Hindawi
Journal of Chemistry
Volume 2022, Article ID 8574935, 12 pages
https://doi.org/10.1155/2022/8574935

Research Article

Physicochemical Characterization and Evaluation of Seasonal Variations of Landfill Leachate and Groundwater Quality around Tanjaro Open Dump Area of Sulaymaniyah City, Kurdistan, Iraq

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Received 5 October 2022; Revised 5 December 2022; Accepted 7 December 2022; Published 20 December 2022

Academic Editor: Claudio Cameselle

The current study is concerned with the primary environmental assessment of the physicochemical characterization of seasonal fluctuations in the leachate of Tanjaro open dump site in Sulaymaniyah City, and its impact on the quality of the groundwater. The primary characteristics of the leachates were their high levels of organic and inorganic components and their toxicity because of the presence of heavy metal concentrations. For almost all physicochemical parameters, the leachate from the Tanjaro area dumping has incredibly high values. All heavy metals were present in leachate, with the exception of cadmium and mercury, albeit at levels below their respective permitted limits. The characterization revealed that Leachate 1 (L1) may be referred to as young leachate, whereas Leachate 2 (L2) and Leachate 3 (L3) can be referred to as old leachate due to their pH values. It was indicated that the Tanjaro dumping is operating and in the early stages of stabilization. BOD_5/COD was around 0.63, and the leachate was highly biodegradable in the anaerobic phase. Groundwater, which contains little to no organic matter, was not found to be severely affected by monitoring wells located close to the dumpsites. The conductivity, total dissolved solids, total hardness, Mn, and Fe were some of the values that went above the WHO guidelines. Correlation analysis was used as a preliminary descriptive technique to establish the strength of the association between the relevant variables. Some parameters were discovered to be statistically significantly correlated with one another, pointing to a close connection between these parameters.

1. Introduction

Open dump area (site) is thought to be active sources for the gradual release of harmful compounds mixed with nontoxic precursors into the environment. Leachate and gases are produced in the open dumpsite as a result of biological, chemical, and physical processes that promote waste disintegration [1]. The most typical kind of landfill, which receives a combination of commercial, municipal, and mixed industrial waste, defines landfill leachate as a water-based solution of four categories of contaminants (dissolved organic matter, inorganic macro components, heavy metals, and xenobiotic organic compounds) [2]. Leachate has a very high concentration of chemical oxygen demand (COD), biological oxygen demand (BOD), ammoniacal nitrogen, heavy metals, and other organic and inorganic contaminants. According to the ratio of $BOD_5/COD > 0.6$, young leachate often contains organic fractions that are readily biodegradable and have significantly lower molecular weights. Older leachates with an organic proportion tend to have persistent features and contain humic and fulvic compounds with greater molecular weights, as seen by BOD_5/COD ratios >0.3. This is because landfills have a longer lifespan. In addition, fewer easily volatilized fatty acids are present in older leachates, which makes them largely comprise refractory materials and may lower the BOD_5/COD ratio [3].

Leachate is dark brown or black in color, and if not collected and treated, it has a great potential to contaminate nearby soil and groundwater [4]. Depending on the type of waste and its age, leachate can have a wide range of compositions, and numerous elements are suspended and dissolved in it. Even at a single dump site, the quality of leachate is largely site-specific and varies from place to place [5]. Municipal solid waste landfills will continue to create contaminated leachate after they are closed; this process can keep going for 30 to 50 years and can have a severe environmental impact if released into the environment untreated [6]. Leachate can have a direct or indirect impact on the properties of soil; however, as opposed to mechanical alteration, leachate contamination of soil typically concentrates on its chemical qualities [7]. When leachate is present, it may affect soil differently than when normal water is present. Leachate contains a variety of chemical components that could regulate its electrical conductivity, which would then affect how it interacts with the soil [8].

In Tanjaro, groundwater is the main source of agriculture and drinkable water. In this study, the impact of open dump area leachate on groundwater quality determined through physical and chemical analysis of both open dump area leachate dumpsites and groundwater (tube wells) samples collected near the Tanjaro open dumpsite in Sulaymaniyah city.

2. Materials and Methods

2.1. Sample Collection. In order to characterization of the leachate generated from open dumpsites and groundwater, three groundwater (tube well) samples surrounding the dumping area and three leachate samples were collected from the dumping during four seasons of the year 2021-2022. Site specifications for sampling points are presented in Table 1 and Figure 1. Table 2 displays the Specifications of the sample analysis instrument, analytical methods, and monitored parameters.

The groundwater samples (W1, W2, and W3) were collected close to the dumping sites; where it was found that the distance between W1 and (L1, L2, and L3) were 1,447, 955, and 925 meters, respectively, while W2 and (L1, L2, and L3) were 862, 448, and 382 meters, and W3 and (L1, L2, and L3) were 1,177, 780, and 714 meters, respectively. The three samples for each were collected throughout four seasons, same like the leachate samples.

2.2. Material Preservation. All samples were collected in 5.0 L precleaned polyethylene containers (MEDILAB-Company-India.), and returned to the laboratory at University of Sulaimani-College of Agricultural Engineering Science- Department of Natural Resources. They were kept at 4°C in the incubator (TC 135 S-Lovibond incubator) before being tested in accordance with standard procedures. To prevent the heavy metals from precipitating, samples for heavy metals were maintained separately by adding 1.0 ml concentrated nitric acid (from Merck).

3. Results and Discussion

3.1. Leachates. The mean values of physicochemical parameters of leachate samples as well as their seasonal variation are summarized in (Table 3 and S1).

