

Sustainable assessment of the solid waste landfill sites environs.

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ABSTRACT

Karachi is the largest metropolitan city of Pakistan, with 10 % of the country's total population, generating more than 18000 tons of solid waste per day. The study's main purpose is to assess the environmental impact of landfill site activities in the study area. The effect of the solid waste activities in the area was considered on climate conditions and the city's waste management situation. The potential impact was identified through literature review, professional judgment, and field observation at selected landfill sites. The Study area was selected within a 1-kilometer radius from the center of each landfill site. Thirty soil samples were collected from 10 centimeters beneath the surface, 30 groundwater samples were collected from both shallow and deep wells at a depth range of 30-200 meters through hand pump or electrically pumped well, and 04 leachate samples were collected from the leachate ponds from each landfill site. To determine the air quality of the studied areas, 8 hours' average samples were done. All the samples were collected under pre pre-inscribed protocol of United States Environmental Protection Agency guidelines. The results showed that the Carbon monoxide level in the air is higher according to prescribed limits. Gondpass is a highly populated landfill site, while Dhabeji is much better. Landfill sites' ground water is alkaline. The ground water quality of Jamchakro and Gondpass is unsuitable for domestic and agricultural use. In contrast, the ground water quality of the developing landfill site in Dhabeji is much better and within acceptable limits. Based on a 2.59 percent population growth rate, future solid waste generation is expected to be 26845.89 tons per day by 2035. Adopting eco-friendly approaches such as waste-to-energy is the greatest way to manage and utilize waste.

KEYWORDS: Air Quality; Ground water; Karachi landfill sites; National environmental quality standards; Solid waste.

INTRODUCTION

Pakistan, a lower-middle-income country, is plagued by serious environmental and public health issues (Hashmi et al., 2020; Aziz et al., 2020). Owing to an insufficiency of effective waste management policies and infrastructure (Korai et al., 2017), there is a corresponding rise in public concerns regarding uncontrolled and open waste dumping time (Korai et al., 2017; Korai, 2019). Massive piles of solid waste are typical in Karachi's urban areas (Sohoo, 2022). Approximately 24 million people, 10% of the country's population, live in Karachi, the largest metropolitan city in Pakistan (Government of Pakistan, 2017). Pakistan's industrial hub, the second-largest Islamic town in the world (Aleluia et al., 2016; Idrees et al., 2023), and a hub of an alarming amount of municipal solid waste (MSW) is Karachi. The rate of solid waste production is more than 18,000 tons per day, which has always been increasing with rapid city population growth (Siddiqui et al., 2022). In fact, the MSW generation rate has escalated thrice in the last two decades, from 6,000 tons per day in 2001 to approximately 11,319 tons per day in 2017 (Shahid et al., 2022).

Karachi is the industrial hub of Pakistan, with a population of approximately 24 million and the second-largest Islamic city in the world (Aleluia et al., 2016; Idrees et al., 2023). Every day, Karachi generates over 18,000 tons of waste (Siddiqui et al., 2022; Kausar et al., 2024). Of this, 60% is dumped at the landfill sites, and the rest 40% remains on the streets and is not properly collected (Shahid et al., 2022). In Karachi city, where population load is much more than expected. 44% of the population lack access to safe drinking water, and the conditions are much more severe in urban areas of the city (Irfan et al., 2018; Mahmood, 2018). According to the census 2017 population growth rate for Karachi city is 2.59% (Government of Pakistan, 2017). Due to the rapid growth of the population, municipal solid waste has become a serious problem that can be rated as a threat to a safer environment and public health. Some of the waste materials prove to become externally toxic and potentially infectious. (Marshall and Farahbakhsh, 2013; Angaye, 2018; Voukkali et al., 2024). With its rapid urbanization, high population density, and underdeveloped waste management system, Karachi's landfills, particularly Jam Chakro, Gond Pass, and the developing Dhabeji site, are highly stressed. Landfill operations have already reached these sites close to its capacity and have given rise to a pressing concern among urban planners, environmentalists, as well as public health officials for the environmental impact of landfill operations (air pollution, groundwater contamination) ranging from Korai et al. (2017), to Siddiqui et al. (2022).

Additionally, the environmental impacts of increasing waste generation in Karachi as a result of growing waste generated warrant immediate focus on sustainable waste management solutions.

This study is conducted by considering the situation of Karachi, the country's most populous city and economic heart, as a case study. This study provides insightful information regarding the city's climate and waste management situation. Karachi has six districts and seven cantonment zones. The Sindh Solid Waste Management Board (SSWMB) and the District Municipal Committee are the main authorities responsible

for solid waste management. The city's waste disposal is divided into three phases (Jamal Rashid, 2019). Front-end collection (FEC) includes garbage collection from "muhalla," Union Councils' "kachra undies," dust bins, and other locations (Javed and Lukumwena, 2023). Garbage transfer stations (GTSs) are large grounds that dump garbage collected from front-end collection points (FECs). The GTS should be a facility to sort recyclables dumped on the land. Landfill sites: Fig. 01 illustrates only two official landfills, Gond Pass and Jam Chakra, and a newly established site called Dhabeji.

