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Environmental Justice in Water Quality: Sulaimani City as a Case Study

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Abstract:

Environmental justice is one of the urban planning approaches in the postmodern era that concerns equal access to environmental benefits in water, air, and soil for all, regardless of race, color, nation, or income. Cities' spatial distribution of environmental quality is frequently influenced by socioeconomic factors, with environmental concerns being disproportionately more prevalent in low-income areas. This may result in disparities in health and access to resources that help enhance health and quality of life, such as safe drinking water. Therefore, despite the urgency of the issue, little to no attention is given to the investigation and assessment to the topic of water quality management services and how it is contributing to increased environmental inequity in Iraqi cities, including Sulaimani City. This study takes qualitative and quantitative approaches in order to assess the effects of the quality of distributed water on increasing environmental injustice among residents of Sulaimani City. It was done by surveying 100 neighborhood residents with a questionnaire, which was then analyzed with the SPSS program. Moreover, twenty samples of supplied water were tested from selected neighborhoods within different topography, socioeconomics, and locations inside 10 different branches of the water directorate that supplies them with water. However, all tested samples were suitable for drinking, but the hydrochemical analysis of water samples revealed that the water is somewhat yellow in color, odorless except for chlorine, tasteless, and characterized by a low value of total dissolved salts. Ultimately, the result of the survey demonstrated that there is a high level of environmental inequality that is brought on by poor management, socioeconomic decay in the neighborhoods of Sulaimani City, a lack of participation by the populace, and a failure of the policy to adequately account for the variety of needs and vulnerabilities faced by households.

Keywords: Environmental justice, Water Management, Water quality, Socioeconomic.

الملخص:

العدالة البيئية هي أحد مناهج التخطيط الحضري في عصر ما بعد الحداثة والتي تتعلق بالوصول المتساوي إلى الفوائد البيئية في الماء والهواء والتربة للجميع ، بغض النظر عن العرق أو اللون أو القومية أو الدخل. كثيرًا ما يتأثر التوزيع المكاني لجودة البيئة في المدن بالعوامل الاجتماعية والاقتصادية ، مع انتشار المخاوف البيئية بشكل غير متناسب في المناطق منخفضة الدخل. قد يؤدي ذلك إلى تفاوتات في الصحة والوصول إلى الموارد التي تساعد على تحسين الصحة ونوعية الحياة ، مثل مياه الشرب صالحة للشرب. لذلك، على الرغم من إلحاح هذه القضية ، لا يتم إيلاء اهتمام يذكر للتحقيق والتقييم لموضوع خدمات إدارة جودة المياه وكيف يساهم ذلك في زيادة عدم المساواة البيئية في المدن العراقية ، بما في ذلك مدينة السليمانية. تأخذ هذه الدراسة مناهج نوعية وكمية لتقييم آثار الجودة المياه الموزعة على زيادة عدم المساواة البيئية بين سكان مدينة السليمانية. تم إجراء ذلك من خلال استبيان لـ 100 فرد من

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سكان الحي، والذي تم تحليله بعد ذلك باستخدام برنامج SPSS. تم اختبار 20 عينة من المياه المزودة من أحياء مختارة ضمن تضاريس واقتصاديات اجتماعية ومواقع مختلفة، ضمن 10 فروع مختلفة لمديرية المياه التي تزودهم بالمياه. ومع ذلك ، كانت جميع العينات المختبرة صالحة للشرب ، لكن التحليل الهيدروكيميائي لعينات المياه أظهر أن الماء أصفر اللون إلى حد ما ، عديم الرائحة باستثناء المياه التي يكثر فيه الكلور ، عديم الطعم ، ويتميز بقيمة المنخفضة للأملاح الذائبة. كما بين في نتائج الاستبيان أن هناك مستوى مرتفعًا من عدم المساواة البيئية الناجمة عن سوء الإدارة ، واختلاف نسب الدخل الاقتصاد الاجتماعي في أحياء مدينة السليمانية ، ونقص مشاركة السكان في اتخاذ القرارات ، وفشل السياسات المتنوعة بنظر الاعتبار الاحتياجات ونقاط الضعف التي تواجهها الأسر.

الكليمات المفتاحية: العدالة البيئية ، إدارة المياه ، جودة المياه ، الاقتصاد الاجتماعي.

پوختە:

داڕەوەری ژینگەیی یەکێکە لە ڕێبازەکانی پلاندانانی شار لە سەردەمی پۆستمۆدێرن کە پەیوەندی بە دەستڕاگەیشتنێکی یەکسان بە سوودە ژینگەییەکان لە ئاو، هەوا و خاکدا هەیە بۆ هەموان، بەبێ گوێدانە ڕەگەز، ڕەنگ، نەتەوە، یان داهات. دابەشبوونی مەکانیی شارەکان لە کوالیتی ژینگەدا زۆرجار لە ژێر کاریگەری هۆکاری ئابووری کۆمەڵایەتییەکاندایە، لەگەڵ کاریگەرییە نەرێنییەکانی ژینگە کە بە شێوەیەکی ناڕێژەیی زیاتر لە ناوچە کەم دەرامەتەکاندا بڵاوبوونەتەوە. ئەمەش ڕەنگە ببێتە هۆی نایەکسانی لە تەندروستی و دەستڕاگەیشتن بە سەرچاوەکان کە یارمەتیدەرن بۆ بەرزکردنەوەی تەندروستی و کوالیتی ژیان، وەک ئاوی خواردنەوەی پاک. بۆیە سەرەڕای بەپەلەیی ئەو پرسە، گرنگییەکی کەم یان هیچ گرنگییەک بە بەدواداچوون و هەڵسەنگاندن بۆ تەوەری خزمەتگوزاری بەڕێوەبردنی کوالیتی ئاو و چۆنیەتی بەشداریکردنی لە زیادبوونی نایەکسانی ژینگەیی لە شارەکانی عێراق بە شاری سلێمانیشەوە نادرێت. ئەم توێژینەوەیە ڕێبازی چۆنایەتی و چەندایەتی دەگرێتەبەر بۆ هەڵسەنگاندنی کاریگەرییەکانی کوالیتی ئاوی دابەشکراو لەسەر زیادبوونی نایەکسانی ژینگەیی لەنێو دانیشتوانی شاری سلێمانیدا. بە بەکارهێنانی ڕاپرسی لەگەڵ ١٠٠ لە دانیشتووانی گەڕەکەکان ، کە دواتر بە پرۆگرامی SPSS شیکرایەوە. جگە لەوەش بیست نمونەی ئاوی دابینکراو لەلایەن ١٠ لقی جیاوازی بەڕێوەبەرایەتی ئاو لە بیست گەڕەکی دەستنیشانکراو لە تۆپۆگرافیای جیاواز و ئابووری کۆمەڵایەتی جیاواز و شوێنی جیاواز تاقیکرانەوە. هەرچەندە هەموو نموونە تاقیکراوەکان گونجاو بوون بۆ خواردنەوە، بەڵام شیکاری هایدرۆکیمیایی نموونەکانی ئاو دەریانخست کە ئاوەکە تا ڕادەیەک ڕەنگی زەردە، بێ بۆنە جگە لەوانەی کلۆریان زۆرە، بێ تامە و بە بەهایەکی کەمی کۆی خوێیە تواوەکان تایبەتمەندە. لە کۆتاییدا ئەنجامی ڕاپرسییەکە دەریخست کە ئاستێکی بەرزی نایەکسانی ژینگەیی هەیە بەهۆی خراپی بەڕێوەبردن و خراپی و جیاوازی لە ئابووری کۆمەڵایەتی لە گەڕەکەکانی شاری سلێمانی و بەشدارینەکردنی خەڵک لە بڕیاردان و شکستی سیاسەت لە بەهەند وەرگرتنی جۆراوجۆری پێداویستیەکان و لاوازییەکان کە ڕووبەڕووی ماڵەکان دەبنەوە.

کلیلە وشە: داڕەوەری ژینگەیی، بەڕێوەبردنی ئاو، کوالیتی ئاو، ئابووری کۆمەڵایەتی.

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1. Introduction

Environmental justice refers to the equitable sharing of environmental advantages (including clean air and water) and the "burdens people experience, at home, at work, or where they learn, play and spend leisure time" [1]. It can also refer to "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" [2]. The combination of "uneven exposure to environmental risks and hazards" and "the systematic exclusion of people from environmental decision-making processes", is known as "environmental racism" or "environmental inequality" [3]. Environmental inequality leads to disparities in health status across populations, such as asthma, obesity, diabetes, lung cancer, and mental health disorders [4].