There is significant effect of leachate temperature change on the organic decomposition, which affected on the gas production. The biodegradation of the waste caused heat to be released, which raised the temperature and accelerated the composition of organic matter, which in turn to increase gas production. There is a clear correlation between temperature and each of the parameters of electrical conductivity, suspended particles, pH, and BOD_5; therefore, the warmer the season, the greater the values of the parameters [9]. The seasonally average temperature distribution (Table 3) shows that the highest temperature in summer (28.5°C) were recorded, and the lowest temperature recorded in winter is (7°C). These values rise gradually from January and evolve into a summer character in July and August. There are a direct proportion between the temperature and each of electrical conductivity, suspended solids, pH, BOD_5 parameters, which means, the warmer is the season, the higher the values of the parameters. Based on the various landfill ages, three types of stabilized leachate-young (less than a year), medium (1–5 years), and old (more than 5 years), can be distinguished in landfills [10]. The pH is an important component in stabilizing the age of the leachate; it is typically found to range from 4.5 to 9, with young leachate having a pH of less than 5.5 and older landfill leachate having a pH of more than 7.5; while the pH in between is considered to be a medium leachate [11]. The pH values of the dumpsites analyzed (Table 3) were found that the pH mean value for L1 is around (6.0), L2 is around (8.0), and L3 is about (7.7). According to Christensen et al. and Salami et al. [11, 12], the age of L1 can be referred to young, but the pH value of both L2 and L3 were referred to old leachate. The leachate from L1 dumpsites is considered to be young because of its pH value, which is less than 6.5 due to the high concentration of volatile fatty acids; however, the leachate from L2 and L3 during the methanogenic stage has been converted into methane and carbon dioxide, causing the pH of the leachate to rise to alkaline levels [13]. The Electro-Conductivity parameter (EC) is dependent on the presence of inorganic components, specifically the levels of different anions, cations, and the soluble salts [14]. The average EC mean values of the leachates for four seasons range from (498.56) to (144514.9) $\mu S{\cdot}cm^{-1}$, which is considerably high amount. The exceptionally high EC values are caused by the abundance of anions and cations. Leachate's weakly alkaline composition is a sign that the dumping site reached mature stage.

Total dissolved solids (TDS), another crucial parameter used to characterize leachate samples, can indicate the presence of some organic material as well as inorganic salts of major cations and anions, and it is used to show the degree of salinity and mineral contents of leachate. Total dissolved solids with high concentrations can reduce water's clarity, which makes it harder for plants for photosynthesis and

Table 1: Site specification for sampling.

Samples	Sampling location and type	Latitude and longitude		Elevations (m)
L1	Leachate collecting point-1	35°29′11″	45°26′12″	700
L2	Leachate collecting point-2	35°28′56″	45°26′4″	650
L3	Leachate collecting point-3	35°28′54″	45°26′5″	650
W1	Tube well-1 (depth = 101 m)	35°28′32″	45°25′40″	670
W2	Tube well-2 (depth = 12 m)	35°28′43″	45°26′12″	650
W3	Tube well-3 (depth = 11 m)	35°28′33″	45°26′17″	660

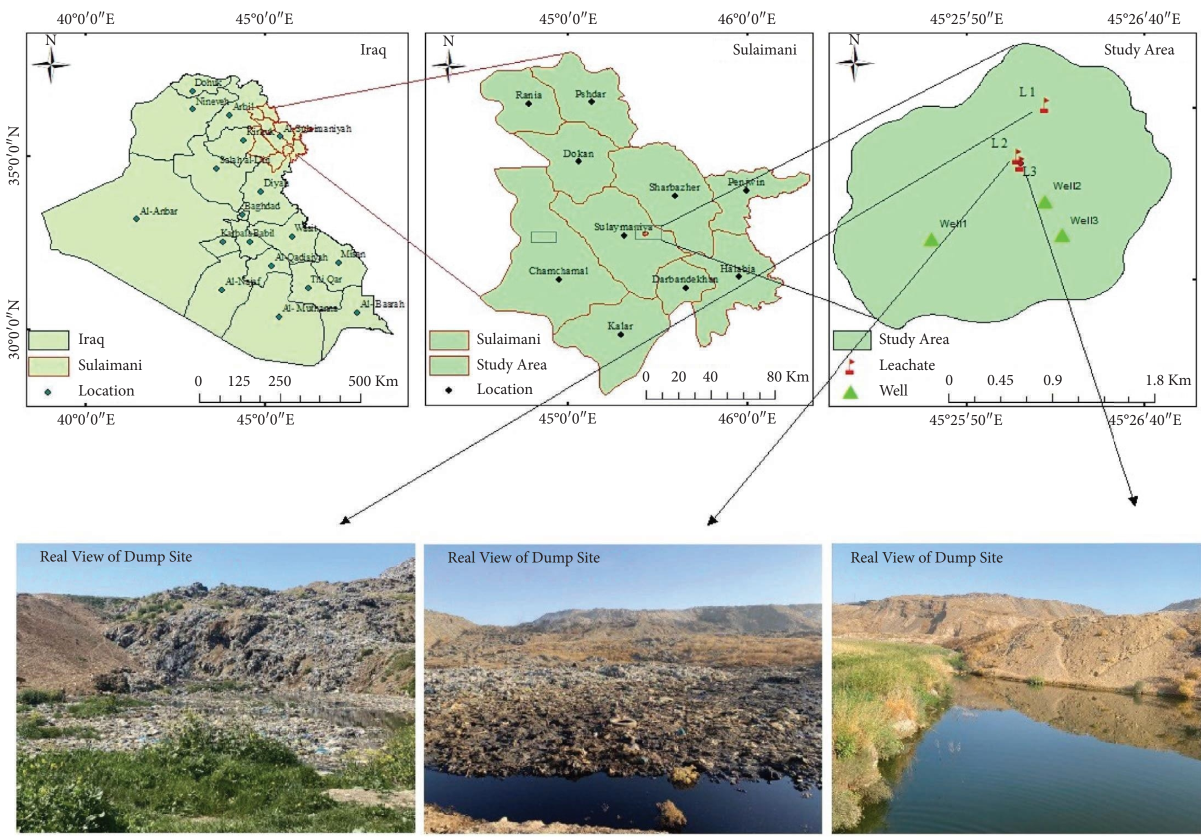

Figure 1: The location of study area (dumping site and wells) at Tanjaro.

raises the water's temperature. The biotic components, such as photosynthetic bacteria and algae, are affected in terms of their growth and development. Many aquatic organisms might become weak and even die due to high TDS levels [15]. The values of TDS as represented in Table 3, is (96825, 51602.5, and 779) for L1, L2, and L3, respectively, which have high TDS values make these leachates biologically polluted, which makes unfavorable tastes, odors, and colors as a result. A decrease in water clarity caused by high TDS levels might contribute to light limitation, which in turn reduces photosynthesis and raises water temperature. This has an impact on the genesis and proliferation of biotic elements like photosynthetic bacteria and algae. Many aquatic species may be killed by high TDS, which restricts their ability to grow [16]. This high concentration of TDS was a result of rainwater intrusion, which caused larger concentrations of contaminants to dissolve. The highest EC and TDS values during dry seasons suggested that they might be the result of dry weather where the cations, anions, and total solids collected at these locations. In contrast, the winter and spring seasons revealed low EC and TDS levels as a result of the dilution of these ions following the season of significant rainfall [17].