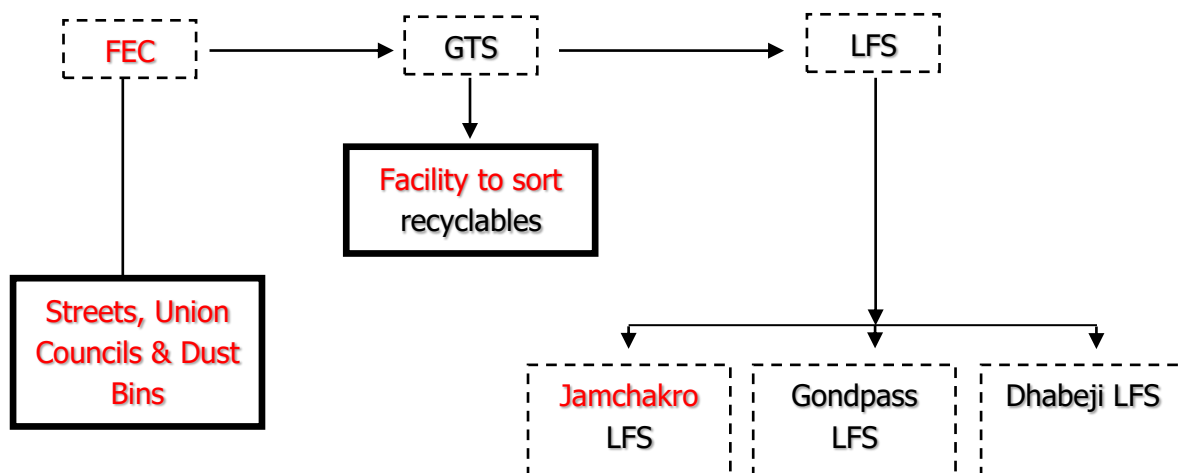


Fig 01: Schematic diagram of a solid waste network of Karachi.

According to the detailed meeting with Sindh solid waste management officials' details of Karachi landfill sites, garbage transfer stations and waste generation data over the previous 12 years are shown in Tables 01 & 02.

Table 01: Details about Landfill sites of Karachi city.

S.no	Name of Landfill Site	Coordinates	Area in Acre	Waste received per day (tons)	Status
1	Jam Chakro	N 25° 01. 675' E 67° 01. 61'	500	8000	The official site was recently privatised. Approximately 250 families of waste pickers live near the site.
2	Gond Pass	N= 25° 00.634' E= 66° 55.263'	500	3000	The official site may reach capacity and close shortly
3	Dhabeji	N = 24°48.804' E = 67°30.567'	3500	Under Construction	Official site. It will shortly become a true working landfill to handle the waste of Karachi city (approx. 150 years' worth of garbage)

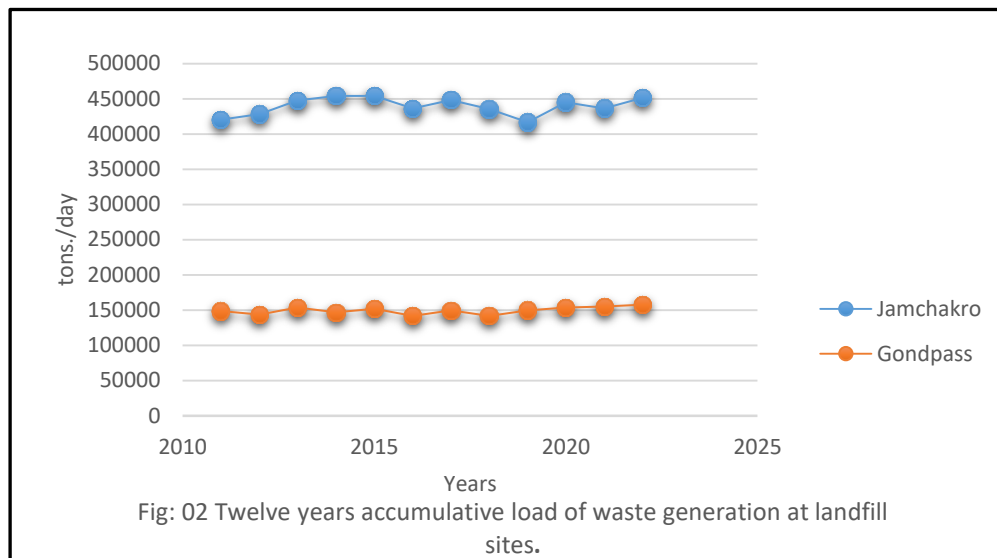
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The current study aims to provide an environmental assessment and waste dumping situation of landfill sites in Karachi city, Sindh, Pakistan. In 2023, a detailed survey was conducted at landfill sites to evaluate the groundwater and air quality of the adjacent area.

MATERIALS AND METHODS

Study area

Karachi is the capital and metropolitan city of Sindh, Pakistan. The main official landfill sites are Jam Chakro and Gondpass near Surjani and Hub River Road. The Dhabeji landfill is under construction near Thatta City.

Sample collection

The study area was selected within a 1 km radius from the center of all landfill sites to collect the samples. A total of 62 samples were collected. Soil samples $n=30$ were collected from 10 cm beneath the surface, groundwater samples $n=30$ were collected from both shallow and deep wells at a depth range of 30-200 meters through hand pump or electrically pumped well, and leachate sample $n=04$ was collected from the leachate ponds from each landfill site. To determine the air quality of the studied areas, 08 eight-hour average sampling was done by the Air quality monitor system model Air pointer (AQM-006). All the samples were collected under the pre-inscribed protocol of the United States Environmental Protection Agency USEPA guidelines.

