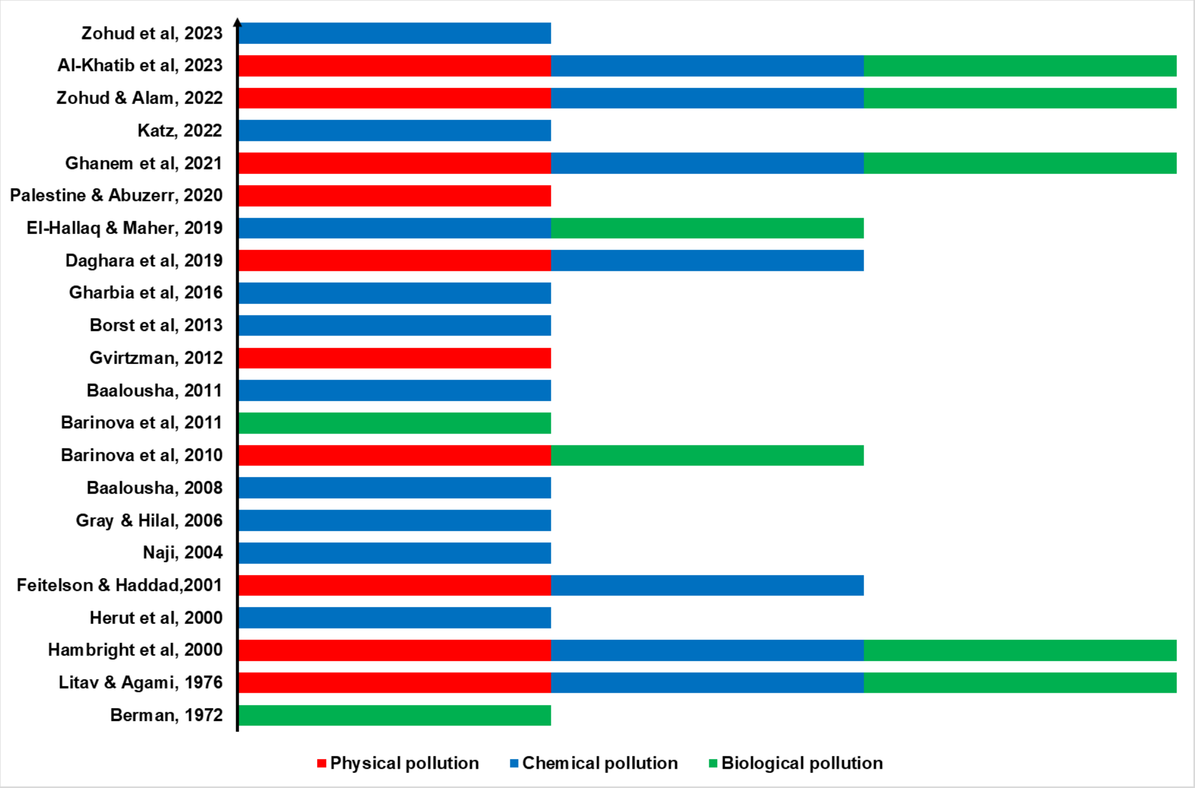

Figure 6. Types of pollution by paper

Physical Pollution

The first analysis regarding physical pollution belongs to Litav and Agami (1976), who examined temperature, conductivity, turbidity, and light intensity for the period of 1971-1972, focusing on the Alexander and Yarkon rivers. It was found that there was a conclusive correspondence in both rivers between pollution levels and light diffusion. Light interference was higher in the Alexander River than in the Yarkon River, reflecting the thicker population of phytoplankton characterizing the Alexander River. Additionally, increased turbidity led to an advanced stage of eutrophication.

Hambright et al. (2000) analyzed various parameters correlated with algal blooms in Lake Kinneret, including turbidity. They found that turbidity values were higher in the winter and spring months, reaching 2.9 nephelometric turbidity units (NTU), compared to 2.2 NTU in the summer and fall months.

Feitelson and Haddad (2001) demonstrated that the Mountain Aquifer is prone to anthropic pollution (industry, agriculture), particularly waste discharge into ephemeral streams in the western region. Additionally, the Turonian-Cenomanian aquifer includes leaks from oil facilities (tanks, gas stations, and pipelines) or accidents (tank leaks, pipeline deteriorations, etc.).

Besides, infiltration into the aquifer can also occur from waste disposal sites, animal farm solid waste, fertilizers, pesticides, and other agriculture and industry chemicals.