The spatial distribution of environmental quality in cities is linked to socioeconomic factors, with disadvantaged neighborhoods having a higher percentage of environmental concerns. Decreasing environmental injustice is often seen as a key factor in creating more sustainable cities [5]. For over a decade, scientists and non-governmental organizations have worked to raise awareness about the unsustainable use of the planet's natural available water resources because human demand for home, industrial, and agricultural water is inevitably growing as the world's population and consumption grow [6]. Water resources are not allocated equitably across the world, with Asia having 60% of the world's population but only 36% of it, and the Middle East having 6.3% but only 1.4% of its pure water. Since 1955, only three Arab nations have experienced a water crisis, but this number has since increased to 11 and seven more nations will experience a water shortage by 2025 [7]. And Iraq is the biggest loser in the Middle East's water wars [8].

Recently, the ancient country of the two rivers (Iraq) has seen growing water loss [6]. According to a UN survey, 3 out of 5 children in Iraq lack access to clean water services and fewer than half of all schools have basic water access, putting children's health, nutrition, cognitive development, and future livelihoods at risk [9]. In addition, the UN requires local governments to formulate environmental policies to protect the environment from pollution and preserve cleanliness, in cooperation with regions and governorates not organized in a region, and to ensure the just distribution of water resources [10]. Furthermore, The UN Committee on Economic, Social, and Cultural Rights (CESCR) recommended that Iraq adopt preventative steps to reduce the spread of diarrhea and cholera, such as providing immunizations and basic sanitation instructions [11].

Water shortage is a major issue in Iraq, with President of Iraq calling for collaboration from Turkey and Iran to overcome it [12]. Because of these factors, reducing water quantity has an impact on water quality and the spread of illnesses. According to statistics, more than 7 million Iraqis do not have adequate access to drinking water [13]. In 2007, a lack of safe drinking water in Iraq caused an epidemic, resulting in 7,000 infections and 10 deaths. In 2015, five women died from cholera in Abu Ghraib, with many more affected [13].

Iraqi Kurdistan region is facing water scarcity due to climate change and mismanagement, which is worsened by political and socioeconomic issues. This has caused water shortages exceeding international standards, posing a greater hazard than climate change [14]. Furthermore, considering recent upgrades to the infrastructure of the water network, service quality remains poor [15], in terms

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of having access of fresh water, water pressure, and the continuity of services [16]. The Ministry of Municipalities and Tourism (MoMT) estimated that losses from leaks or illegal private connections to the public grid account for around 50–60% of the drinking water that is provided to consumers. [14]. According to [17] The water is unsuitable for human consumption because of the manganese concentrations in the samples taken from areas near trash dumps or the Tanjero River. Certain chemical components have polluted the wells near the trash dump, changing the quality of the pumped water and its fitness for human consumption in Sulaimani City [18].

Therefore, this potentially contributes to increased environmental inequity and its subsequent negative effects on sustainable development in the city which is an issue. Therefore, despite the urgency of the issue, little to no attention is given to the investigation and assessment to the topic of water quality management services and how it is contributing to increased environmental inequity in Iraqi cities, including Sulaimani City. The main objective of this study is assessing the effects of the quality of distributed water on increasing environmental injustice among residents of Sulaimani City using water quality analysis and questionnaire's survey.

1.1 Water Quality and Diseases in Sulaimani

Cholera diseases came back in Iraq in 2022 because the water and food were not clean, especially in Sulaimani City. The Iraqi Ministry of Health declared on June 23, 2022, that the first documented case of cholera was recorded, and the overall number of cases in several Iraqi cities stands at 15 [19].

According to the World Health Organization, cholera is a sudden case of diarrhea caused by eating or drinking food or water that is contaminated with the Vibrio cholera bacterium. Cholera affects both children and adults and can kill within hours if left untreated, leading to death. Inadequate access to clean water and sanitation services is intimately connected to cholera transmission [20]. Peri-urban slums and camps for internally displaced people or refugees are examples of high-risk places where basic needs such as clean water and sanitation are not addressed. Its prevention and control are accomplished by a mix of monitoring, water, sanitation, and hygiene, social mobilization, treatment, and the use of oral cholera vaccines. [20]

According to the Kurdistan Region's Ministry of Health, the spread of cholera is not normal, and Kurdistan Region's lack of clean water is unacceptable. On Tuesday (June 21), the Ministry stated that diarrhea and vomiting are indications of seasonal illnesses that grow in the summer, but new test results reveal that cholera has spread in Kurdistan Region this year. They said that cholera was spread by contact with contaminated drinking water and food, particularly vegetables [21].

The World Health Organization (WHO) in Iraq said that it has delivered urgent medicine and medical supplies to Sulaimani governorate to assist with the rapid cholera epidemic. "The increase in new cholera cases in Sulaimani and other governorates is a reason for concern for WHO" [22].

Kurdistan Region's Health Minister stated that the number of reported cases of such symptoms was large, and it is assumed that the patients caught cholera [23]. The minister, announced that water supplies are the primary source of cholera outbreaks, with the transmission of Cholera linked to contaminated drinking water, food, and basic hygiene [24]. According to the Sulaimani Health Directorate, 656 instances of diarrhea were documented in local hospitals in only 24 hours [23].

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It also reported a rise in vomiting and diarrhea cases in hospitals, leading to 3,165 hospitalizations and a warning about viral diarrhea and vomiting. Four individuals, including two children, died from the sickness [24].

Sulaimani residents are at risk of cholera, diarrhea and vomiting infection, with over 4000 individuals admitted to hospitals and the Iraqi health ministry has asked Sulaimani governorate to establish a state of emergency in the city, and health experts have encouraged households to avoid using unsustainable drinking water [25].

The Water Directorate recorded and remedied the following reasons for contaminating citizens' drinking water:

According to the data from the Water Directorate, Table 1, there were numerous factors involved in water pollution between 2010 and 2021. It concentrates on a few major factors that kept occurring, as shown in the table below, but there are also some unusual factors, such as mixing a private house's generator's gas with the neighborhood's drinking water pipes.

Table 1: Causes of water quality problems in Sulaimani City [26].

Year	Water supply lines that are old and in poor condition and mingle with sewage	Combined leakage from broken sewage and water pipelines	Obstruction of the supplying water pipes	Obstruction of the sewage pipe and mixing with drinking water	The proximity of water supply and sewage pipelines	pipes breaking as a result of construction activities	Total cases
2010	18		3				21
2011	2	1	5	2	1		11
2012	5	2	1			2	10
2013	5				2		7
2014	2		2			2	6
2015	Has not data	-	-	-	-	-	-
2016	3		2				5
2017	1						1
2018	1	1				2	4
2019	2			3		3	8
2020	3	1					4
2021	5	4					8

For determining bacteriological and non-chlorinated water, the water directorate and ministry of health evaluated a large number of samples, Table 2.

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Table 2: Survey conducted by Sulaimani Water directorate for bacteriological test [26].

Year	Number of samples	Contaminated Samples	Non-Chlorinated Samples
2010	1529	29	34
2011	3015	52	25
2012	2810	17	17
2013	5564	392	321
2014	1955	101	168
2015	1909	42	26
2016	1807	33	25
2017	1376	22	25
2018	1830	58	31
2019	1929	17	3
2020	1930	5	0
2021	2245	16	7

2. Study Area

Sulaimania is a city in northeastern Kurdistan Region of Iraq, 35 km west of the Iraqi-Iranian border and roughly 80 km northeast of Kirkuk City [27]. About 472 Km^2 of the city's land area is covered by the master-plan project, located between longitude (45° 12' 00" and 45° 32' 00" E) and latitude (35° 25' 30" and 35° 40' 00" N), (Fig.1) [28]. The city's elevation ranges from 800 meters above sea level (m.a.s.l.) in the west to 1050 meters above sea level (m.a.s.l.) in the eastern section of an intermountain plain. The Old City, or the center of the city, is located at an elevation of about 870 meters above sea level. Approximately, 20% of city is considered as a mountainous region with The Piramagroon, Azmar-Goizha, and Baranan Mountains. Low areas are restricted to significant valleys, such as the Tanjero valley, where the height reaches 675 m.a.s.l [27]. Winters are cold and snowy, summers are long and warm and dry, and autumn and spring are short. Daily temperatures in the summertime can reach 45 °C [18]. After 2003, the city's size and population grew significantly. Up until 2003, the Malik-Mahmood main road was regarded as the boundary of growth. Around the Malik-Mahmood main road, the city expanded. Fig 2 shows the city's growth before and after the year 2003. The development of several new neighborhoods and cities necessitated the construction of more services and infrastructure, including new water lines, to meet the needs of the residents. The management of the water system remained, nevertheless.