Sample analysis

The quality of analytical data was ensured through careful standardisation, repeated analysis, and procedural measurements. All samples were analysed using the methods described by the American Standard of Testing Materials (ASTM), the American Public Health Association (APHA), and the Environmental Protection Agency (EPA), as shown in Table 02.

Table 02: Details of methods and instruments used

S#	Parameters	Methods	Instrument Used
1.	pH	ASTM D1293	Peak Instrument (S-610L)
2.	Electrical Conductivity	ASTM D1125	BANTA Instrument (DDS11AW)
3.	TDS	APHA 2540 C	Drying Oven Leaidal England (DNO9020), Water Bath CHINA (HH-S), Analytical Balance (FA 2204)
4.	Turbidity	USEPA Method 180.1	Turbidity Meter China (ZD-2A)
5.	Total Hardness as CaCO ₃	APHA-2340 C	Titrimetric Analysis
6.	Ca Hardness	APHA 3500-Ca D	Titrimetric Analysis
7.	Mg	By Calculation (from Total Hardness)	Titrimetric Analysis
8.	Chloride	ASTM -D512	Titrimetric Analysis
9.	Dissolve Oxygen	DO Meter	DO Analyzer (DO9100)
10.	Salinity	V-cone Separator	Gravimetric
11.	Sodium	Flame Photometer, Lab R&A	Flame Photometer China (FP-640)
12.	Potassium	Flame Photometer, Lab R&A	Flame Photometer China (FP-640)
13.	Lead	APHA 3500	Genesis UV-VIS
14.	Cadmium	HACH 8017	Thermoscientific (2L9P153003)
15.	Chromium	HACH 8024	HACH DR 2500 Spectrophotometer
16.	Copper	HACH 8506	HACH DR 2500 Spectrophotometer
17.	Nickel	HACH 8150	HACH DR 2500 Spectrophotometer
18.	Zinc	ASTM 3500-Zn B	Thermo scientific (2L9P153003)
19.	Air Quality Parameters	ASTM Methods	Air Quality Monitor System - Air Pointer (AQM-006)

RESULTS AND DISCUSSIONS

Air Quality of landfill sites of Karachi

Air quality is the main factor for public health. It is a crucial issue for a city with a possible health concern. In Table. 03 results indicated that landfill sites' carbon monoxide (CO) concentration exceeded the NEQS and SEQS defined limits. The Gondpass is a highly polluted landfill site with a concentration of CO 12.8-18.7 ppm, and particulate matter (PM₁₀) is 315-332 ppm, while the Jam chakro value of PM₁₀ is 322-355 ppm. The air quality of the Dhabeji landfill site is much better, with PM₁₀ 90-180 ppm.

Table 03: Air quality of studied landfill sites all results in ($\mu\text{g}/\text{m}^3$)

S#	Parameters	Jam Chakro lfs	Gond pass lfs	Dhabeji lfs	SEQS limits
1	Nitrous Oxide (NO)	35	40	9.35	40
2	Nitrogen dioxide (NO ₂)	85	90	0.13	80
3	Carbon monoxide (CO)	15.63	15.43	13.03	05
4	Sulfur dioxide (SO ₂)	135	145	1.45	120
5	Particulate Matter - PM ₁₀	318	256	184	150
6	Particulate Matter - PM _{2.5}	123	88	82	75

Sindh Environmental Quality Standard SEQS, the Sindh Govt. Gazette, Part – 1 Ext. Jan. 28, 2017, for Ambient Air

According to table (3) the levels of Nitrous Oxide (NO) was found in the permissible limit of Sindh Environmental Quality Standard (SEQS) at Jam Chakro (35 $\mu\text{g}/\text{m}^3$), Gond pass (40 $\mu\text{g}/\text{m}^3$) but to a lesser extent at Dhabeji (9.35 $\mu\text{g}/\text{m}^3$) which shows that it looks as if Dhabeji in this aspect may have an air quality better than at this moment. However, Jam Chakro (85 $\mu\text{g}/\text{m}^3$) and Gond Pass (90 $\mu\text{g}/\text{m}^3$) both exceed the SEQS limit of 80 $\mu\text{g}/\text{m}^3$ for Nitrogen Dioxide (NO₂), indicating that these areas are more polluted with nitrogen oxides, which are bad and cause respiratory problems.

Compared to Dhabeji, an area with a concentration of 0.13 $\mu\text{g}/\text{m}^3$, Dhabeji is much cleaner in this respect currently. All three landfill sites have levels of Carbon Monoxide (CO) which are quite above the SEQS limit of 5 $\mu\text{g}/\text{m}^3$ as they have 3 times higher levels of CO than the limit, which means that these sites must be highly air polluted and thus result in severe health risk of headaches, dizziness and cognitive impairment. However, even though Dhabeji is still overshooting the SEQS limit of 13.03 $\mu\text{g}/\text{m}^3$, it fares a bit better but continues to be a concern. Sulfur Dioxide (SO₂) concentrations at Jam Chakro (135 $\mu\text{g}/\text{m}^3$) and Gond Pass (145 $\mu\text{g}/\text{m}^3$) also exceed the SEQS limit of 120 $\mu\text{g}/\text{m}^3$, which can worsen respiratory diseases caused due to industrial activities or emissions from wastes. However, the levels at Dhabeji (1.45 $\mu\text{g}/\text{m}^3$) are still a long way below the levels detected at the older sites, indicating that the environmental impact at the developing site is now slightly less than at the older sites.