Total Alkalinity (TA), caused by bicarbonate, carbonate, and hydroxyl ions, is one of the physicochemical parameters studied in leachate. The high alkalinity in leachate gives a disagreeable flavor that could have an impact on human health, and the higher levels in tube well samples indicate that the water is not used for drinking due to the taste. The biological decomposition and dissolution process that takes place within disposal sites causes TA values for leachate to be much higher. Significant amounts of bicarbonate, which is dissolved carbon dioxide and one of the main components of alkalinity, are produced during the biodegradation of organic matter [16]. Alkalinity of leachate samples were mainly due to the presence of carbonate ions, in which high

Table 2: Details of parameters monitored, methods of analysis, and instrument used.

Parameter	Method adopted	Apparatus/instrument used
Temperature	Electrometric method	Thermometer, electronic pH meter, and conductivity meter, (medidor multiparâmetro milwaukee MW804)
pH	Electrometric method	
Electrical conductivity (EC)	Electrometric method	
Total dissolved solid (TDS)	Gravimetric method	
Total alkalinity as $CaCO_3$ (TA)	Titrimetric method	
Total hardness as $CaCO_3$ (TH)	EDTA titrimetric method	
Biological oxygen demand (BOD_5), and chemical oxygen demand (COD)	Winkler's method	Portable dissolved oxygen meter (oakton DO 110 portable dissolved oxygen meter)
Anions		
Chloride (Cl^-)	Argentometric method	UV-visible spectrophotometer (ultraviolet_visible shimadzu 1800 spectrophotometer screening method)
Nitrate (NO_3^-)	UV-vis. spectrophotometric screening method	
Sulphate (SO_4^{2-})	Turbidimetric method	
Phosphate (PO_4^{3-})	Ascorbic acid method	
Cations		
Calcium (Ca)	EDTA titrimetric method	Flame photometer (jenway 500801 PFP7/C clinical flame photometer)
Magnesium (Mg)		
Sodium (Na)	Flame emission photometric method	
Potassium (K)	Flame photometric method	
Heavy metals		
Arsenic (As)	Atomic emission spectrometric method	Inductively coupled plasma-mass spectrometric instrument ICP-MS: Agilent 7500 ICP-MS, equipped with Asx-520 autosampler (England)
Cadmium (Cd) Chromium (Cr)		
Mercury (Hg)		
Lead (Pb)		
Zinc (Zn)		
Copper (Cu)		
Manganese (Mn)		
Iron (Fe)		
Cobalt (Co)		
Nickel (Ni)		
Selenium (Se)		

Table 3: Physicochemical parameters of three leachate samples collected from Tanjaro dumping during four seasons during (2021-2022).

	L1			L2			L3		
	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD
Temp	13	28.5	20.63 ± 6.45	7	21.8	14.53 ± 7.14	8	21.9	16.40 ± 6.70
pH	5.9	6.4	6.08 ± 0.24	7.3	8.6	8.01 ± 0.60	7.06	8.3	7.72 ± 0.55
EC	85328.36	297298.5	144515 ± 102466	30522.39	160716.4	77019 ± 59068	352	608	499 ± 119
TDS	57170	199190	96825 ± 68652	20450	107680	51603 ± 39575	550	950	779 ± 186
TA	23600	50000	33180 ± 12004	12900	30000	18285 ± 7893	760	15000	4359 ± 7094
TH	12400	40000	22080 ± 12335.06	5300	20000	12525 ± 6011.863	751	30000	8731.25 ± 14234
BOD_5	270.6	4554	2596 ± 1831	348	11100	3257 ± 5234	184.8	379.5	302 ± 91
COD	381.546	7331.94	4151.971 ± 2967.092	490.68	18204	5304.87 ± 8607.63	260.568	607.2	474.942 ± 161.1
BOD_5/COD		0.625221			0.61387			0.636551	
Cl^-	6920	15000	9293 ± 3859	5650	15500	10913 ± 4473	240	6500	1831 ± 3113
NO_3^-	1153	4990	2321.75 ± 1790.627	717	3589	2273 ± 1447	65.2	4871	1398 ± 2322
SO_4^{2-}	653	8673	3569 ± 3610	265	11224	5040 ± 5251	108	6887	1988 ± 3277
PO_4^{3-}	27	88	48 ± 27	18	110	59 ± 43	5	79	28 ± 35
Ca	4400	15200	8103 ± 4825	1280	7200	3785 ± 2552	172	8800	2728 ± 4069
Mg	486	2600	1250 ± 927	371	510	439 ± 70	75	1944	554 ± 927
Na	375	10000	4544 ± 4733	720	17000	6868 ± 7712	100	2500	775 ± 1153
K	304	3600	1756 ± 1566	233	5000	2121 ± 2052	8	1260	332 ± 619
Cr	0.18	1.4	0.5325 ± 0.5832881	0.16	4.88	1.62 ± 2.205826	0.01	0.02	0.0125 ± 0.005
Mn	43.1	100.25	74.0325 ± 30.47551	0.16	4.88	1.62 ± 2.205826	0.07	1.77	0.573 ± 0.81037
Ni	0.28	2.33	1.29 ± 1.127445	0.11	4.1	1.3425 ± 1.871138	0.01	0.02	0.0125 ± 0.005
Cu	0.01	0.11	0.04 ± 0.046904	0.07	0.44	0.2475 ± 0.18482	—	—	—
Fe	39.64	152.15	83.45 ± 54.08593	6.52	24.67	14.4 ± 7.657271	0.01	0.33	0.1425 ± 0.1513
Co	0.07	0.615	0.30375 ± 0.255974	0.02	0.73	0.25 ± 0.329545	—	—	—
Zn	0.44	1.69	0.9325 ± 0.54027	0.89	3.72	1.81 ± 1.328734	0.01	0.44	0.1625 ± 0.1899
As	0.01	0.1	0.0375 ± 0.04272	0.05	0.37	0.18 ± 0.136137	—	—	—
Pb	0.01	0.06	0.025 ± 0.023805	0.01	0.09	0.0375 ± 0.03594	—	—	—
Se	0	0.02	0.01 ± 0.008165	0.01	0.02	0.0125 ± 0.005	—	—	—

∗ (all concentrations are given in mg·L^{-1}, except pH), EC ($\mu S \cdot Cm^{-1}$), and Temp. (°C).