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"Sulaimani has made some progress in the field of infrastructure in the past years, as 83.2% of homes have been linked with the public sewerage network and 85.5% with the drinking water network" [29].

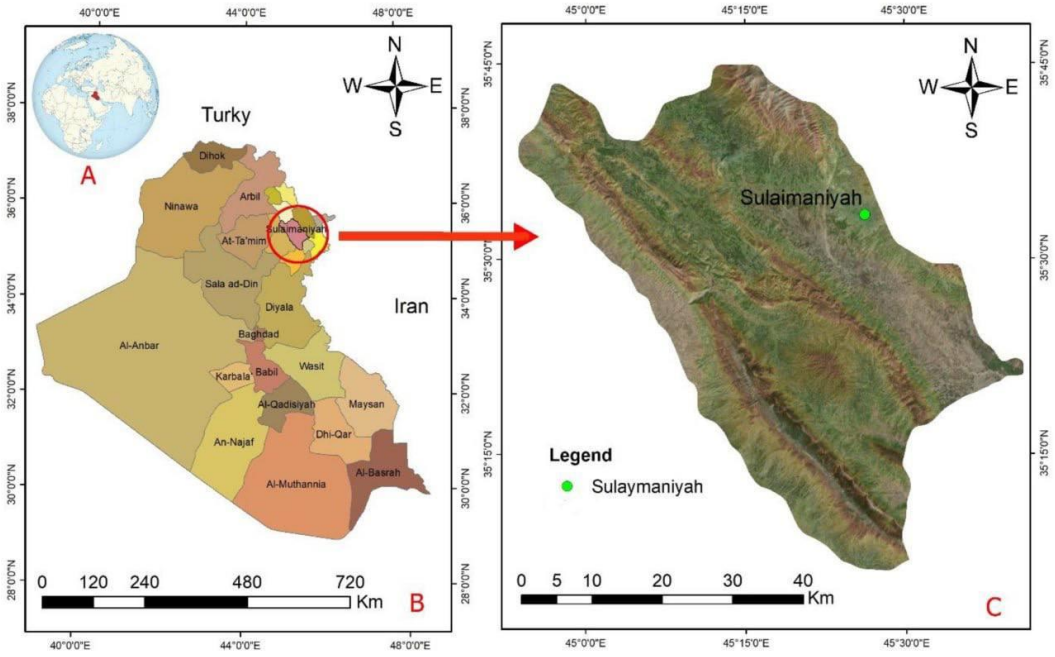

Figure 1: Location map of the study area [28].

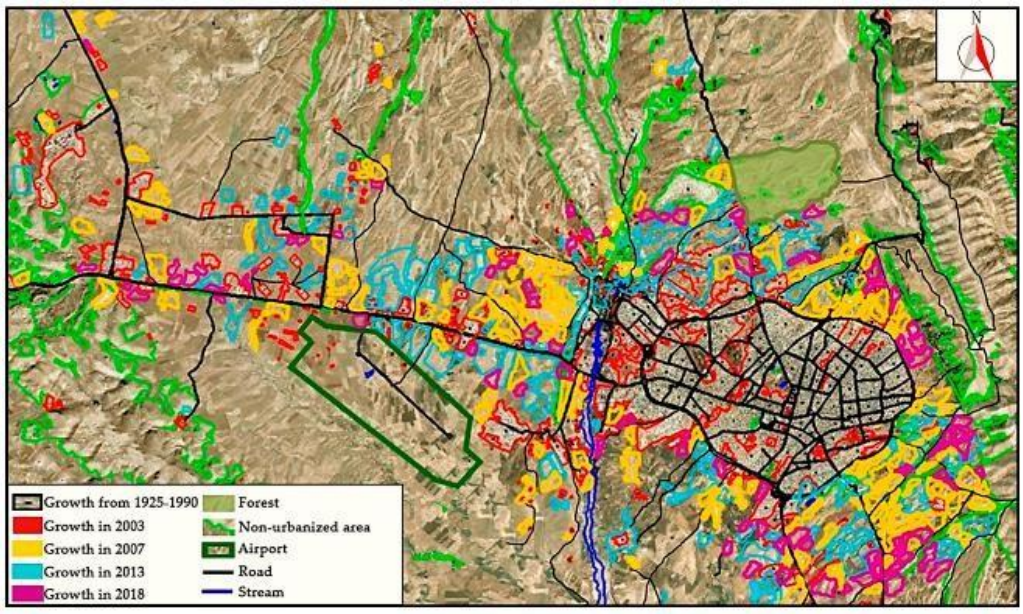

Figure 2: Sulaimani City's expansion [30].

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The Dukan Dam is the primary source of water supply for the Sulaimani City, located on the Zab River in the Governorate of Iraq. It was constructed in 1954 and was finished in 1959. It has water reserves of 6 billion cubic meters and a Russian company built a hydroelectric power station in 1970. Its height above sea level is 516 meters Sarchnar, Dukn line-1, and Dukilan line-2 are the primary transmission feeders for water distribution, fig 3. Due to population expansion and financial difficulties, the city only has intermittent water delivery, which endsures for a few hours every three days [31].

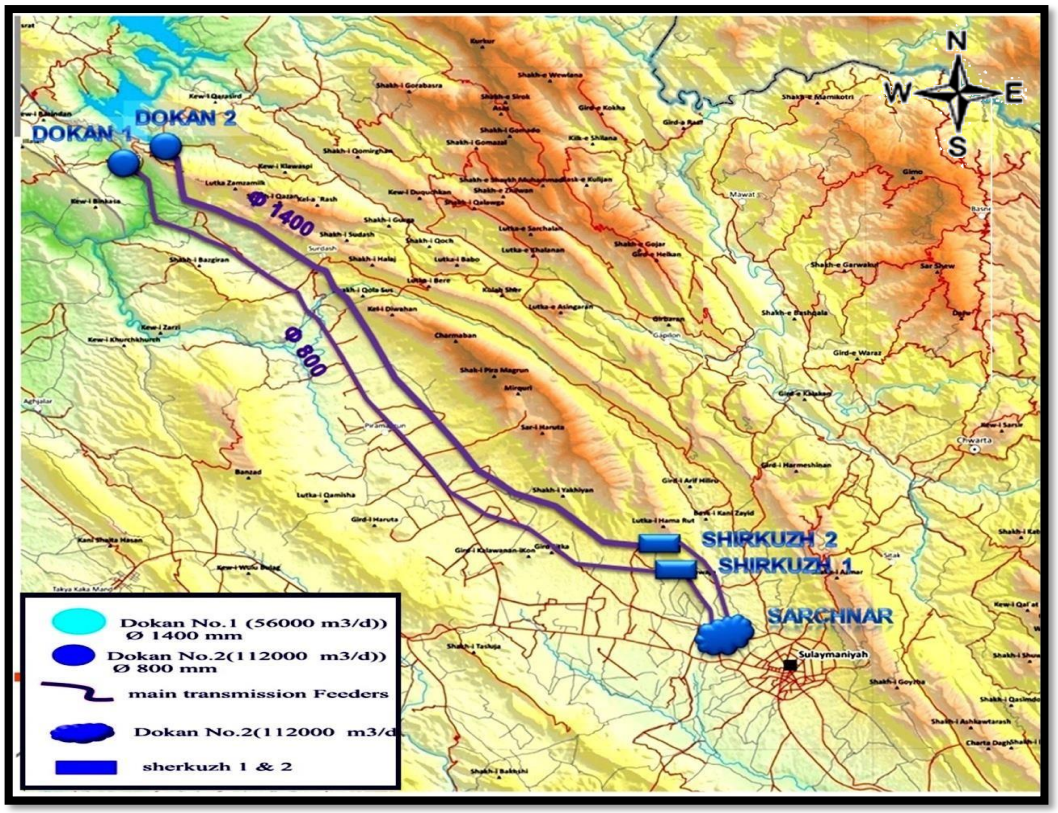

Figure 3: Location of drinking water sources Dukan water project first and second lines [31].