Jam Chakro and Gond Pass have higher levels of detrimental pollutants than Dhabeji, indicating that air quality issues compromise the older sites more. Addressing waste management practices and limiting harmful landfills at these sites, particularly for

CO and NO₂ levels, is imperative to ensure immediate public health. Physicochemical characterisation of water, soil and leachate samples. The illegal Dumping of mixed refuse endangers surface and groundwater (Ziraba, 2016). The deposited solid waste progressively releases its initial interstitial water, known as leachate, which contains various organic and inorganic compounds and is a severe danger to groundwater resources. Karachi's official landfill sites are quite old, and the Gond Pass landfill site may reach capacity and close shortly. Unfortunately, landfill site personals openly deposited waste at landfill sites without regard for health and safety precautions (Gautam and Agrawal, 2021; Siddiqua et al., 2022). Table. 04, 05 & 06 show the investigated areas' groundwater, leachate and soil quality. The mean pH value of the Jamchakro and Gondpass leachate samples was 7.83 & 7.81, respectively, which refers to a mature landfill leachate based on the study of Zuberi and Ali (2015) and Senthamil and Palanivel (2016). Notably, groundwater may become more alkaline due to landfill leachate, which may help form trihalomethane (THM), which is hazardous (Kumar and Alappat, 2005). The dissolved oxygen content in both landfill leachate samples was very low, indicating a possible correlation with EC. This finding also showed significant inorganic components (Naveen et al., 2017). Both landfill leachates have extremely high salinity levels, which may have an impact on the salinity of groundwater. All leachate samples were found to have total hardness levels beyond the Sindh government. Gazette, 2016 allowable limits. The pH values of all landfill sites' groundwater are alkaline. The total dissolved solids (TDS) levels at Gond Pass and Jam Chakro exceed the allowable limits. The Gond pass landfill site has phenomenologically high total dissolved solids, 1422 to 1509 ppm. Leachate is gradually affecting the groundwater channel at the Jam Chakro and Gond Pass landfill sites. As a result, the groundwater at both landfill sites is unsuitable for domestic and agricultural use. However, the groundwater quality in the under-developed landfill site in Dhabeji is much better and within acceptable levels.

Table 04: Analysis of Jam chakra, Gondpass and Dhabeji lfs groundwater samples

Sample id	pH (ms/cm)	EC NTU	Turbidity (mg/l)	TDS (mg/l)	TH (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Salinity (mg/l)	Cl (mg/l)	DO (mg/l)
JC-GW-1	7.06	4.0	0.74	2560	947.2	286.5	66.41	342.3	20.5	1.89	998.4	1.26
JC-GW-2	7.27	2.2	0.37	1106	409.2	123.8	28.69	147.9	8.8	1.05	431.3	2.32
JC-GW-3	7.35	3.6	0.62	2360	873.2	264.1	61.22	315.5	18.9	1.7	920.4	2.3
JC-GW-4	7.29	4.4	0.69	2816	1041.9	315.1	73.05	376.5	22.5	2.08	1098.2	1.2
JC-GW-5	7.39	1.8	0.28	1152	426.2	128.9	29.88	154.0	9.2	0.85	449.3	4.36
JC-	7.4	2.8	0.12	1798	665.	201.	46.6	240.	14.4	1.41	701.	2.8