Barinova et al. (2010) evaluated both temperature and conductivity for the Oren and Zin rivers. Two species of *Chara* (Charophyta) were identified, populating clear waters with reduced conductivity, low total dissolved solids, and alkaline pH values. Subspecies variability is poor, as it is typical for algae species in Israel generally. Diversity varies depending on sampling points, and species abundance is firmly associated with conductivity levels.

In 2012, Gvirtzman emphasized that the Hebron stream, which flows into the Beer Sheva Valley, has changed into a polluted canal of wastewater for nearby Palestinian and Israeli villages, with settlements suffering greatly from polluted water, odors, flies, and mosquitoes. Another example is the Nablus rivulet, which flows into the coastal plain and has turned into a wastewater canal for Nablus and Tulkarm. Additionally, Kishon, Alexander, Modiin, and Kidron have also become wastewater repositories.

Daghara et al. (2019) showed that groundwater turbidity in the West Bank is an indicator of water pollution resulting from organic matter decomposition and inappropriate dumping of domestic and industrial solid waste and wastewater. Turbidity values ranged from 0.05 to 9.9 NTU, with an average value of 1.57 NTU (Daghara et al, 2019). A modest portion of samples (25%) exceeded the allowable turbidity limit. The maximum value was recorded in March, possibly as a result of anthropic activities, a water level decline, and an augmentation of suspended particulate matter.

Palestine and Abuzerr's article (2020) provide an overview of Gaza Strip environmental pollution during the COVID-19 pandemic and its impact on the healthcare system and public health. It refers to the provision of water, sanitation, and hygiene (WASH) services, solid waste handling, soil deterioration, coastal and marine contamination, as well as air pollution. The massive electricity shortage affecting the Gaza Strip, along with the lack of proper sanitation infrastructure, causes the discharge of 100-108 million liters of deficiently treated wastewater into the sea day-to-day.

Ghanem et al. (2021) showed that wastewater in the West Bank could contaminate drinking water in various ways, originating from septic tanks, partially treated sewage, sludge, and sewer leaks through soil infiltration and groundwater pollution.

Zohud and Alam (2022)'s study presented 127 samples from 300 sources distributed throughout the West Bank. Most physical characteristics of spring water fell within admissible standard limits, except for turbidity. They also highlighted that raw sewage is one of the main sources of West Bank groundwater pollution, where wastewater is discharged into neighboring valleys and water bodies, generating excessive pollution.

Moreover, the region's trash is mostly industrial or domestic and causes significant damage to the environment, surface and groundwater. According to Zohud and Alam (2022), in 2019, Palestinians generated approximately 4333 tons of solid waste per day, or about 0.9 kg per person daily, adding up to 1.58 million tons per year, the north of the West Bank contributing with 441,650 tons of waste/year. Developing sewage systems, wastewater treatment plants, and reducing septic tanks in rural areas of the West Bank significantly reduce pollutant concentrations. In Figure 7, the correlation between waste quantity and wastewater volume in the West Bank can be observed. Thus, a direct linear correlation between the two parameters is clearly noticed (r = 84), with the highest values of 149,650 tons of solid waste/year in the Nablus district, while in Tubas the value is only 23,735 tons of solid waste/year.