Figure 4 displays the exact locations of the water reservoirs and water pumping stations for the Sulaimani City. It should be mentioned that the distribution of reservoir locations depends on the topography of the area, (figure 4 and 5). Water is seldom pumped using pumps, and the locations of the stations are spaced apart in order to minimize the loss brought on by the level difference.

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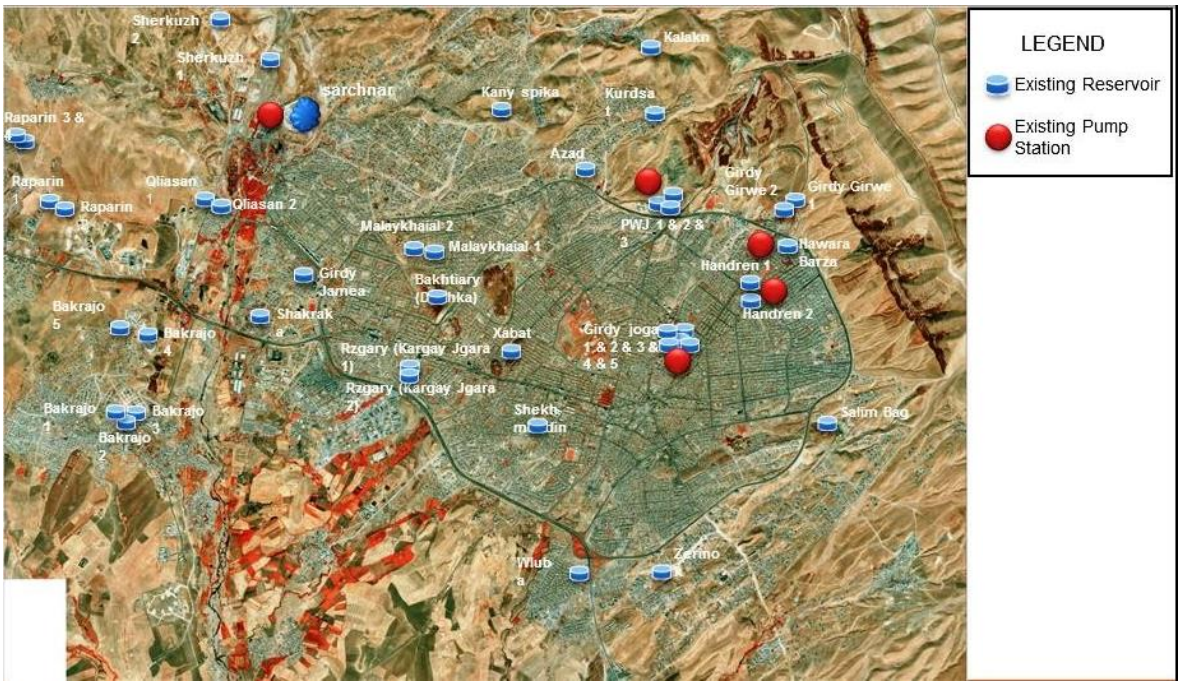

Figure 4: The network's existing pump stations and main reservoir feeders in Sulaimani City [26].

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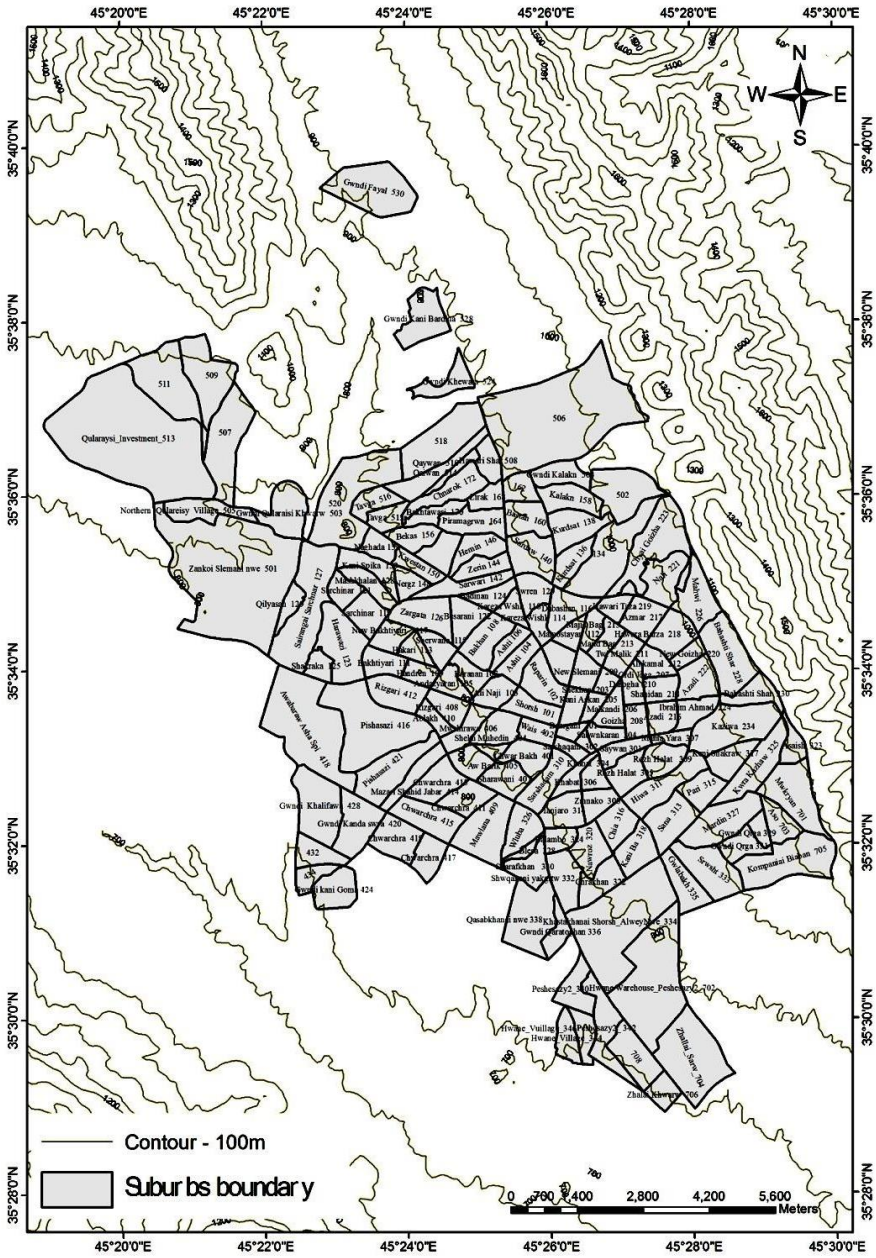

Figure 5: Contour map of Sulaimani City [32].

Figure 6 depicts the locations of the water tanks for the city of Sulaimani, as well as how to distribute water from those tanks inside the main water supply network and the usage of various types of pipelines to carry water based on population distribution and land use as required.