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GW-6		1		.6	5	3	6	5			5	
JC-	7.05	3.4	0.65	2196	812.	245.	56.9	293.	17.6	1.62	856.	2.3
GW-7		3			5	8	6	6			4	
JC-	7.25	1.9	0.11	1216	449.	136.	31.5	162.	9.7	0.9	474.	3.3
GW-8					9	1	4	6			2	
JC-	7.4	2.2	0.21	1446	535.	161.	37.5	193.	11.6	1.19	564.	2.36
GW-9		6		.4	2	9	2	4			1	
JC-	7.33	2.5	0.13	1612	596.	180.	41.8	215.	12.9	1.07	629.	2.36
GW-10		2		.8	7	5	4	6			0	
GP-	7.72	5.1	0.76	3200	1184	358.	83.0	427.	25.6	2.37	1248	2.2
GW-1					.0	1	1	8			.0	
GP-	7.5	5.8	1.02	3712	1373	415.	96.2	496.	29.7	2.84	1447	2.1
GW-2					.4	4	9	3			.7	
GP-	7.92	3.6	0.69	2316	857.	259.	60.1	309.	18.5	1.71	903.	2.31
GW-3		2		.8	2	3	0	7			6	
GP-	7.82	3.2	0.13	2060	762.	230.	53.4	275.	16.5	1.52	803.	2.91
GW-4		1		.2	3	6	4	4			5	
GP-	8	4.1	0.71	2604	963.	291.	67.5	348.	20.8	1.95	1015	1.22
GW-5		2			5	4	5	1			.6	
GP-	7.28	3.9	0.65	2456	908.	274.	63.7	328.	19.6	1.86	957.	2.98
GW-6		3			7	9	1	4			8	
GP-	7.51	4.5	0.69	2932	1084	328.	76.0	392.	23.5	2.17	1143	1.2
GW-7		8			.8	1	6	0			.5	
GP-	7.07	7.0	1.12	4512	1669	505.	117.	603.	36.1	3.35	1759	1.21
GW-8		6		.6	.7	0	06	3			.9	
GP-	8.01	4.0	0.73	2622	970.	293.	68.0	350.	21.0	1.93	1022	1.26
GW-9		8		.2	2	5	2	6			.7	
GP-	7.52	5.3	1.01	3430	1269	383.	88.9	458.	27.4	2.54	1337	2.22
GW-10		6		.2	.2	9	8	6			.8	
DJ-	7.2	3.7	0.62	2368	876.	265.	61.4	316.	18.9	1.74	923.	2.2
GW-1					2	0	3	6			5	
DJ-	7.8	2.5	0.41	1600	592.	179.	41.5	213.	12.8	1.18	624.	6.01
GW-2					0	1	0	9			0	
DJ-	7.9	1.1	0.2	716.	265.	80.2	18.5	95.8	5.7	0.56	279.	4.5
GW-3		2		6	1		9				5	
DJ-	7.6	5.6	1.04	3590	1328	401.	93.1	480.	28.7	3.0	1400	2.21
GW-4		2			.3	8	2	0			.1	
DJ-	7.5	0.9	0.34	634.	234.	71.0	16.4	84.8	5.1	0.51	247.	5.32
GW-5		9		6	8		6				5	
DJ-	8.28	1.7	0.32	1120	414.	125.	29.0	149.	9.0	0.79	436.	3.31
GW-6		5			4	3	5	7			8	
DJ-	7.69	2.3	0.48	1476	546.	165.	38.2	197.	11.8	1.08	575.	2.96
GW-7		1			1	2	9	3			6	
DJ-	7.88	2.3	0.48	1497	554.	167.	38.8	200.	12.0	1.1	583.	2.94

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GW-8		4		.2	0	6	4	2			9	
DJ-	7.32	3.0	0.49	1926	712.	215.	49.9	257.	15.4	1.46	751.	2.85
GW-9		1		.4	8	6	7	6			3	
DJ-	7.62	1	0.24	640	236.	71.6	16.6	85.6	5.1	0.39	249.	5
GW-10					8		0				6	
SEQs	6.5-8.5	--	5.0	1000	500	--	--	--	--	--	250	--
WHO	6.5-8.5	--		500		75	150	200	12	--	250	--

American Public Health Association APHA, Sindh Environmental Quality Standard SEQS, the Sindh Govt. Gazette, Part –1 Ext. Jan. 28, 2017, for drinking water quality, Below Detection Limit BDL World Health Organization guideline for drinking water Quality WHO

Table 04 interpret the analysis of the groundwater quality from Jam Chakro, Gond Pass, and Dhabeji landfill sites found varying degrees of contamination. They all have pH values within the acceptable range of 6.5–8.5, indicating that the water is neither too acidic nor too alkaline. However, the Electrical Conductivity (EC) values are higher at Gond Pass and Jam Chakro, possibly due to contamination from leachate or waste runoff. Similarly, the Total Dissolved Solids (TDS) levels are very high in many samples and exceed the SEQS limit of 1000 mg/l at Gond Pass and Jam Chakro, indicating significant contamination. Noteworthy also are high Total Hardness (TH) levels, especially in Gond Pass may indicate the presence of calcium and magnesium, possibly from leachate. Groundwater at Gond Pass and Jam Chakro have chloride (Cl) concentrations well above the SEQS limit of 250 mg/l, indicating contamination. Finally, there is low Dissolved Oxygen (DO) across most samples, particularly at Gond Pass and Jam Chakro, as a manifestation of poor water quality and anaerobic conditions. On the other hand, groundwater quality is quite close to acceptable standards, and groundwater contamination appears to be much less in Dhabeji. Jam Chakro and Gond Pass have significant groundwater contamination from leachate, whereas Dhabeji shows moderate water quality.

Table 05: Results of Surface Leachate samples Jamchakro, Gondpass

Leachate	pH	EC ms/cm	Turbidity (NTU)	TDS (mg/l)	TH (mg/l)	Salinity (mg/l)	DO (mg/l)
SLS-JC-1	7.85	40.70	22.90	20350	2660	36.20	0.27
SLS-JC-2	7.80	38.76	21.81	19381	2532	34.48	1.06
SLS-GP-1	7.72	60.42	33.99	30212	2500	53.75	0.19
SLS-GP-2	7.89	61.42	34.56	30712	3975	54.64	0.19