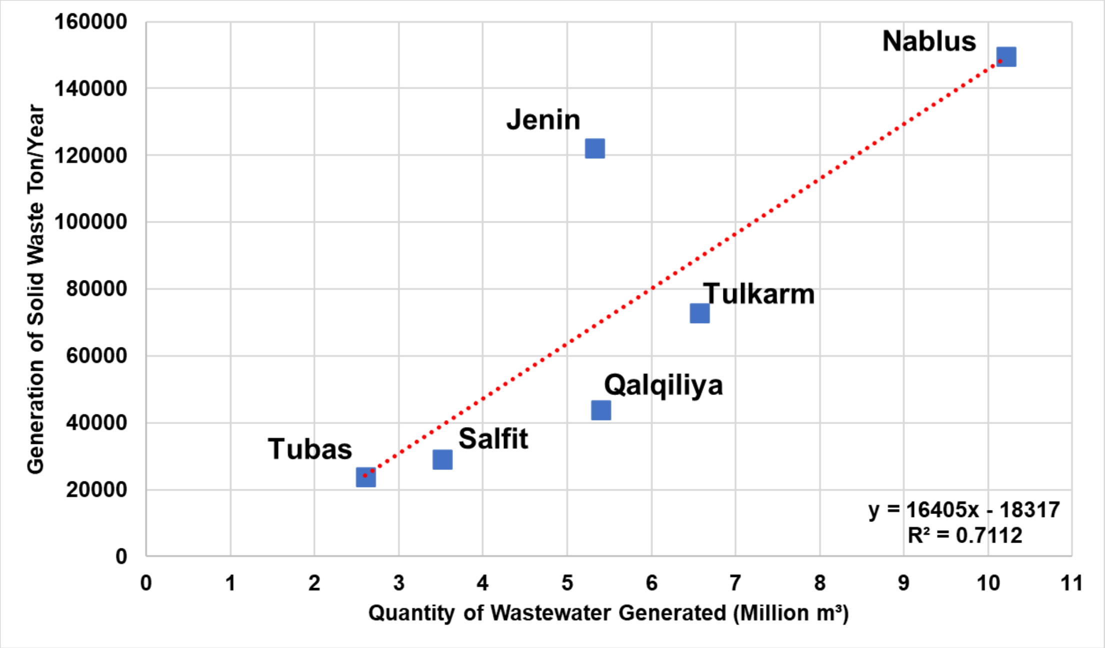

Figure 7. The correlation between the quantity of solid waste and the volume of wastewater in the main districts of the West Bank
Data source: Zohud and Alam, 2022

Al-Khatib et al. (2023) measured the household water quality in the Jenin governorate, located in northern West Bank. The assessed parameters consisted of electrical conductivity, turbidity, and total hardness. It was found that there are limited pollution contents regarding total hardness and electrical conductivity, falling within acceptable standard limits. Additionally, a broader spectrum of turbidity (0.05–9.9 NTU) was recorded for drinking water originating in natural sources, associated with anthropic activities and an augmentation of suspended particles (Al-Khatib et al, 2023).

Chemical Pollution

The initial approaches to chemical pollution belong to Litav and Agami (1976), who analyzed dissolved oxygen, pH, ammonia, nitrites, orthophosphates, and total dissolved solids in the region's main rivers, namely the Yarkon and Alexander Rivers, for the period 1971-1972. According to the scientists mentioned above, dissolved oxygen values revealed high variations throughout the year, from 4% saturation in December, to 70-80% saturation in April and September, provoked by algal blooms that sometimes arose in polluted sections. In degraded sectors, there was a substantial raise in detergent, ammonia, and phosphate concentrations during winter compared to summer, resulting from the discharge of large amounts of wastewater, mainly from irrigation.

In 1990-2000, chemical pollution was analyzed by Hambright et al. (2000) and Herut et al. (2000). The first group of authors investigated seasonal Lake Kinneret regarding chlorides, total dissolved solids, phosphorus concentrations, and nitrite. In 1998, total dissolved solids and phosphorus concentration exceeded acceptable water quality limits, with 4.5 mg/l recorded in winter and spring, and 2.7 mg/l in summer and autumn for total dissolved solids, while for phosphorus, values recorded were 24µg/l in winter and spring, and 15µg/l during summer and autumn. The second group of authors analyzed nutrient concentrations (nitrates, nitrites, phosphates, ammonia, and salicylic acid) over nine years (1990-1998) for 11 rivers, which are eroding at 2-3 stations downstream. Thus, typical concentrations of dissolved nutrients in seawater above the continental shelf near Israel range from below the detection limit to 0.09, 0.9, and 2.5 µM for phosphate, nitrates, and silicate. In most rivers, upstream stations had concentrations greater by more than an order of magnitude than downstream stations. The nutrient contamination level of the rivers recorded the following decreasing sequence: Soreq > Poleg > Alexander > Hadera ≈ Yarkon ≈ Lachish > others for phosphates; Poleg > Soreq > Alexander > Yarkon > Naaman > others for ammonia; Taninim ≈ Naaman ≈ Alexander > others for nitrates; and Poleg > Soreq > Alexander > Naaman > Hadera > others for salicylic acid.

In 2001, Feitelson and Haddad investigated the groundwater quality in the West Bank and Jerusalem area. In the northern basin, wells confronted with a recent increase of salinity, from 140 mg/l natural Cl to 700 mg/l Cl and a slight escalation of nitrate concentration. The Turonian-Cenomanian limestone aquifer comprises 870 wells, of which only 550 provide drinking water, with lithological characteristics playing a significant role in pollution propagation (Feitelson and Haddad, 2001).

As reported by Naji (2004), chloride has a concentration of 1763 mg/l in the Jordan Valley area. In the Gaza Strip, total dissolved solids amount to values of 3200 mg/l in Khan Younis and 4000 mg/l in Rafah. The absorbed sodium ratio is up to 8.8 in the Jericho area, West Bank.