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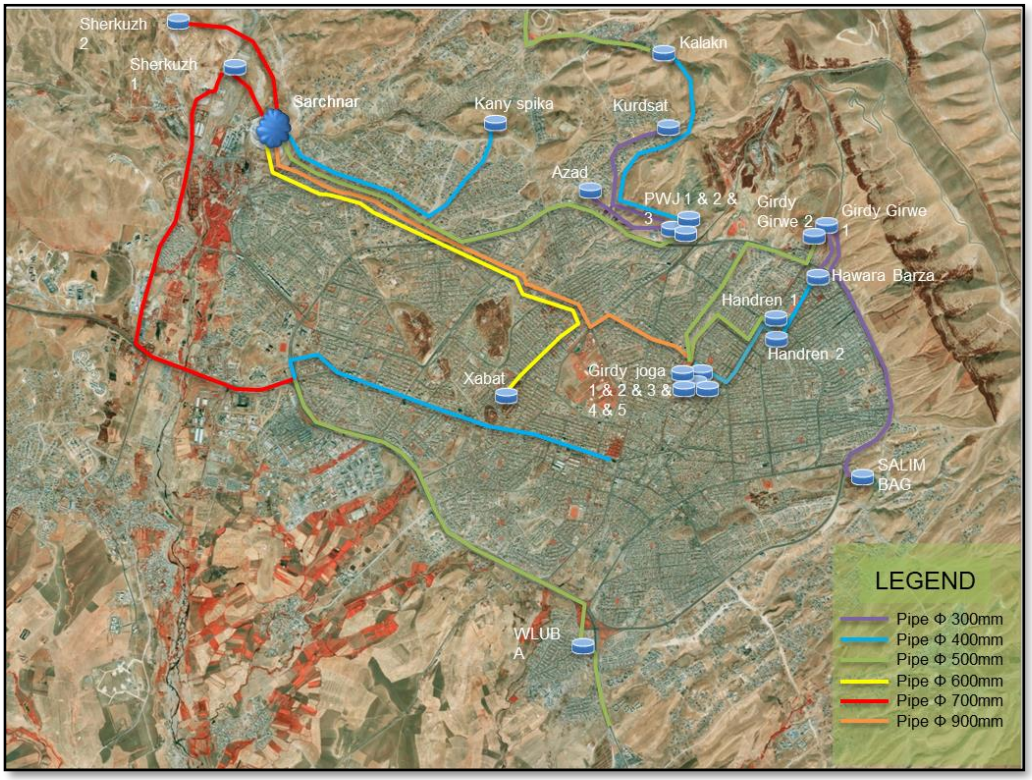

Figure 6: Main Transmission Feeders serving the entire Sulaimani City [26].

The local administration built 34 wells in the city to provide water to the people, and to fulfill their demands especially for newly developed areas and those that are illegal or without the permission of the municipality and official authorities [26].

The supply of water for Sulaimani City's inhabitants is frequently dependent on the main network that supplies water; however, there are many variances in the types of pipelines to comprise the infrastructure that distributes water to the population, (fig 7). Furthermore, some new neighborhoods have appeared on the map, particularly those developed on publicly owned land without official or legal approval from the city government, and therefore lack access to the main supply network. The government will offer water trucks to these locations in order for them to benefit from it and deliver water [31]. Nevertheless, the water directorate administrator claimed that because of a drop in water production, they will be unable to deliver water to those residences in 2022, even via trucks [26]. From this, it can be observed that wells, or more specifically groundwater, have an impact on providing water security for residents of those areas who do not have access to water supply networks, and in contrast, the benefits of thode wells are for fertilizing and irrigation of a number of those gardens, trees, and plants planted on the islands' Center Street. It is important to note that the irrational use of groundwater caused by the overuse of fresh water poses an increasingly significant danger to environmental sustainability and sustainable development.

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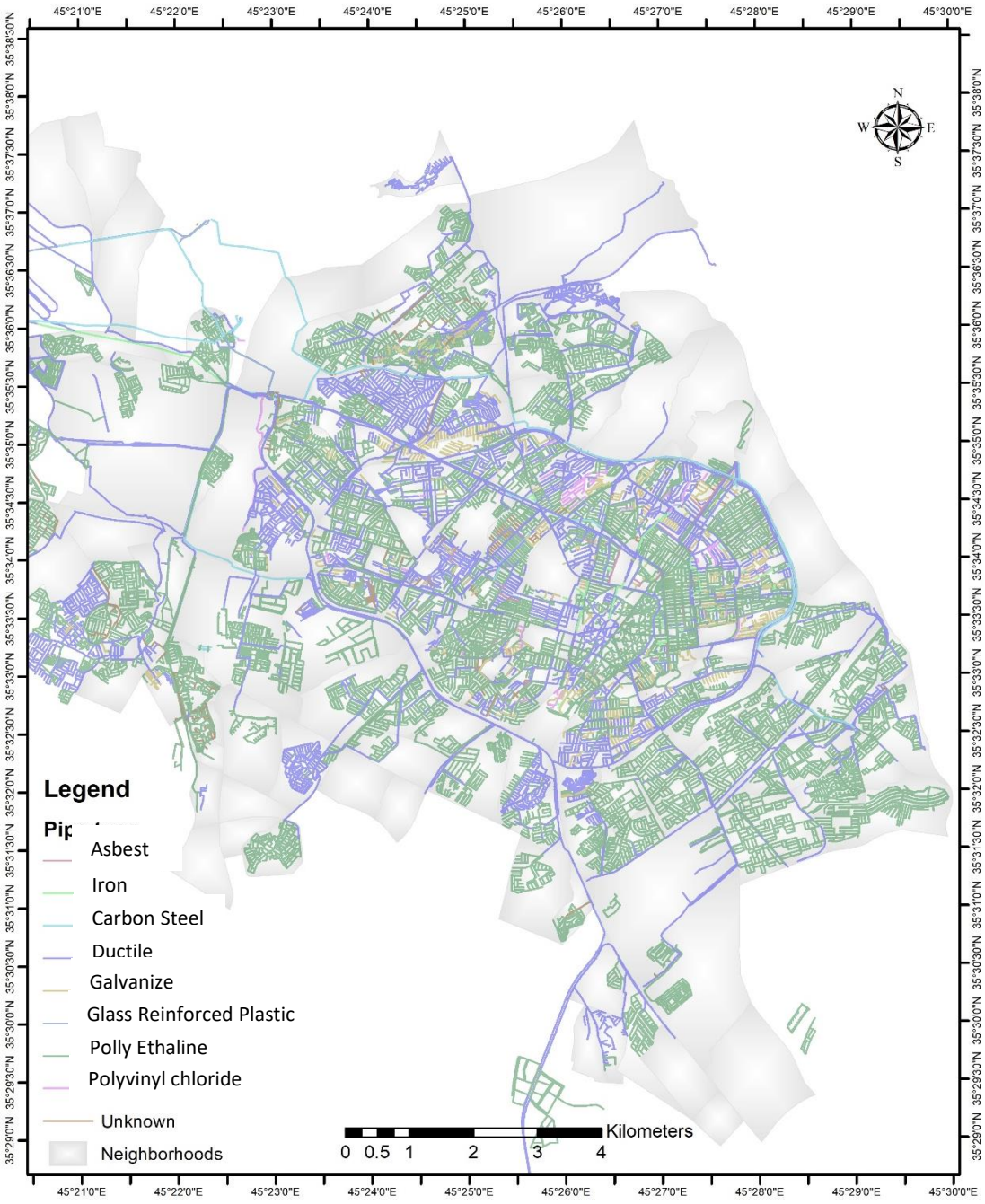

Figure 7: Types of pipes throughout the entire city of Sulaimani [26].

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3. Methods and Materials

3.1 Water sampling

Sulaimani is a city with 188 neighborhoods, including Tasluja and Raparin districts, and 20-one out of which is in the Bakrajo district. Sampling was used to reduce the area of investigation due to the large number of neighborhoods[33]. However, according to Surveys C. and Bullen P. the typical maximum sample size is in the range of 10%. This implies that out of 188 neighborhoods, we had to choose 19, but because of the city's continued expansion toward the Tanjaro district, we were forced to choose 20 neighborhoods with the goal of spreading the selected neighborhoods around the city equally in regard to spatial distribution [34, 35]. As consequence, a new neighborhood in the city called Hwana, previously part of the Tanjaro district, has been selected as an additional neighborhood in the city. These selections were through the using of systematic sampling which is a statistical technique used by researchers to focus on the population they are trying to investigate, and is a more comprehensive application of probability sampling in which each person in the group is randomly chosen to create a sample.[36, 37].

Furthermore, stratified random sampling, which is a kind of systematic sampling utilized in this study, is a systematic sampling method that involves dividing samples into strata based on a specific characteristic, such as income bracket or nationality. The goal is to ensure that each group is well represented in the sample. [38]. In the light of this evidence, these neighborhoods were chosen from various socioeconomics, locations, and topographies to be spatially equally distributed, in order to evaluate environmental justice.

Therefore, water samples are collected from all branches of the water directorate for supplying water, which are 8 branches with Bakrajo and Raparin branches except the Raparin branch. Randomly selected samples from these 20 Sulaimani neighborhoods were chosen for detailed chemical analysis. It took nearly two months for each neighborhood to take their samples, from August 27 to October 6, 2022, due to their inconvenient time of receiving public tap water. As a result, twenty samples of public tap water were collected, one for each neighborhood, to figure out whether the quality of their public tap water is suitable for drinking, thus meeting the study aim of "assessing the effects of the quality of distributed water on increasing environmental inequity among residents of Sulaimani city." Selected samples' locations were determined using GPS, Fig.10.