Table 05 indicates that The surface leachate samples from Jam Chakro and Gond Pass landfill sites exhibit significant contamination by several pollutants. The measured

leachate pH values were within a neutral range (7.72 to 7.89), indicating that the leachate was not very acidic or basic. Nevertheless, the Electrical Conductivity (EC) values are quite excessive, especially at Gond Pass (EC values between 60.42 ms/cm and 61.42 ms/cm) and Jam Chakro (EC values between 38.76 ms/cm and 40.70 ms/cm) which implies high solution with dissolved ions, probably attributed to the breakdown of waste. Also, Turbidity levels are high in basically every sample. However, Gond Pass shows the most turbidity (33.99 NTU, 34.56 NTU), which indicates high levels of suspended waste particles in the leachate. The Total Dissolved Solids (TDS) are quite high and predominantly above the acceptable limit of TDS in drinking water at Gond Pass (30,212 mg/l – 30,712 mg/l) and Jam Chakro range (19,350 mg/l – 19,381 mg/l). Containing calcium and magnesium ions typical in landfill leachate, the high levels of Total Hardness (TH) (at about 2,500 mg/l to 3,975 mg/l) is indicative. Also, the Salinity are raised, especially at Gond Pass (53.75 to 54.64 mg/l) due to dissolved salts from waste contamination. The most concerning was the Dissolved Oxygen (DO) levels; they were extremely low, especially at Gond Pass (both samples: 0.19 mg/l) and Jam Chakro (0.27 – 1.06 mg/l). This suggests anaerobic conditions, such as landfill leachate with low DO levels and carries major environmental and health risks. Overall, the data demonstrates that the two landfill sites were severely contaminated with high concentrations of pollutants that are harmful to the environment and can contaminate groundwater quality.

Table 06: Elemental analysis of soil samples

S#	Parameters	Unit	JamChakrolfs	Gondpasslfs	Dhabejlfs	Control Sample
1.	Ph	S.U	8.30	7.95	7.20	7.50
2.	EC	ms/cm	8.949	7.289	0.694	0.647
3.	Moisture	%	25.42	4.83	3.75	1.37
4.	Carbon content	%	13.48	3.42	1.32	2.13
5.	Total Dissolved Solids	ppm	5,879	2,746	689	395
6.	Lead (Pb)	ppm	16.7	10.8	14.9	1.65
7.	Cadmium (Cd)	ppm	2.04	1.65	2.6	0.06
8.	Copper (Cu)	ppm	2.02	1.56	1.08	0.03
9.	Zinc (Zn)	ppm	32.2	18.5	12.8	6.4
10.	Chromium (Cr)	ppm	13.4	6.7	3.4	1.8
11.	Nickel (Ni)	ppm	2.2	1.76	1.02	0.01

Table 06 shows that significant contamination in the Jam Chakro and Gond Pass landfills vis à vis Dhabeji and the control sample is found in the soil analysis. It is found that Jam Chakro has a high pH, EC and moisture content, which proves to be polluted. Heavy metals, including lead (16.7 ppm), cadmium (2.04 ppm), copper (2.02 ppm), zinc (32.2 ppm), chromium (13.4 ppm), and nickel (2.2 ppm), are elevated at Jam Chakro and Gond Pass, indicative of severe contamination most likely from the landfills leachate. Most of the parameters have lower contamination levels at Dhabeji.

Table 07: Heavy metal analysis of groundwater samples of Jam chakra, Gondpass and Dhabeji lfs

S#	Sample id	(all results in ppm)			
		Pb	Cd	Cr	Ni
1.	JC-GW-1	0.10	0.04	0.046	BDL
2.	JC-GW-2	0.11	0.02	0.032	BDL
3.	JC-GW-3	0.16	0.03	0.018	0.01
4.	JC-GW-4	0.12	0.04	0.010	0.012
5.	JC-GW-5	0.08	0.01	0.054	0.007
6.	JC-GW-6	0.13	0.05	0.03	0.012
7.	JC-GW-7	0.14	0.03	0.023	0.014
8.	JC-GW-8	0.11	0.01	0.040	0.012
9.	JC-GW-9	0.19	0.04	0.041	BDL
10.	JC-GW-10	0.15	0.03	0.032	0.016
11.	GP-GW-1	0.15	0.02	0.014	0.006
12.	GP-GW-2	0.16	0.04	0.08	0.014
13.	GP-GW-3	0.18	0.02	0.012	0.017
14.	GP-GW-4	0.11	0.03	0.009	BDL
15.	GP-GW-5	0.12	0.04	0.031	0.016
16.	GP-GW-6	0.07	0.03	0.026	0.015
17.	GP-GW-7	0.09	0.02	0.014	0.016
18.	GP-GW-8	0.04	0.04	0.020	0.0021
19.	GP-GW-9	0.06	0.06	0.06	0.014
20.	GP-GW-10	0.06	BDL	0.038	0.003
21.	DJ-GW-1	0.02	BDL	BDL	BDL
22.	DJ-GW-2	0.02	BDL	BDL	BDL
23.	DJ-GW-3	0.04	BDL	BDL	0.001
24.	DJ-GW-4	0.02	BDL	0.006	0.001
25.	DJ-GW-5	0.19	BDL	BDL	BDL
26.	DJ-GW-6	0.03	BDL	BDL	BDL
27.	DJ-GW-7	BDL	BDL	0.032	BDL
28.	DJ-GW-8	BDL	BDL	0.1	BDL
29.	DJ-GW-9	BDL	BDL	BDL	0.001
30.	DJ-GW-10	BDL	BDL	0.11	BDL
	SEQs	≤ 0.05	0.01	≤ 0.05	≤ 0.02
	Leachate				
31.	SLS-JC-1	0.05	0.03	0.02	0.16