For Gaza waters, the scientific study by Gray and Hilal (2006) shows that nitrate is a severe pollutant of this aquifer, in some regions reaching values of over 500 mg/L, well above the WHO recommended limit of 50 mg/L for total nitrogen. Nitrate pollution originates from sewage poisoning and agrochemical contagion. Almost 80% of Gaza wastewater is not treated in any way. Unfortunately, the most vulnerable pollution areas of the aquifer are in the densely inhabited Gaza Strip’s north and south, where water easily permeates into the sandy layers that cover the aquifer.

Baalousha's 2008 study analyzes the groundwater chemical composition in the Gaza Strip, which depends on the land use. Agricultural areas have calcium rich water due to fertilizers, while residential areas, with wastewater runoff, have water augmented in sodium, nitrates, and chloride. The chloride concentration near wastewater treatment plants is likely the result of wastewater, not seawater intrusion. Thus, polluted groundwater with wastewater has low calcium concentrations and reduced HCO_3/Cl ratios, indicating calcite precipitation. Wastewater contains Na at concentrations between 300 and 500 mg/l and chloride between 250 and 500 mg/l, resulting in a Na/Cl ratio of about 1. Wastewater runoff disrupts cation balance and determines Na-Ca exchange, with calcite precipitation. Additionally, nitrate concentrations range from 50 to 420 mg/l and are found in heavily populated or intensive agriculture areas. This chemical separation process could be activated by the Ca removal from water. This is the explanation for the wells’ low Ca concentration caused by agricultural activities (Baalousha, 2008). Also, statistically, in Figure 8, positive deviations of the analyzed parameters can be observed. Among these, Na and NO_3 have the most positive deviations, while Mg shows no such deviations, falling within the quartile range. SO_4 and HCO_3 have two outliers, while Ca, K and total dissolved solids have just one outlier value.

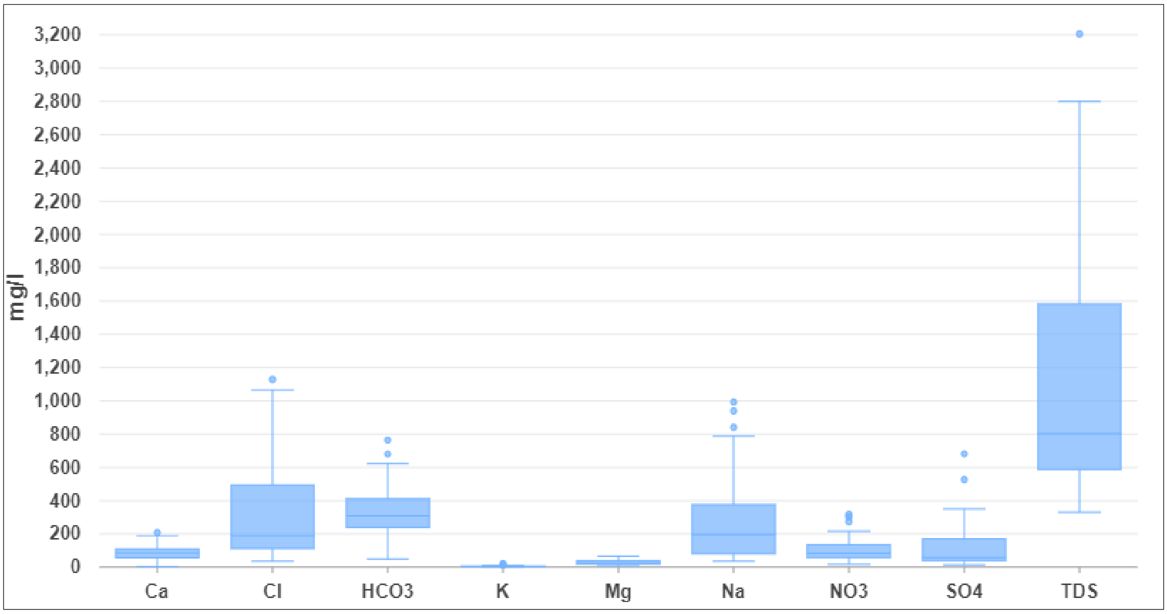

Figure 8. The boxplot of the analyzed parameters
Data source: Baalousha, 2008

In 2011, Baalousha's studies emphasized that nitrate is the main groundwater contaminant in Gaza Strip and is presumed to be of anthropogenic origin. Pathogens and viruses originate from wastewater unloading and agricultural activities. While pathogenic microorganisms and viruses can be naturally attenuated in the unsaturated waters, nitrate is difficultly diminished. Chloride is another widespread groundwater's pollutant in Gaza Strip, causing a high salinity.