All samples for water quality are analyzed according to the standard guidelines [39]. Chemical analysis of the collected water samples is carried out at the laboratories of the Sulaimani Health Protection Directorate. The samples are reserved in acid-washed 250- and 500-ml polyethylene bottles. The bottles have been completely filled with the water samples to reduce the reaction between the water and air, which may result in changing the concentration of bicarbonate [40]. The samples were analyzed immediately for hydrogen ion concentration (pH), temperature (T^{o}C), and electrical conductivity (EC), using a portable multiparameter analyzer model (TPS/90FL-T Field Lab Analyzer) as shown in Fig.8. Tools for water quality diagnosis, monitoring, and evaluation are required to analyze the environmental implications of various activities involving water [41, 42]. This monitoring can be done by regularly evaluating the indicators listed in Table 3.

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Table 3: Drinking Water Quality Standards [43, 44].

Parameters	WHO [45]	Allowed maximum range according to Iraqi standards [46]
PH (standard Units)	6.5–9.2	6.5 – 8.5
TDS (Total Dissolved Solid) (mg/l)	500	1000
EC (Electrical Conductivity) (μS/cm)	–	–
Cl^- Chloride (mg/l)	500	250
Na^+ Sodium (mg/l)	6.5	200
K^+ potassium (mg/l)	1.2	12
Ca^{2+} Calcium (mg/l)	100	150
Mg^{2+} Magnesium (mg/l)	150	100
$SO2^-$ sulfate (mg/l)	100	250 PPM (taste and corrosion)

The samples were analyzed immediately for hydrogen ion concentration (pH), temperature (T^{o}C), and electrical conductivity (EC), using a portable multi parameter analyzer model (TPS/90FL-T Field Lab Analyzer) as shown in Fig.8.

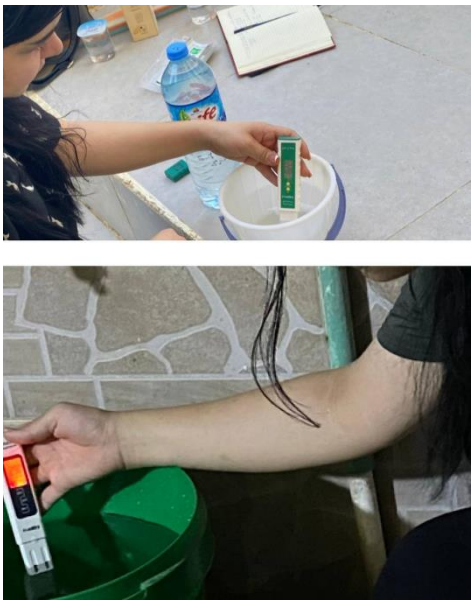

Figure 8: analyzing for hydrogen ion concentration (pH), temperature (T^{o}C), and electrical conductivity (EC) (Source: Authors).

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The accuracy and precision of the analysis are calculated, and the results are found to fall within the accepted limit, which means they are dependable for hydrochemical interpretations.

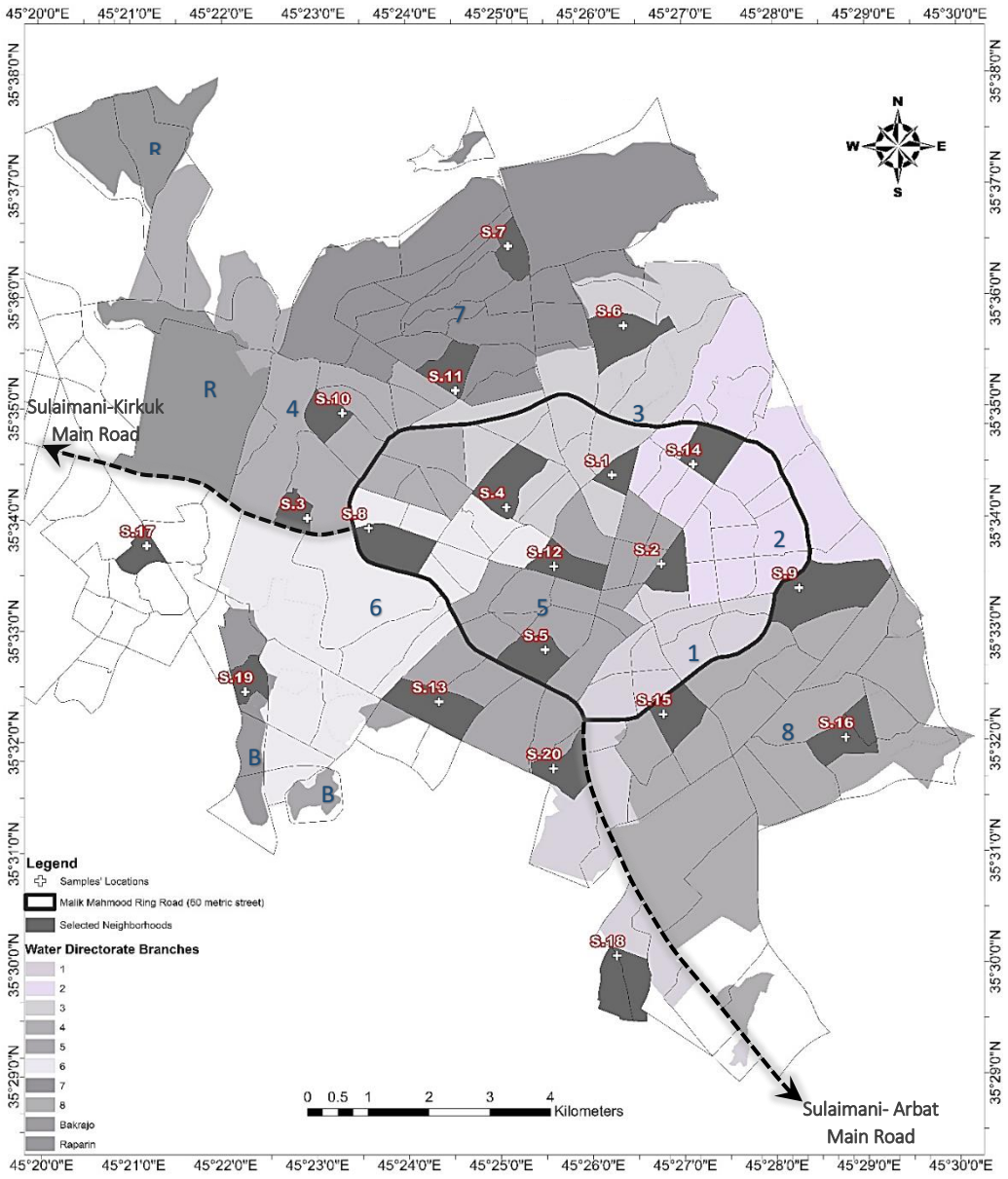

Figure 9: Locations of the water samples in neighborhoods and branches of the water directorate (Source: Authors)

3.2 Questionnaire of water quality

The principle of environmental justice states that all individuals should have a role in environmental decision-making and that no group should be treated unjustly as a result of those decisions [47].

As a result, public participation in environmental justice requires determining public concerns, providing opportunities for collaboration, developing alternatives, listening to the public, integrating

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public concerns and suggestions, and providing feedback on how decisions reflect or do not reflect the feedback, as must be done in environmental justice [48].

The quantitative and qualitatie data were collected to determine the adequacy and quality of the distributed and used water in those neighborhoods by using a GIS program and a questionnaire as tools. In addition, the majority of statisticians believe that a sample size of 100 participants is necessary for surveys in order to get results that are relevant. This study selected 20 neighborhoods to survey, with 100 participants for the entire city divided into five participants from each of these twenty neighborhoods. All participants were selected randomly, As a result of the inappropriate time to receive public tap water, it was hard to collect their samples and interview with the participants. This took place from August 27 to October 6, 2022, or nearly 40 days. In this study, data was gathered through interviews with local residents using a questionnaire. As a secondary source of information, various sources such as research papers, journals, the Internet, and books are consulted. For the study, both primary and secondary data were utilized.