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32.	SLS-JC-2	0.09	0.06	0.01	0.18
33.	SLS-GP-1	0.11	0.08	0.04	0.19
34.	SLS-GP-2	0.10	0.05	0.05	0.17
35.	SLS-GP-2	0.10	0.05	0.05	0.17

SEQS Sindh Environmental Quality Standard, the Sindh Govt. Gazette, Part –1 Ext. Jan. 28, 2017, for drinking water quality

Concentration of heavy metal in leachate, water and soil samples

Table. 07 illustrate the results of the heavy metal concentration in the soil, water, and leachate samples. Whereas the value of Dhabeji lfs ground water is < 0.05 ppm, the mean concentration of Pb in leachate, ground water, and soil exceeds permissible limits. Prolonged exposure to high levels of Pb could harm a person's essential organs (Tong, 2000; Riess and Halm, 2007). The maximum allowable limits established by SEQS are exceeded by the mean concentrations of Cd, Cu, Zn, Cr, and Ni found in soil, water, and leachate samples; however, the concentration found in Dhabeji LFS water samples was within the standard limits or BDL.

Table 08: Correlation matrix of Study area Jam Chakro lfs collected water samples.

	pH	EC (ms/cm)	Turbidity (NTU)	TDS (mg/l)	TH (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Salinity (mg/l)	Cl (mg/l)	DO (mg/l)
Ph	1											
EC (ms/cm)	-	1										
Turbidity (NTU)	-	0.84	1									
TDS (mg/l)	-	0.98	0.81	1								
TH (mg/l)	-	0.98	0.81	1.0	1							
Ca (mg/l)	-	0.98	0.81	1.0	1.0	1						
Mg (mg/l)	-	0.99	0.81	1.0	1.0	1.0	1					
Na (mg/l)	-	0.99	0.81	1.0	1.0	1.0	1.0	1				

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	42											
K	-	0.99	0.81	1.0	1.0	1.0	1.0	1.0	1.0	1		
(mg/l)	0.			0	0	0	0	0	0			
	39											
Salini	-	0.99	0.83	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1	
ty	0.			8	8	8	8	8	8	8		
(mg/l)	42											
Cl	-	0.99	0.81	1.0	1.0	1.0	1.0	1	1.0	0.98	1	
(mg/l)	0.			0	0	0	0		0			
	42											
DO	0.	-0.82	-0.64	-	-	-	-	-	-	-	-	1
(mg/l)	45			0.7	0.7	0.7	0.7	0.7	0.7	0.81	0.7	
				6	6	6	6	6	6		64	

Table 08 represents the several apparent significant relationships between key parameters can be seen in the correlation matrix for the Jam Chakro landfill site water samples. Most parameters such as EC, Turbidity, TDS, TH, Ca, Mg, Na, K, Salinity, and Cl have a strong negative correlation with pH, whereby as pH decreases (i.e. more acidic conditions) tend to increase. The EC and TDS values show a very high positive correlation ($r > 0.98$), indicating that the dissolved ions are highly correlated with each other and hence they both tend to get higher with increased salinity and conductivity. In the same way, Ca, Mg, Na, and K have strong positive correlations ($r = 1$), meaning that these ions are likely to go up together. Also there is a strong negative correlation of DO (Dissolved Oxygen) with almost all the parameters, particularly with EC, Turbidity, TDS and Salinity which implies that as the water becomes contaminated its oxygen content decreases. Such an example highlights the poor quality of water and the anaerobic conditions present in landfill leachate.

Table 09: Correlation matrix of Study area Gondpass lfs collected water samples

	pH	EC	Turbi	TD	TH	Ca	Mg	Na	K	Sali	Cl	DO
		(ms/cm)	dity	S	(m	(m	(m	(m	(m	nity	(m	(m
			(NTU	(m	g/l)	g/l)	g/l)	g/l)	g/l)	(mg/l)	g/l)	g/l)
			)	g/l)								
pH	1											
EC	-	1										
(ms/cm)	0.											
	69											
Turbi	-	0.86	1									
dity	0.											
(NTU	50											
)												
TDS	-	1.00	0.85	1								
(mg/l)	0.											
	68											
TH	-	1.00	0.85	1.0	1							
(mg/l)	0.			0								

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	68											
Ca	-	1.00	0.85	1.0	1.0	1						
(mg/l)	0.			0	0							
	68											
Mg	-	1.00	0.85	1.0	1.0	1.0	1					
(mg/l)	0.			0	0	0						
	68											
Na	-	1.00	0.85	1.0	1.0	1.0	1.0	1				
(mg/l)	0.			0	0	0	0					
	68											
K	-	1.00	0.85	1.0	1.0	1.0	1.0	1.0	1			
(mg/l)	0.			0	0	0	0	0				
	68											
Salini	-	1.00	0.86	1.0	1.0	1.0	1.0	1.0	1.0	1		
ty	0.			0	0	0	0	0	0			
(mg/l)	69											
Cl	-	1.00	0.85	1.0	1.0	1.0	1.0	1	1.0	1.00	1	
(mg/l)	0.			0	0	0	0		0			
	68											
DO	-	-0.41	-0.46	-	-	-	-	-	-	-0.40	-	1
(mg/l)	0.			0.4	0.4	0.4	0.4	0.4	0.4		0.4	
	07			2	2	2	2	2	2		2	

Table 09 represent the correlation matrix for Gond Pass landfill site groundwater samples shows very strong positive correlation between most parameters, including those showing zero to a 1.00 correlation, such as EC (ms/cm), TDS (mg/l), Salinity (mg/l), Ca (mg/l), Mg (mg/l), Na (mg/l) and K (mg/l). By indicating the others tend to increase with increasing this parameter, then it argues for consistent contamination in the water, and most specifically: pH is negatively strongly correlated in most points to most parameters especially EC TDS, and Salinity which indicates higher contamination levels corresponds with lower pH. The relationship between Dissolved Oxygen and nearly all the parameters is negative, especially EC, TDS, and Salinity, implying that as contamination increases the oxygen level in the water is decreasing which means poor water quality.