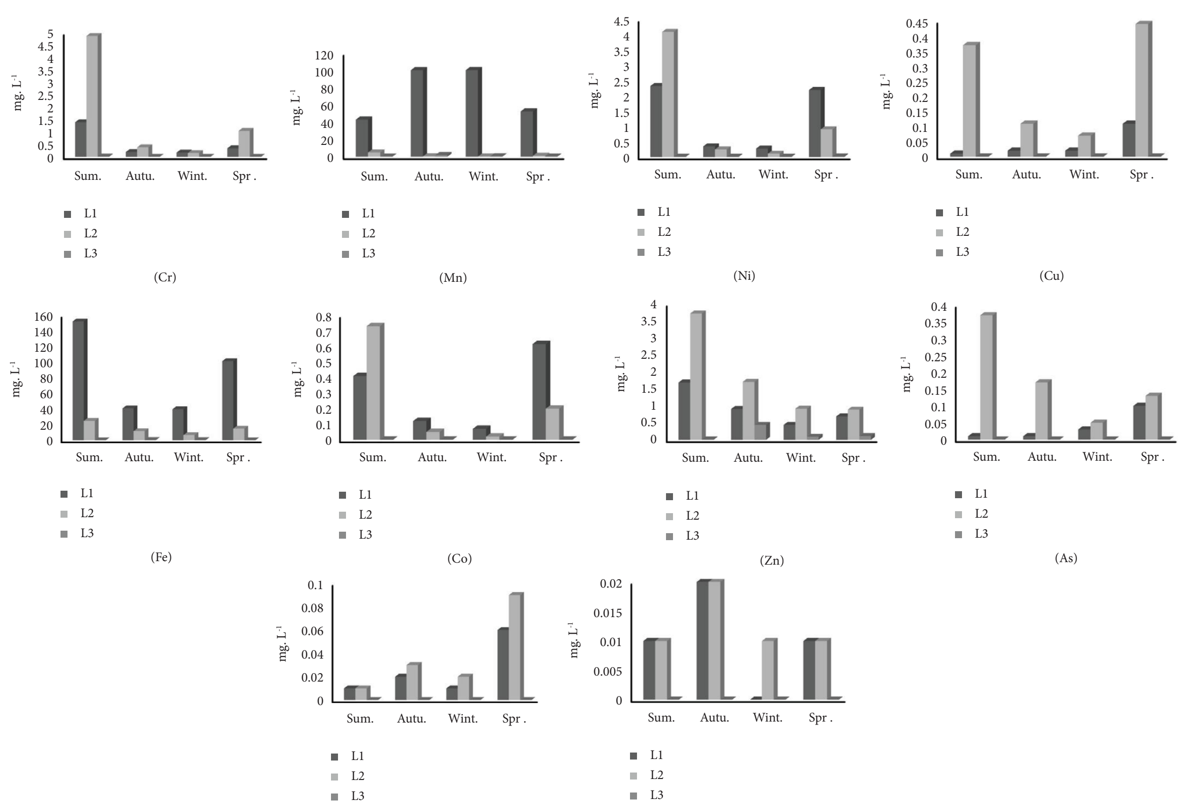

Figure 2: Heavy metals (Cr, Mn, Ni, Cu, Fe, Co, Zn, As, Pb, and Se) of three leachate samples were collected from the dumping during four seasons the year 2021-2022.

Table 4: Physicochemical parameters of three groundwater (tube well) samples surrounding the open dump area during four seasons of the year 2021-2022.

	W1			W2			W3		
	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD
Temp.	19.2	23	21 ± 1.608312	18	21	19.9 ± 1.428286	16.9	21.7	19.5 ± 2.280351
pH	7.8	8.4	8.075 ± 0.25	6.9	8.04	7.435 ± 0.467155	6.8	7.89	7.3475 ± 0.446869
EC	859.375	1078.125	943.3594 ± 95.33704	796.875	859.375	823.8281 ± 26.92386	650	687.5	674.219 ± 17.7466
TS	0	691	467.5 ± 316.8812	0	604	411.625 ± 277.2897	0	523	351.75 ± 237.5898
TDS	550	690	603.75 ± 61.01571	510	550	527.25 ± 17.23127	416	440	431.5 ± 11.35782
TSS	1	11566	2892.25 ± 5782.5	1	11452	2863.875 ± 5725.417	1	23018	5755.75 ± 11508.17
TA	36	660	274.5 ± 268.5237	42	800	332.25 ± 325.9861	32	480	241.75 ± 183.6453
TH	68	220	132.75 ± 63.46324	458	520	484.25 ± 27.28095	434	480	449.25 ± 21.28184
BOD_5	0.4	1.6	1.0675 ± 0.511949	0.51	3.7	1.7375 ± 1.507103	0.1	3	1.4925 ± 1.196422
COD	0.476	1.904	1.270325 ± 0.609219	0.6069	4.403	2.067625 ± 1.793452	0.119	3.57	1.776075 ± 1.423742
Cl^-	30	110	84.75 ± 37.64195	82	90	84.75 ± 3.774917	60	80	67 ± 8.906926
NO_3^-	5.9	51	19.6 ± 21.22436	6.3	50	24.825 ± 19.00498	7.3	52	31.575 ± 20.64273
SO_4^{2-}	92	153	125 ± 26.77063	84	110	95.5 ± 11.81807	43	84	54.75 ± 19.56826
PO_4^{3-}	0.31	0.59	0.4125 ± 0.122848	0.3	0.55	0.435 ± 0.119583	0.26	0.39	0.3325 ± 0.062915
Ca	22.4	62	46.85 ± 17.273	86	160	122.75 ± 38.13463	86	144	116.25 ± 23.81001
Mg	2.8	15	9.45 ± 5.086911	19.7	29	23.875 ± 4.73524	20	32	25.9 ± 5.592257
Na	8	110	64.75 ± 42.3271	5	67	36.25 ± 25.34265	3	67	25.75 ± 28.22971
K	0.16	2.6	1.06 ± 1.062575	0.56	10.3	3.885 ± 4.363374	0.48	10.3	3.185 ± 4.757293
Fe	0	0.06	0.0175 ± 0.028723	0	0.03	0.0125 ± 0.015	—	—	—
Zn	0	0.19	0.105 ± 0.094692	0	0.29	0.0925 ± 0.13326	0	0.12	0.0525 ± 0.057373

* (all concentrations are given in $mg \cdot L^{-1}$, except pH), EC ($\mu S \cdot Cm^{-1}$), and Temp. (°C).