According to Borst et al. (2013), high pollutant levels in Nablus (Palestine) wastewater are determined by low water consumption, a common situation in developing countries. In their study, the chemical analyses of municipal wells' groundwater indicate increases in nitrate concentration. The measured nitrate levels have been of 22 and 25 mg/l NO3- in wells at depths of 204 and 205 meters, respectively, and of 11 mg/l NO3- at a depth of 125 meters.

In 2016, Gharbia et al. examined the geographical distribution of groundwater quality in Gaza Strip. Based on geostatistical algorithms of multiple parameters (pH, nitrates, sulfates, total dissolved solids, hardness, calcium, alkalinity, magnesium, chlorides, fluoride), the distribution of groundwater quality resulted in three classes of values: poor, localized in the northern and southwestern part of the area; very poor, occupying most surfaces; and improper for consumption in the northern part, near the capital, and in the center of the region.

El-Hallaq and Maher (2019) identified high concentrations of organic matter and heavy metals in the Gaza wadi basin based on satellite imagery.

Also in 2019, the study by Daghara et al. investigated the chemical characteristics of water in the West Bank using standardized testing procedures. The scientists measured temperature, pH, total hardness, and concentrations of nitrates, chlorine, and turbidity. Chloride load varied from 22.0 to 284 mg/L, with an average of 75.4 mg/L. Nitrate contents extended from 0 to 106 mg/L, with an average of 30 mg/L, and approximately 21% of samples surpassed the concentration admissible limit, the water being unsuitable for domestic use and causing health problems for humans and animals. Sodium ion load varied from 16.9 to 137 mg/L, with an average of 41 mg/L (Daghara et al, 2019). Regarding the pH values of different water sources, they narrowly went from 7.08 to 8.19, showing neutral to slightly alkaline features.

In 2021, Ghanem et al. analyzed the contents of calcium (Ca2+), magnesium (Mg2+), potassium (K+), and sodium (Na+), as well as the ions Cl-, NO3–, SO42-, and HCO3, and found that the average concentration of Ca2+ for all samples evaluated was 91.64 mg/l, varying between 26.4 mg/l in the A'kari spring of Betillu village and 132.3 mg/l in the Al-Balad spring of Beit Sourik village. The midpoint pH value for all springs was 7.18, shifting from 6.91 in the Al-Balad spring of Atara village to 7.65 in the Qiblia spring of Salfit city. As stated by Katz (2022), the Dead Sea salinity levels are nearly ten times higher comparing to the ocean, and the Jordan River fresh water turns progressively into salty water while approaching its mouth.

The area of the West Bank is analyzed again, this time from the chemical perspective, by Zohud and Alam (2022), who highlighted as main contaminants the followings: nitrates, chloride, sodium, ammonia, phosphates, total dissolved salts, and salinity. Human activities such as intensive agriculture and waste disposal contribute to the deterioration of groundwater quality by soil infiltration of nitrogen, phosphorus, and heavy metals' high loads, which subsequently reach groundwater. Additionally, there is a risk that agricultural areas and contaminated waste dumps in northern West Bank could exacerbate the problem. Palestine is one of the numerous countries where groundwater nitrate contamination has been announced recently. It is important to note that nitrate is one of the main water quality indicators that exceeded the allowable limit for 18% of the samples taken (Zohud and Alam, 2022).

According to Al-Khatib et al. (2023), potable water quality is a worriment in Palestine as a result of pollution sources. These scientists' work evaluated the household water quality in the Jenin governorate of the northern

West Bank. The tested chemical parameters included salinity, pH, total alkalinity, nitrate, nitrite, sulfate, chloride, sodium, potassium, aluminum, and fluoride, measured in samples collected from household water and wells. According to the local and international standards, there is a limited pollution generated by total dissolved solids, total hardness, and calcium.

As Zohud et al. (2023) stated, the West Bank groundwater pollutants are inorganic compounds, including total dissolved solids, heavy metals, cations, and anions, noting that increased nitrate levels exceeding 50 mg/L can bring future health hazards. Additionally, the concentration of Cl^- in northern West Bank groundwater is lower than the legal limit of 250 mg/L. However, the West Bank groundwater quality usually is depreciated at the time of the dry season and recovers throughout the rainy period.