To investigate the public's awareness of the quality of drinking water and justice in Sulaimani City. This questionnaire's specific survey questions cover responses to questions about drinking water quality and justice. These questions included respondents' demographic information, their awareness of drinking water safety (types of household drinking water, satisfaction with drinking water quality, degree of trust in drinking water safety, common tap water problems and solutions, and awareness of local water quality), and their awareness of drinking water contamination. There are five questions in the questionnaire. The principal questions are listed in Appendix.

The demographic information includes location, number of residents in the house. Each questionnaire only takes about 5 minutes to complete. The responses were collected at the time of the interviews. Respondents were randomly selected. All interviews were conducted face-to-face. Data from the surveys was collected, coded, and entered into MS Excel. The statistical analysis of the data was performed using SPSS Statistics for Windows version 28. Significant differences among respondents were analyzed by multinomial logistic regression analysis.

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4. Result

4.1 Water quality evaluation

The results of the chemical analysis of the water samples are tabulated in Table 4 and 5. The hydrochemical study of water samples, showed that the water is slightly yellow color, odorless except for chlorine, tasteless, and characterized by a low value of total dissolved salts. The predominant ions are calcium and bicarbonate, and the chemical type of the water is calcium bicarbonate. All samples are suitable for drinking according to WHO, 2022, and IDWS, 2009 (Table 6).

Table 4: Physical Parameters of Water Samples (Source: Authors)

No.	pH	EC	TDS
		µs/cm	mg/l
S1	7.64	354	226.6
S2	7.59	353	226
S3	7.51	350	224
S4	7.69	356	227.8
S5	8.23	355	227.2
S6	7.72	355	227.2
S7	8.19	355	227.2
S8	7.62	356	233.6
S9	7.9	356	227.8
S10	7.59	395	252.8
S11	7.8	359	229.8
S12	7.91	361	231
S13	8.01	354	226.6
S14	8.2	359	229.8
S15	8.06	352	225.3
S16	8.29	347	222
S17	7.49	350	224
S18	8.1	351	224.6
S19	8	431	275.8
S20	7.44	437	262.4

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Table 5: Cation and Anion of Water Samples (Source: Authors)

No.	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SUM %epm	$SO4^{2-}$	Cl^{-}	HCO_3^{-}	CO_3^{2-}	SUM %epm
S1	71.36	23.79	4.34	0.51	100.00	16.93	12.04	71.04	0.00	100.00
S2	70.84	24.31	4.35	0.50	100.00	17.63	9.86	72.51	0.00	100.00
S3	71.63	23.14	4.70	0.52	100.00	16.93	9.78	73.28	0.00	100.00
S4	75.77	19.06	4.72	0.44	100.00	17.59	11.61	70.80	0.00	100.00
S5	72.82	21.85	4.81	0.52	100.00	19.09	6.28	74.63	0.00	100.00
S6	71.86	22.75	4.87	0.52	100.00	17.88	7.69	74.43	0.00	100.00
S7	72.40	21.82	5.22	0.55	100.00	18.38	5.57	76.06	0.00	100.00
S8	74.49	20.69	4.32	0.50	100.00	17.39	7.53	75.08	0.00	100.00
S9	73.06	21.49	4.86	0.59	100.00	17.63	6.78	75.59	0.00	100.00
S10	75.15	21.59	2.93	0.33	100.00	16.09	6.73	77.19	0.00	100.00
S11	76.15	18.80	4.54	0.51	100.00	14.07	9.76	76.17	0.00	100.00
S12	73.00	21.90	4.57	0.52	100.00	15.52	9.27	75.21	0.00	100.00
S13	73.17	21.15	5.06	0.61	100.00	18.83	9.41	71.76	0.00	100.00
S14	74.20	20.69	4.59	0.51	100.00	17.93	9.25	72.82	0.00	100.00
S15	71.46	22.69	5.33	0.52	100.00	17.03	9.73	73.23	0.00	100.00
S16	70.85	24.72	4.01	0.42	100.00	17.66	10.99	71.35	0.00	100.00
S17	75.70	19.79	4.13	0.38	100.00	17.11	11.68	71.21	0.00	100.00
S18	75.53	20.14	3.94	0.39	100.00	16.82	8.54	74.65	0.00	100.00
S19	74.79	23.12	1.78	0.31	100.00	17.27	7.84	74.89	0.00	100.00
S20	74.92	22.86	1.77	0.46	100.00	18.18	7.96	73.86	0.00	100.00

Table 6: Water sampling results according to [45] and [46]. (Source: Authors)

Parameters	Range	Average	WHO standard [45]	Iraqi standard [46]
pH	7.44 - 8.29	7.85	6.5–8.5	6.5 – 8.5
TDS (mg/l)	224 - 252.8	229.5	500	1000
EC (μS/cm)	347 – 431	363.4	1500	1500
Cl^{-} (mg/l)	7.00 - 16.00	11.65	250	250
Na^{+} (mg/l)	1.60 - 3.90	3.36	200	200 ppm (taste)
K^{+} (mg/l)	0.50 - 0.80	0.65	12	12 ppm
Ca^{2+} (mg/l)	42.00 - 62.00	51.25	75	150 ppm
Mg^{2+} (mg/l)	8.00 - 11.50	9.13	125	100 ppm
SO42- (mg/l)	25.00 - 33.50	30.15	250	250 ppm (taste and corrosion)
HCO3- (mg/l)	153.00 - 178.00	163.55	N.G	200

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4.2 Questionnaire

Following the distribution of the questionnaire to the locals, several significant findings would have emerged from their replies, which demonstrate the existence of a wide spectrum of environmental injustice between the neighborhoods, particularly through the socioeconomic component, as shown below:

According to the first question of the questionnaire about what type of drinking water participants use, it defines that, 51.4% of participants in the overall participation consume tap water, 21.6% drink filtered or bottled water, and 2.7% drink well or boiling water.

Table 7 shows that, overall, 38.6% of the participants don't trust public tap water, which is why they drink other types; 33.3% of them don't trust public tap water but can't afford clean water; only 17.1% of them do, which is why they drink tap water; and 4.7% of them don't trust the water in their storage tanks. 1.8 percent drink well water because they trust it, 1.8 percent do not trust well water, 0.9 percent do not trust bottled water but trust public tap water because they drink tap water, 0.9 percent use filtered water to reduce chlorine odor in public tap water, and 0.9 percent of total samples do not have any idea about why they drink that type of water.

Table 7: Reasons why participants are using that type of water for drinking (Source: Authors)

Reasons	**Frequency**	**Percent**
We don’t trust public tap water.	40	38.6
We don’t trust public tap water, but we can't buy clean water.	35	33.3
We trust public tap water	18	17.1
We trust well water	2	1.8
We don’t trust well water	2	1.8
To reduce chlorine odor	1	0.9
We don't trust bottled water	1	0.9
We don't trust our storage tank water	5	4.7
No idea	1	0.9
Total	105	100.0

To determine if a certain form of drinking water was significant or not, Table 8 compares the types of drinking water participants drank with their justifications. Because the p-value of the chi-square is smaller than the standard alpha of 0.05 and equals 0.000, there is a totally statistically significant association between them.

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Table 8: Comparing the type of drinking water used by participants to the reasons why they drink it (Source: Authors)

Count	Tap water	Well water	Filtered water	Bottled water	Boiled water	Total
We don't trust public tap water.	6 (5.1)	0 (0.0)	18 (15.1)	19 (17.0)	2 (1.6)	45 (38.8)
We don't trust public tap water. but we can't buy clean water.	34 (28.6)	1 (0.8)	1 (0.8)	1 (0.8)	2 (1.6)	39 (32.6)
We trust public tap water	15 (12.6)	2 (1.6)	1 (0.8)	2 (1.6)	0 (0.0)	20 (16.6)
We trust well water	2 (1.6)	2 (1.6)	0 (0.0)	0 (0.0)	0 (0.0)	4 (3.2)
We don't trust well water	0 (0.0)	0 (0.0)	2 (1.6)	0 (0.0)	0 (0.0)	2 (1.6)
To reduce chlorine odor	0 (0.0)	0 (0.0)	1 (0.8)	0 (0.0)	0 (0.0)	1 (0.8)
We don't trust bottled water	1 (0.8)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.8)	2 (1.6)
We don't trust our storage tank water	2 (1.6)	0 (0.0)	2 (1.6)	1 (0.8)	0 (0.0)	5 (4.0)
No idea	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.8)	0 (0.0)	1 (0.8)
Total	60 (50.4)	5 (4.0)	25 (20.4)	24 (21.0)	5 (4.2)	119
Chi- Square	113.44	P-value	0.000	Result	Full Significance	

Another question demonstrates that If municipal teams are sent to examine the water quality. Unfortunately, 98.0% of all samples indicated that municipal teams do not visit to evaluate the water's quality; just 1.0% said otherwise, and 1.0% had no information.