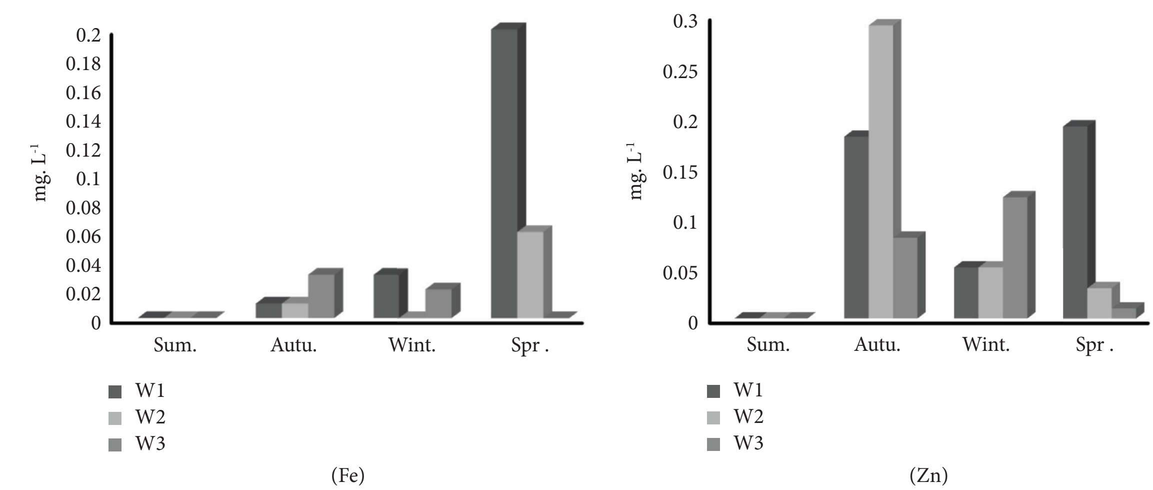

Figure 3: Heavy metals (Fe and Zn) of three groundwater (tube well) samples were collected near the dumping site during four seasons during (2021-2022).

concentrations were found in L1, L2, and L3 (33180, 18285, and 4359 $mg \cdot L^{-1}$), respectively, as a result of disintegration and liquefaction processes. Total Hardness (TH), specifically calcium and magnesium, may have contributed to the leachate samples' TH values. TH in ground water samples can be related to anthropogenic influences and mineral leaching, which are the main governing elements of the loading [18]. The total hardness was detected in high concentrations in L1, L2, and L3 (22080, 12525, and 8731.25 $mg \cdot L^{-1}$), respectively. The excessive alkalinity in leachates lends a disagreeable taste that could have an impact on human health in addition to the high value TDS, TH, and pH. Enhanced.

Biological Oxygen Demand-5-day (BOD_5), an essential physicochemical parameter, was used to detect the presence of organic maters in the leachate and groundwater samples. Higher BOD_5 values signify a high concentration of organic matter that is either decomposing or being biodegraded [19]. The BOD_5 and COD concentrations of leachate sample ranges from (184.8 to 11100) and (260.568 to 18204) $mg \cdot L^{-1}$, respectively. High values of organic matter in the wastes are indicated by the high BOD_5 and COD concentrations. The L2 was determined to have more organic matter than that of the other two leachates based on the BOD_5 and COD results [20]. The results indicate that the BOD_5/COD ratios exceeded 0.6 for all samples taken from the three dumpsites.

Table 5: Correlation matrix for different leachate parameter.