Biological Pollution

Berman (1972) highlighted aspects related to algal blooming in the Kinneret Lake. This usually occurred from late winter to mid-spring, namely from February to April, typically with dinoflagellates (*Peridinium westii*), harmful to the environment.

Litav and Agami (1976) divided the Yarkon and Alexander rivers into sectors, in accordance with the homogeneity of water quality state, and the species were identified and listed for each sector separately. Eutrophication in the rivers mentioned above was the result of different pollution sources such as fertilizers, urban wastewater, and industrial waste. These sources increased the concentrations of nitrogen compounds, phosphates, and detergents in river water. Significant fluctuations in dissolved oxygen levels and the occurrence of algal blooms suggested the impact of biological pollution on aquatic ecosystems.

In accordance with Hambright et al. (2000), the Kinneret Lake is a vital water source in Israel, providing almost half of the country's drinking water and exhibiting a meso-eutrophic state. In the past, the lake was affected by blooms of *Peridinium gatunense* (dinoflagellate) and later by the unusual appearance of potentially toxic cyanobacteria. There were two notable periods of unacceptable water quality in Lake Kinneret, 1994-1995 and 1998. The first one was characterized by exceptional algal blooms, while in the second period, fecal coliform bacteria and zooplankton biomass exceeded the acceptable limits, during the winter rainy season. Additionally, the intensive use of lake water and drought conditions contributed to increased salinity, and the persistence of cyanobacteria and high chlorophyll levels indicated an intensification of eutrophication processes.

The study of Barinova et al. (2010) gathered material from 94 phytoplankton and periphyton samples extracted from 16 Oren River sampling stations and from 47 algae specimens obtained from 16 Zin River stations. The

Oren River ecosystem presented 218 algal species from nine taxonomic divisions, representative for alkaline temperate waters. Zin River showed 55 species and subspecies, being part of four taxonomic divisions of algae and cyanoprokaryotes. Diatoms were firmly preeminent, with *Nitzschia* and *Navicula* as prevalent genera.

Another article by Barinova et al. (2011) provides a comparative analysis of algal communities in Israeli rivers, highlighting the repercussion of environmental variables on biodiversity. The work showed that 671 algal and cyanobacterial species of nine taxonomic divisions were present from 2002 to 2009 in the Yarkon, Alexander, Hadera, Qishon, Oren, upper and lower Jordan, and Zin rivers. The scientists found that the most abundant indicator species inhabit alkaline waters with low flow, medium salinity, and low to moderate organic pollution.

According to El-Hallaq and Maher (2019), biological pollution was found in the Gaza Wadi, characterized by high levels of organic matter, fecal coliforms, and fecal streptococci. These pollutants were then dispersed along the shoreline by coastal currents, more than 11 km having a medium to high degree of contamination.

Ghanem et al. (2021) collected samples from 50 West Bank springs to determine the quality of water for domestic use. In agreement with their analysis, total coliforms were present in 100% of samples, while fecal coliforms existed in only 63% of them. Zohud and Alam (2022) pointed out that West Bank springs have high loads of total and fecal coliforms, indicating septic tanks and wastewater discharges as potential pollution sources. Results regarding fecal and total contamination indicators showed that 1.3% of groundwater samples were infected in the northern of West Bank.

In 2023, Al-Khatib et al. investigated microbiological parameters regarding the distribution of total coliforms. They analyzed 2494 samples for fecal coliforms, of which 93.30% showed no health risk, 2.34% presented a medium hazard, 0.9% exhibited a great danger, and 0.58% had a very high risk according to WHO guidelines and classifications. Total and fecal coliform results indicated the presence of microbial pollution sources, which is unacceptable for potential potable water sources.

Discussions

Based on the results presented above, it can be said that the pollution in the analyzed region is moderate. Spatially, chemical pollution is most prevalent in the study region (Figure 9). Thus, the HaMerkaz district in Israel, as well as the governorates in the Gaza Strip, recorded the most problems related to exceeding the permissible standards for various chemical parameters (Gray et al., 2006; Baalousha, 2008; Gharbia et al., 2016; Daghara et al., 2019; El-Hallaq and Maher, 2019; Zohud and Alam, 2022 etc). Additionally, physical pollution presents significant issues in the Hefa region, where watercourses are also subject to eutrophication phenomena. In the West Bank, especially in the Hebron and Jerusalem governorates, cases of physical pollution predominate, mainly appearing in groundwater resources (Daghara et al., 2019; Palestine and Abuzerr, 2020; Zohud and Alam, 2022 etc). Biological pollution is absent in Khan Yunis, Rafah, and North Gaza, as well as in the Yerushalayim district.