Table 10: Correlation matrix of Study area Dhabeji lfs collected water samples.

	pH	EC (ms/cm)	Turbidity (NTU)	TDS (mg/l)	TH (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Salinity (mg/l)	Cl (mg/l)	DO (mg/l)
pH	1											
EC (ms/cm)	-	1										
Turbidity	-	0.97	1									
	0.											
	36											
	0.											

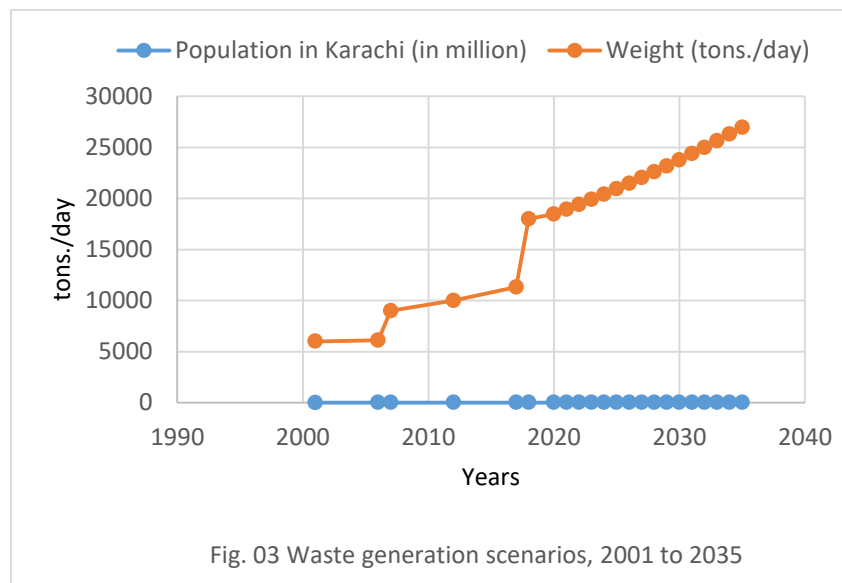


Fig. 03 illustrated that waste generation is directly proportional to the increase in the city's population. In 2001, the population was 9.99 million, and the waste generated was 6000 tons/day. 2017 the population increased to 14.91 million; waste was generated at 11319.33 tons/day. Waste generation is expected to reach 268956 tons/day by 2035. The circular economy is a novel idea for improved waste management (Ngoc and Schnitzer, 2009; Iqbal A, 2022; Khan and Ali, 2022); it calls for zero waste in urban areas and an increased emphasis on recycling and reuse. Although this idea is still in its early stages of development, European nations are beginning to include it in their waste management plans (Aiman Jahangir, 2018). Due to the current state of infrastructure, underdeveloped nations would find it extremely challenging to implement this idea (Cetrulo et al., 2018).

CONCLUSIONS

The primary challenge confronting society is unlawful dumping and open rubbish burning. These activities negatively affect the entire city's environment and its citizens' health and well-being. Authorised landfill points are at capacity due to the city's fast-expanding waste per day ratio. Modern techniques, such as implementing technical training programs for waste management employees, providing separate bins for recyclable and disposal waste, and implementing eco-friendly waste utilisation options, can alleviate the overloaded system. Several underdeveloped and developing nations are utilising their refuse as electricity. Our country is facing an energy crisis. Thus, the waste-to-energy option is a smart way to compensate for this critical issue, and it will also be beneficial and valuable to the entire society. Most sites have poor air quality due to improper air quality and dumping. The air quality, especially at Jam Chakro and Gondpass sites, is highly polluted; CO₂, CO and PM values are higher than NEQS limits. It can create nuisance and health problems. The pH of the groundwater samples is slightly alkaline, and more than 70% samples have higher TDS and conductivity, which showed the leachate effect. The people's livelihood in study areas mainly depends on garbage collection and labor work. Different communities have settled in areas for garbage collection and selling. There

is are lack of adequate health facilities in the regions. The people of these areas suffer great pollution, sanitation, garbage and unhygienic problems. The communities present are poor and vulnerable, with low human development indicators. To improve the solid waste management situation in Karachi, there should be proper strategies in the future for reduction, recycling, long-term waste management policies, involvement of the private sector and a proper formal waste management system in which all the stakeholders are involved. Waste management should be promoted through public advertising and education initiatives, particularly at the school level. A proper waste management system includes monitoring, collection, storage, transportation, and no leaching from landfill sites. The local solid waste management department should appoint highly qualified personnel who better understand and can solve the regional problems.

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