	Temp	pH	EC	TDS	TA	TH	BOD_5	COD	Cl^-	NO_3^-	SO_4^{2-}	PO_4^{3-}	Ca	Mg	Na	K	Cr	Mn	Ni	Cu	Fe	Co	Zn	As	Pb	Se
Temp																										
pH	−0.98688																									
EC	0.64902	−0.76335																								
TDS	0.65092	−0.76497	1																							
TA	0.69027	−0.79805	0.99846	0.99859																						
TH	0.83419	−0.91229	0.96095	0.96164	0.97484																					
BOD_5	0.004184	−0.1656	0.76348	0.76186	0.72643	0.55496																				
COD	−0.011701	−0.14992	0.75312	0.75147	0.71542	0.54168	0.99987																			
Cl^-	0.050832	−0.21143	0.79278	0.79125	0.7577	0.59317	0.99891	0.99804																		
NO_3^-	0.26288	−0.41522	0.90463	0.90356	0.87956	0.75137	0.96592	0.96169	0.97694																	
SO_4^{2-}	−0.28018	0.12149	0.54846	0.54636	0.50117	0.29566	0.95877	0.96316	0.94446	0.85253																
PO_4^{3-}	−0.13721	−0.024536	0.66452	0.66265	0.62199	0.4318	0.98996	0.99208	0.98229	0.91963	0.98931															
Ca	0.88167	−0.94629	0.93121	0.93212	0.95001	0.99571	0.47556	0.46153	0.51608	0.68705	0.20595	0.34644														
Mg	0.98512	−0.99994	0.77011	0.77171	0.80435	0.91656	0.17598	0.16032	0.22172	0.42478	−0.111	0.035064	0.94964													
Na	−0.16785	0.0064654	0.64104	0.63911	0.59742	0.40363	0.9851	0.98771	0.97601	0.90702	0.99336	0.99952	0.31719	0.004068												
K	0.024726	−0.18583	0.77659	0.77501	0.7404	0.57193	0.99979	0.99934	0.99966	0.97103	0.95273	0.98685	0.49353	0.19617	0.98136											
Cr	−0.48452	0.3369	0.35105	0.3487	0.2985	0.07824	0.87275	0.88039	0.84902	0.71665	0.9755	0.93299	−0.01439	−0.32696	0.9437	0.86254										
Mn	0.95012	−0.98801	0.85392	0.85522	0.88151	0.96458	0.31586	0.30075	0.35978	0.55068	0.03319	0.17857	0.98486	0.98958	0.14798	0.33528	−0.18752									
Ni	0.18296	−0.33931	0.86668	0.86542	0.83763	0.69479	0.98388	0.98091	0.99115	0.99664	0.89248	0.94872	0.62522	0.3492	0.93846	0.98734	0.77137	0.48046								
Cu	−0.62664	0.49257	0.18618	0.18371	0.13132	−0.093	0.77668	0.78659	0.74645	0.58717	0.92367	0.85792	−0.18475	−0.48338	0.87344	0.76358	0.98534	−0.35232	0.6515							
Fe	0.9208	−0.9717	0.89435	0.89546	0.91781	0.98322	0.39388	0.37923	0.43634	0.61837	0.11643	0.26	0.99589	0.97413	0.22994	0.41268	−0.10495	0.99652	0.55192	−0.27305						
Co	0.37595	−0.52065	0.94896	0.94817	0.92998	0.82463	0.9282	0.92218	0.94455	0.99288	0.78419	0.86629	0.76872	0.52961	0.85039	0.93565	0.62845	0.6462	0.97978	0.48655	0.7076					
Zn	−0.33574	0.17923	0.49871	0.49653	0.44979	0.23939	0.94054	0.94582	0.92367	0.82057	0.99829	0.97911	0.14847	−0.16886	0.98494	0.93336	0.98668	−0.02522	0.86462	0.94446	0.058242	0.74663				
As	−0.58882	0.45058	0.23275	0.23031	0.17837	−0.0455	0.80579	0.8151	0.77729	0.62505	0.94087	0.88141	−0.13774	−0.44115	0.89563	0.79346	0.99235	−0.30736	0.68689	0.99887	−0.22693	0.5276	0.95904			
Pb	−0.11436	−0.047555	0.68155	0.67972	0.63986	0.45246	0.99295	0.99471	0.98634	0.92844	0.98569	0.99973	0.36795	0.058073	0.99854	0.99031	0.92445	0.20118	0.95575	0.84586	0.28217	0.87756	0.97417	0.8703		
Se	0.02873	−0.18976	0.7791	0.77753	0.74308	0.57521	0.9997	0.99918	0.99976	0.97198	0.9515	0.98619	0.49701	0.20009	0.98058	0.99999	0.8605	0.33905	0.98797	0.76099	0.41633	0.93706	0.93192	0.79102	0.98974	

Table 6: Correlation matrix for different well parameters.

	Temp	pH	EC	TDS	TA	TH	BOD_5	COD	Cl^-	NO_3^-	SO_4^{2-}	PO_4^{3-}	Ca	Mg	Na	K	Fe	Zn
Temp																		
pH	0.98876																	
EC	0.94681	0.88807																
TDS	0.94681	0.88807	1															
TA	0.10208	−0.04776	0.41676	0.41676														
TH	−0.93906	−0.97989	−0.77849	−0.77849	0.24611													
BOD_5	−0.80795	−0.88695	−0.57536	−0.57536	0.5037	0.96127												
COD	−0.80795	−0.88695	−0.57536	−0.57536	0.5037	0.96127	1											
Cl^-	0.70613	0.59235	0.89642	0.89642	0.77647	−0.41968	−0.15328	−0.15328										
NO_3^-	−0.94389	−0.88392	−0.99996	−0.99996	−0.42488	0.77284	0.56801	0.56801	−0.90036									
SO_4^{2-}	0.93752	0.87497	0.99961	0.99961	0.44183	−0.76077	−0.55244	−0.55244	0.90838	−0.99982								
PO_4^{3-}	0.54269	0.41104	0.7841	0.7841	0.89094	−0.22088	0.056468	0.056468	0.97795	−0.78963	0.80103							
Ca	−0.9435	−0.98244	−0.78669	−0.78669	0.23332	0.99991	0.95756	0.95756	−0.4316	0.78113	−0.76925	−0.23371						
Mg	−0.98917	−1	−0.88933	−0.88933	0.045027	0.97934	0.88568	0.88568	−0.59456	0.8852	−0.87629	−0.41354	0.98192					
Na	1	0.98835	0.9477	0.9477	0.10483	−0.9381	−0.80632	−0.80632	0.70808	−0.9448	0.93847	0.54501	−0.94258	−0.98876				
K	−0.87728	−0.93917	−0.67617	−0.67617	0.38791	0.98882	0.99163	0.99163	−0.27961	0.66955	−0.65546	−0.07295	0.98676	0.93823	−0.87595			
Fe	0.9865	0.9999	0.88134	0.88134	−0.06219	−0.98267	−0.89353	−0.89353	0.58065	−0.87707	0.86789	0.39783	−0.98503	−0.99985	0.98605	−0.94404		
Zn	0.84892	0.76038	0.97384	0.97384	0.61242	−0.6155	−0.37445	−0.37445	0.97368	−0.97584	0.97977	0.90462	−0.62583	−0.76216	0.85038	−0.49107	0.75092	

The higher value shows that the young leachate has more organic fractions that can break down into biodegradable compounds (majority of organic compound is biodegradable). Old leachate is more resistant to degradation than young leachate primarily because it contains humic and fulvic acids [21].

The values of the anions (Cl^-, NO_3^-, SO_4^{2-}, and PO_4^{3-}) and cations (Ca, Mg, Na, and K) are shown in Table 3. It is clear that the concentrations of cations and anions vary during the wet and dry seasons. Regarding the anions, the high amount of chloride contents of L1, L2, and L3 were (9292.5, 10912.5, and 1830.5) are due to mixing of domestic waste. Kitchen waste from homes, hotels, and restaurants are potential anthropogenic sources of chloride. Higher nitrate and sulfate concentrations in L1, L2, and L3 were (2321.75, 2272.75, and 1397.8) and (3569, 5040, and 1988.25), correspondingly, and these amounts are mostly attributable to domestic wastes [7, 22]. A mature stage of the dumping site is also indicated by the increased phosphate values in L1, L2, and L3 (48.225, 59.25, and 28.1), respectively [23]. Domestic wastes are regarded as the most probable sources for leachate cations. Due to the increased evaporation impact in a semiarid climate, the concentrations of all cations-Ca, Mg, Na, and K-show greater values (8103, 3785, 1249.75, 438.75, 4543.75, and 1756, 2120.75, and 331.7, respectively [24].