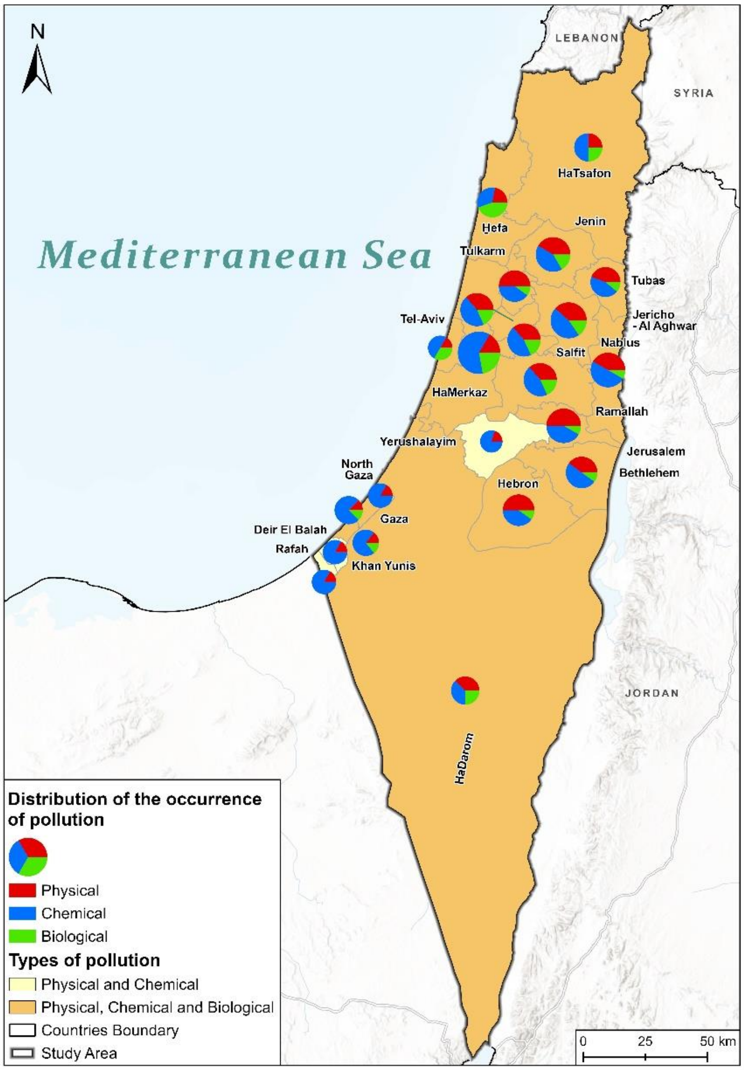

Figure 9. Distribution of the pollution occurrence by districts

Gaza Strip is the most affected by water quality problems because it lacks sewage treatment plants. Moreover, a significant portion of groundwater is primarily polluted by nitrate, whose values exceed the WHO's permissible limit by over 10 times (Gray et al., 2006). It easily infiltrates into aquifers due to the sandy substrate in the region. Besides nitrates, other contaminants include fluoride and chloride (Daghara et al., 2019). High chloride is incompatible with the potable water, less than 10% of groundwater in the area meeting the World Health Organization standards for chloride. Thus, excessive fluoride in groundwater may induce fluorosis, affecting teeth and bones, and long-term fluoride ingestion can lead to potentially severe skeletal problems. Additionally, the Gaza Valley, the main surface water source of the Gaza Strip, is polluted with organic matter, fecal coliforms, and fecal streptococci (El-Hallaq and Maher, 2019), owing to the lack of adequate sanitation infrastructure, which led to a water crisis during the COVID-19 pandemic. Thus, in 2020, the highest concentrations of fecal bacteria in sewage-polluted seawater induced an increased risk of gastrointestinal infections, as well as skin and eye infections, especially among children, the elderly, and individuals with weak immune systems.