According to Table 9, 32.4% of respondents felt that their water needed additional filtering since it wasn't as clear as it could be for drinking. Additionally, 13.9% of them believe that the government should implement improved management and policies for water quality. Only 2.6% of people were impacted by the infrastructural change. However, the majority of respondents, who made up 37.0% of the total responses, feel that the problem of poor water quality will never be solved since the government does not take population decisions into account.

Table 9: solutions for water bad quality according to the participant's opinions (Source: Authors)

Class	Frequency	Percent
More Filtration	49	32.4
Improved management and policy	21	13.9
it will never be solved since the government does not take population decisions into account.	56	37.0
The modification in Infrastructure.	4	2.6
no idea	21	13.9
Total	151	100.0

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5. Discussion

5.1 Water quality evaluation

Table 4 and 5 showed the results of the chemical tests done on the samples of water. The hydrochemical study of water samples illustrated that the water is slightly yellow, odorless except for chlorine, tasteless, and characterized by a low value of total dissolved salts. The predominant ions are calcium and bicarbonate, and the chemical type of the water is calcium bicarbonate. All samples are suitable for drinking according to WHO, 2020, and IDWS, 2009. Additionally, this proves that there isn't any environmental injustice through the result of water quality tests, because all samples from different socioeconomic and places were the same in quality.

5.2 Questionnaire

After the questionnaire was given to the people in the neighborhood, some important things would have been learned from their answers, which show that there is a lot of environmental injustice between the neighborhoods, especially when the socioeconomic factor is taken into account. The first question was meant to find out how different groups of people got their drinking water, which shows how unequal their social and economic situations are and makes environmental injustice a lot worse.

Table 7 displays the justifications offered by the participants. The majority of them drink bottled or filtered water because they don't trust tap water, and the second-highest value is given to those who drink tap water despite not trusting it because they are lower-income. It demonstrates that there are significant socioeconomic gaps, forcing lower-income households to consume tap water which rises the ratio of environmental injustice. Moreover, participants who did not trust the water in their storage tanks did so because they believed it may interact with high temperatures and the tank's material, making the water filthy and unsuitable for consumption. Because they believe the high level of chlorine in tap water is harmful to their health, 0.9% of people who use filtered water do so to lessen the chlorine odor. Therefore, the answer to this question revealed a wide range of environmental injustice between these socioeconomically different groups who drank or did not drink public tap water.

Additionally, table 8 demonstrated the totally statistically significant correlation between the participants' preferred type of water and the justifications for doing so. The most important cell is the proportion of individuals who drink tap water—34 out of 60 people—but don't trust it because they can't afford clean water. This represents more than half of all people who consume tap water. This demonstrates that there is a high rate of socioeconomic inequality, which pressures people to drink a type of water they don't like but are obligated to do so because they have no other options due to their low income. The socioeconomic disparity is the most significant influencing factor in this situation, which raises the ratio of environmental injustice.

The remaining 5 participants use tap water, but when cholera or other infections are present, they purchase clean water or use filtered, well, or boiling water instead since they are unable to purchase clean water on a regular basis due to their lower income. Additionally, several of them indicated that they occasionally purchase clean water since unclean water smells like sewage. This demonstrates that individuals would only judge their water based on what they could see and smell about it. After

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drinking it, one of the participants said that they experienced acute stomach pain. Even some of them admitted to contracting cholera after drinking tap water, yet they are unable to address the issue. They are aware that drinking tap water is detrimental to their health and that they should stop doing so after seeing their doctor, but because of their poor income, they are unable to address their health issues, whereas others with greater incomes can always purchase pure water. There is evidence of a high ratio of environmental injustice in Sulaimani as a result of the low quality of water.

The second-most significant cell in this comparison is the proportion of participants—19 out of 24—who would choose bottled water over tap water because they did not trust it to be safe to consume. This demonstrates that those with greater incomes who can purchase clean water do not trust public tap water due to negative tap water consumption experiences. Participants also stated that "people think it's not clean, and when we replace our filter tab, it's really dirty" as further justifications for not drinking tap water, this shows a highly range of environmental justice differences between different groups of who drinks tap water or filtered or bottled water.

In addition to this, the third most significant cell in the comparison is the one where the participant uses filtered water because they don't trust tap water for the reasons they listed, such as "Already, if it is clean, it will be unclean in our tanks" and "one of us had kidney disease, and the doctor stated that it was due to our unsanitary water"; "Because of our contaminated tap water, we occasionally catch diseases". This demonstrates that the water either negatively affects both groups who've been drinking filter and bottled water, or they are unable to consume it since they can smell it or notice its color. Therefore, they purchased clean water to fix their dilemma. Most of the participants, who drank tap water, did notice this problem, but they were unable to address it due to their low income. This demonstrates that there are numerous environmental inequities. The fact that just 15 out of the 43 participants in this study regularly consume tap water and have confidence in it is highlighted in this table.

Furthermore, as illustrated before, 98.0% of total samples stated that municipal teams do not attend to test the water quality; just 1.0% of those polled replied yes. This demonstrates that administrations do not take water quality concerns seriously, which should be checked carefully in order to fix them if problems exist and thus reduce the frequency of environmental injustice regarding water quality.

Consequently, based on Table 9, 32.4% of respondents were influenced by increased water filtering because they perceived their water was not as clear as it could be for drinking. What's more, 13.9% believe that the government should improve water quality management and policies. Only 2.6% of participants were affected by modifications to the infrastructure of supplying water, such as pipes, to reduce the ratio of uncleaned water, particularly if the water converses within the material properties, as well as because they believed that not every place possessed the same infrastructure or pipe type, which is not equitable to the population. Nevertheless, the majority of respondents believed that the solution to poor water quality will never be developed since the government does not count population decisions, which account for 37.0% of total involvement. It demonstrates that community engagement for city management, particularly for vulnerable people, is frail, and water management would have been done entirely by the government with no return to the individuals who live in the city; this exemplifies the lack of public participation in decision-making processes in the city, which usually result in a wide range of environmental injustices.

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6. Conclusions and Recommendations

This study has the following conclusions:

- Improving environmental justice in the management of water quality is a key strategy for improving health status for all urban populations. High levels of environmental inequality are caused by poor management and socioeconomic decay in the neighborhoods of Sulaimani city.
- This is the first investigation of environmental justice in drinking water quality in Iraq and the Kurdistan region. As the result of the assessment of the quality of distributed water effects on increasing environmental inequity among residents of Sulaimani City in twenty neighborhoods with different socioeconomics, location, and topography.
- As a result of analyzed water quality sampling, testing, and the survey of 100 participants, the findings illustrated that the hydrochemical analysis of water samples characterized by a low value of total dissolved salts. All samples were suitable for drinking according to WHO, 2022, and IDWS, 2009.
- The second section of this study demonstrated that the majority of participants in Sulaimani city distrust public tap water and that they consume tap water because they cannot purchase clean water owing to their lower income. This causes a high ratio of environmental injustice owing to socioeconomic inequality since we discovered that populations with greater incomes were less likely to be affected by illnesses brought on by poor water quality.
- More than half of participants who drink bottled water do so as a result of having had bad experiences with tap water. As a result, water either negatively affects the two groups who are drinking filtered and bottled water, or they can smell it and it has a yellow color, which prevents them from drinking it.
- The majority of responses ultimately hold the opinion that there will never be a solution to poor water quality because the government does not take population decisions into account. This fact results in a wide range of environmental injustice because it excludes the public from decision-making, which is at the core of environmental justice. The majority of respondents also supported stronger government water policy and management, as well as more water filtration.

This study has the following Recommendations:

- This research suggests that policies will require taking into account the perceptions and experiences of local populations in order to uphold environmental justice principles and ensure successful water quality management at the local and municipal levels.
- It is crucial to involve the local communities in the decision-making process and provide them with adequate information to increase their awareness and participation. This can lead to more effective and equitable water management policies that benefit both the environment and people.

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