The mean concentrations of Cr, Mn, Ni, Cu, Fe, Co, Zn, As, Pb, and Se for L1, L2, and L3 were summarized in (Table 3 and Figure 2). There was a high concentration of Mn ($74.0325\,mg{\cdot}L^{-1}$) and Fe ($83.45\,mg{\cdot}L^{-1}$) detected in L1 samples of the study area. The L3 exhibited that Cu, Co, As, Pb, and Se were not detectable, also represented relatively high concentrations of Cr ($0.0125\,mg{\cdot}L^{-1}$), Mn ($0.573\,mg{\cdot}L^{-1}$), Ni ($0.0125\,mg{\cdot}L^{-1}$), Fe ($0.1425\,mg{\cdot}L^{-1}$), and Zn ($0.1625\,mg{\cdot}L^{-1}$). Relatively high concentrations of Cr, Mn, Ni, Cu, Fe, Co, Zn, As, Pb, and Se were detected in the L2. Similar outcomes were discovered by De et al. [25]. While the three leachates showed that Cd and Hg were not detectable.

3.2. Groundwater (Tube Wells). Groundwater quality (tube well) seasonal variations have been well investigated, the mean values of physicochemical parameters of well samples as well as their seasonal variation are summarized in (Table 4).

Table 4 displays the seasonal average temperature distribution, the highest temperature ever recorded was 23°C in the summer, and the lowest temperature ever registered was 16.9°C in the winter. These values gradually increase starting in January and take on a summer aspect by July and August. The latitude and topographic heights, according to (Lee and Hahn) [26], play a significant effect in the temperature distribution, but there are also occasional values that cannot be described by the abovementioned simple criteria. In this instance, local man-made factors including groundwater pumping, surface vegetation, land use, and host rock geology could be potential drivers for the variations of temperature value. According to Table 4's analysis of the tube well pH values, W1, W2, and W3's respective mean pH values were (8.075, 7.435, and 7.3475). This table makes it clear that the pH fluctuated from 6.9 to 8.4, which is ideal for bacteria that produce methane. Similar outcomes were discovered by Visvanathan et al. [27], who discovered that ground water (tube well) samples had a slightly high pH and stayed in the range of 7.0–8.0 throughout the operations, indicating the brief acidic phase and early methanogenic phase. The analysis revealed that the conductivity (EC) of the three monitored wells under investigation (W1, W2, and W3) recorded high values with means of (943.3594, 823.8281, and 674.2188) $\mu S{\cdot}cm^{-1}$ and a maximum value of 1078.125 $\mu S{\cdot}cm^{-1}$ detected in one of them.

Each of the three water samples (W1, W2, and W3) had a total dissolved solid (TDS) value of (603.75, 527.25, and 431.5) $mg{\cdot}L^{-1}$, respectively. Total dissolved solids concentrations in groundwater may increase as a result of improperly lined landfills. The mean BOD and COD values of the three monitoring wells (W1, W2, and W3), as shown in (Table 4), were determined to be (4.27, 6.95, and 5.97) $mg{\cdot}L^{-1}$ and (1.270325, 2.067625, and 1.776075) $mg{\cdot}L^{-1}$, respectively, in groundwater, which contains little to no organic matter. This proves that the groundwater around the site is not contaminated with organic material due to leachate. Hassan and Ramadan [28], has also been found this after evaluating the effects of the same sanitary leachate on groundwater and found that there was no organic contamination of piezometer wells near the landfill's active cells.

Table 4 illustrates that for the three monitoring wells, the mean values of the chloride content (84.75, 84.75, and 67) $mg{\cdot}L^{-1}$, sulfates concentrations (125, 95.5, and 54.75) $mg{\cdot}L^{-1}$, nitrate concentrations (19.6, 24.825, and 31.575) $mg{\cdot}L^{-1}$ are also noted. According to WHO, the acceptable values are (250, 250, and 50) $mg{\cdot}L^{-1}$ for chloride, sulfate, and nitrate, respectively. These recorded levels of chloride, sulfate, and nitrate in the three monitoring wells are suitable for drinking [29]. The concentrations of phosphate ions detected in the three wells were (0.4125, 0.435, and 0.3325) $mg{\cdot}L^{-1}$, phosphate concentrations remained unaffected and suitable for drinking.

Acceptable concentrations (mean value) according to the WHO [29] of cations in groundwater (tube well), surrounding the open dumpsite recorded (Table 4), were represented by calcium (46.85, 122.75, and 116.25) $mg{\cdot}L^{-1}$, magnesium (9.45, 23.875, and 25.9) $mg{\cdot}L^{-1}$, sodium (64.75, 36.25, and 25.75) $mg{\cdot}L^{-1}$, and potassium (1.06, 3.885, and 3.185) $mg{\cdot}L^{-1}$, for the W1, W2, and W3, respectively. The reason behind these acceptable values because of the soil's permeability and antiseepage system.

Heavy metal pollution of the groundwater was examined (Cr, Mn, Ni, Cu, Fe, Co, Zn, As, Pb, Se, Cd, and Hg). All the heavy metals were discovered to be absent during the summer for all three of the monitored tube wells, and most of them were absent during the other seasons of the year, with the exception of Fe and Zn. The antiseepage system and the permeability of the soil are the causes of this phenomenon. Therefore, if the antiseepage system was compromised, the soil's permeability and unsaturated zone made it more likely for pollutants to infiltrate the groundwater, the leachate might contaminate the groundwater [30], and the chances of contaminant of the groundwater by heavy metals is by mixing with rain water in the rainy season [31]. The mean concentrations of Fe and Zn W1, W2, and W3 were summarized in (Table 4 and Figure 3). The concentration of Fe (0.028723, 0.0125, and 0.00) $mg \cdot L^{-1}$ and Zn (0.105, 0.13326, and 0.057373) $mg \cdot L^{-1}$ were detected in the three tube-well samples of the study area, while the other heavy metals were not detected. These values are acceptable for drinking-water compared with the standard of WHO, in which the upper limit of iron presence in drinking water is ($0.3\ mg \cdot L^{-1}$) and zinc is ($3\ mg \cdot L^{-1}$).