In the West Bank, wastewater is the main source of pollution due to high levels of phosphates, confirming that groundwater is heavily polluted with untreated or inadequately treated wastewater. Also, the presence of high nitrogen concentrations in groundwater is an indicator of its pollution and may result from nitrogen leaching from various sources, such as septic tanks, urban sewerage networks, irrigation with contaminated water, fertilizer use, and untreated wastewater discharges. Contamination with coliform bacteria usually results from the contact with untreated wastewater, many villages in this area discharging untreated wastewater into open drainage channels. Groundwater contamination, either from anthropogenic or natural sources, poses risks to human health or leads to waterborne symptoms in humans, such as diarrhea and vomiting. Permeable sewage tanks (septic tanks), which are common in two-thirds of West Bank households not connected to the sewerage network, release organic and inorganic nitrogen compounds that subsequently degrade the groundwater quality. Wastewater treatment plants are present and mainly used in urban centers (Lin et al., 2022), where about 60% of the population uses the public sewerage network, while the rest use septic tanks and cesspools to dispose the wastewater (Zohud and Alam, 2022). The percentage of the population served by septic tanks and the sewerage network in northern West Bank is 54.5% and 45.5%, respectively.

In Israel, pollution is mainly found in the wadi network that flows into the Mediterranean Sea. Thus, the massive influx of urban and industrial wastewater reaching the Alexander and Yarkon rivers has induced profound changes in several physical and chemical parameters of water (Litav and Agami, 1976). The most prominent among these are dissolved oxygen and ammonia concentration, turbidity, and the presence of detergents. It should be emphasized that except for the cleanest sectors of the rivers, all other sections, including the unpolluted ones, were in a fairly advanced stage of eutrophication. This is evident from their high nitrate and phosphate content, high cation concentration, and turbidity. There is a clear relationship between the degree of pollution and the floristic composition of hydrophytic and hydrophilic vegetation; the cleanest sectors of both rivers contain the highest number of species, including all submerged and floating-leaved plants, which are actually exclusive to these sections.

Over time, the Mountain Aquifer area in northern Israel has been affected by pollution, as a result of anthropogenic activities (Feitelson and Haddad, 2001). Untreated wastewater infiltrates into the groundwater of the Mountain Aquifer, deteriorating its quality and contaminating downstream wells. The absence of wastewater treatment by Palestinians and the parallel expansion of water supply networks have provoked an increasingly severe environmental pollution. If wastewater is not recycled and reused, and land use is not appropriate, deterioration in the quality of groundwater can be expected in all three basins. In addition to reducing groundwater pollution, wastewater reuse can provide an important source of water for agricultural use.

At the lake level, salinization is the main process found on the shores of the regions around the Dead Sea. The major causes of salinization are excessive pumping of wells, the intrusion of seawater into the coastal aquifer, the presence of deep saline water, and geological factors. Additionally, the Sea of Galilee is affected by eutrophication, as evidenced by high turbidity values, caused by the blooming of Peridinium in the spring months, which requires treatment through sedimentation or filtration before the water is suitable for human consumption.

Conclusions

Within this review, 22 scientific papers from 1972 to 2023 were analyzed, mostly represented by articles from various journals. The theme addressed water pollution in the Israel and Palestine, focusing on the main three types of pollution: physical, chemical, and biological, with chemical pollution being the most approached in 17 sources. Also, from a spatial perspective, the regions most affected by pollution are represented by the Gaza Strip, the Israel Rivers that flow into the Mediterranean Sea, the Mountain Aquifer in the central-northern region of Israel and the West Bank, as well as the Dead Sea and the Sea of Galilee.

Studies on chemical pollution conducted in the Israel-Palestine region brought up significant issues related to water quality, especially in groundwater sources. The analyses have highlighted fluctuations in concentrations of chemical substances such as nitrates, phosphates, chlorides, heavy metals, and total dissolved solids, which often exceed recommended limits for water quality. These pollution problems are the result of human activities, such as intensive agriculture, inadequate waste disposal, and uncontrolled use of chemicals.

Biological pollution represents a significant threat to aquatic ecosystems in the analyzed regions, through the occurrence of eutrophication. This manifests through algal blooming, especially in western Israel’s lakes, but also along the course of temporary water networks on the coast region of the Mediterranean Sea. In addition to this process, a high number of fecal coliform bacteria were found in water bodies, having a negative repercussion on water quality and public health.

The Alexander and Yarkon rivers, the Sea of Galilee, and regions in the West Bank and Gaza Strip are areas where a large part of physical pollution is concentrated, caused by turbidity fluctuations, and household and industrial waste. In addition to these, untreated wastewater is a main pollution source, leading to high levels of phosphates and nitrogen in groundwater.

The Israel and Palestine region presents numerous pollution sources that affect the main water bodies in the region, already under stress from climate change and anthropogenic influence. An adequate management and water resources’ monitoring are imperative to reduce pollution and prevent the risk of various medical conditions among the population.

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