3.3. Statistical Correlations. A preliminary descriptive method to determine the degree of relationship between the variables involved is correlation analysis. The correlation matrixes of the physicochemical properties and heavy metals of the leachate and groundwater (tube well) samples are presented in (Tables 5 and 6). It was found that some parameters had statistically significant correlations with one another, indicating a close relationship between these parameters. Due to the combined effects of spatial and temporal fluctuations, the correlation coefficients (r) should be taken with care. However, it is simple to infer certain correlations. For the leachate's samples (Table 5), BOD_5 had a positive correlation with each of (COD, Cl^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, Na, K, Cr, Ni, Cu, Co, Zn, As, Pb, and Se) with positive correlations of ($r > 0.9$). Also, for groundwater (tube well) samples, since little to no organic matter was found in the groundwater, as revealed by the analysis, BOD_5 and COD had a positive connection, at the same time BOD_5 had a positive correlation with each of (NO_3^-, SO_4^{2-}, Ca, Mg, Na, K, and Fe) (Table 6). Temperature and (TH, Ca, Mg, Mn, and Fe) also showed a good correlation (r) value of (0.83419, 0.88167, 0.98512, 0.95012, and 0.9208), respectively, and moderately correlations with (EC, TDS, and TA) with (r) value of (0.64902, 0.65092, and 0.69027), as shown in (Table 5). The statistical correlation matrix for the three wells (Table 6) represented that the temperature and (SO_4^{2-}, Cl^-, Na, Fe, and Zn) also showed a good correlations (r) value of (0.93752, 0.70613, 1.00, 0.9865, and 00.84892), respectively, also the temperature had a negative correlation with TH ($r = -0.93906$), NO_3^- ($r = -0.94389$), Ca ($r = -0.9435$), Mg ($r = -0.98917$), and K ($r = -0.87728$). The high association between the pH of the leachate and the concentration of heavy metals is indicated by the negative correlation of pH with Mn, Fe, with r value (−0.98801 and −0.9717), respectively, and the slightly weaker negative correlation with Co ($r = -0.52065$). Reduced pH increases the solubility of several metals. Metals that form cations become more mobile as pH is lowered, in contrast to elements that produce anions and complexes, whose solubility decreases as pH is lowered [32]. Same thing repeated for the correlation matrix for the pH of the tube well and its association with and the concentration of (Fe and Zn), it is indicated by the good correlation of pH with Fe ($r = 0.9999$), and moderate correlated with Zn ($r = 0.76038$). Good correlations were found between Cr, Cu, Zn, As, and Pb ($r > 0.9$), whereas moderate correlations were found between Cr and Ni ($r = 0.77137$), Co ($r = 0.62845$), and Se ($r = 0.86050$). The simultaneous accumulation of Cr, Cu, Zn, As, and Pb is a common occurrence at smelting sites and is caused by the elements' or compounds' shared chemical environment or absorptive pathways [33].

All the parameters in Table 5 exhibit high correlations, and some of the parameters in Table 6 also exhibit high correlations. The three Tanjaro dumpsites' waste compositions appear to be comparable based on the significant connection between the leachate parameters in all three leachates. A preliminary indication that the particle size of waste, degree of compaction of waste, hydrology of the dumpsites, moisture content, and accessible oxygen in the Tanjaro dumpsite are also similar is provided by the significant connection between the leachate parameters in the Tanjaro dumpsites. Similar results indicating a substantial association was shown by leachate parameters from the dumpsites were shown by (Salami and Susu) [34]. The leachate characteristics of the Tanjaro dumpsites show a strong association, which suggests that the existing approach of mixing garbage in the dumpsite is ineffective. Wastes from the domestic, municipal, medical, hazardous, and industrial sectors should be separated into their own categories.

4. Conclusion

In this study, the main environmental issue is the physicochemical characterization and evaluation of seasonal variations of leachate of Tanjaro open dumpsite of Sulaymaniyah city, and its effect on the groundwater quality. High levels of organic and inorganic compounds, as well as their toxicity due to the presence of heavy metal concentrations, were the main characteristics of the leachates. The leachate from the Tanjaro dumping area has extraordinarily high values for nearly all the physicochemical parameters. All heavy metals, with the exception of cadmium and mercury, were found in leachate at concentrations below their respective acceptable limits. The characterization showed that the age of L1 can be referred to young, but the pH value of both L2 and L3 were referred to old leachate. According to the study's findings, the Tanjaro dumpsites are currently functioning and in the initial stabilization process. The leachate had a high degree of anaerobic phase biodegradability (BOD_5/COD is about 0.63) and was highly biodegradable. Monitoring wells near the dumpsites showed that the groundwater was not severely contaminated, due to time required for migrations of H.M through soil profile till reaching groundwater which contains little to no organic matter. Whereas some parameters exceeded the WHO standards, in which the (conductivity, total dissolved solids, total hardness, Zn, and Fe) were some of these characteristics.

4.1. Recommendations. Tanjaro dump area is an unengineered landfill. When considering remediation measures, the landfill site should be taken into account. Since it takes approximately 500 years for plastic bags and polythene to completely degrade, they should be strictly separated before MSW is dumped [35]. Composting and anaerobic digestion are the preferred methods for processing biodegradable trash, with landfilling only being used for nonbiodegradable, inert, or garbage that cannot be recycled. Industrial and biomedical wastes must not be combined with MSW. Municipalities must upgrade their MSW storage facilities to protect residents who live close to open dump area, which lead to unclean and unhealthy conditions in the neighborhood. After closure, parks may be built on a landfill [31]. The findings of the current study therefore call for the Sulaymaniyah Municipality Directorate to implement adequate solid waste management in Tanjaro open dump area as a long-term policy, and the groundwater in and surrounding Tanjaro's open dumpsite has to be continuously monitored.

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Supplementary Materials

Table S1: the physicochemical parameter values of leachate and ground water (tube well) samples as well as their seasonal variation. (*Supplementary Materials*)

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