Remediation of an existing solid waste disposal site

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ABSTRACT : Presented in this paper are the field and laboratory studies performed for the remediation of a solid waste disposal site located in İzmir, one of the major cities of Turkey. The design studies implemented in order to eliminate the associated geoenvironmental problems involved the determination and evaluation of the geometrical, geotechnical and contamination data for the disposal site. Static Cone Penetration Testing (CPT) was performed to determine the subsoil conditions. Water and gas samples have been taken from various depths with the aid of a special device connected to the penetration device. Laboratory testing of the samples were made which enabled the systematic assessment of the degree of contamination. The results of the stated field and laboratory tests have been evaluated in the development of the remedial design project. Hence, it is expected that the geoenvironmental effects of the solid waste disposal site will be eliminated upon the implementation of the proposed design.

1. INTRODUCTION

Detailed in-situ investigations, laboratory testing and office studies have been performed for the remediation of a previously closed solid waste disposal site, located in İzmir; one of the major cities of Turkey. The disposal site is located within one of the main extensions of the city and partially occupies the extension zone of a large scale housing development project, locally known as Mavişehir. The site has been used over the years for waste disposal by the municipality of İzmir. No precautions such as impermeable base liner and cover have been taken to isolate the waste and contamination from the environment. Although the site is closed, the storage area is a source of contamination and presents major environmental problems.

Now with the development of the city towards north, near the site, remedial measures have to be taken to prevent the major problems related with contamination. Integrated field and laboratory studies have been conducted to enable the solution of the existing environmental problem with determination and assessment of geometrical geotechnical and contamination parameters of the disposal site.

Cone penetration testing has been performed to determine the goetechnical parameters of the waste and subsoil. Water and gas samples have been taken from the waste and subsoil with a special device connected to the penetration cone. Laboratory testing has been performed on the samples and the extent and the degree of contamination within the area has been systematically assessed.

A remedial project has been designed with the evaluation of the geotechnical model and contamination data to eliminate the present and future complications related to waste storage. The solid waste distributed over a large region within the storage space is planned to be compacted and stored in a limited area.

The leachate collection system has been designed with the evaluation of hydrological conditions of the site and vicinity and a gas collection system has been proposed to eliminate the problems associated with the decomposition of the irregularly stored solid waste.

A new storage geometry has been proposed to minimize the area of storage and the proposed design has been checked in terms of stability and settlement. The final storage scheme has been optimized with the evaluation of these analyses. A monitoring system consisting of settlement columns and piezometers has been proposed in the design to monitor the settlements and pore water pressures expected to occur during the construction of the compacted waste and are critical in terms of stability.

2. FIELD AND LABORATORY INVESTIGATIONS

The extent and geometry of the irregularly stored solid waste have been determined with topographical investigations performed at the initial stage of the studies. Cone Penetration Testing (CPT) has been conducted at 17 locations within the storage area, in order to determine the depth of the waste, subsoil stratification, corresponding geotechnical properties and parameters.

Water and gas samples have been taken from various depths with a special device connected to the penetration device (Durgunoğlu and Toğrol, 1995). The degree of contamination within the subsoil and groundwater has been systematically assessed with the laboratory testing of the samples. The plan of the solid waste disposal site and the test locations are shown in Figure 1.

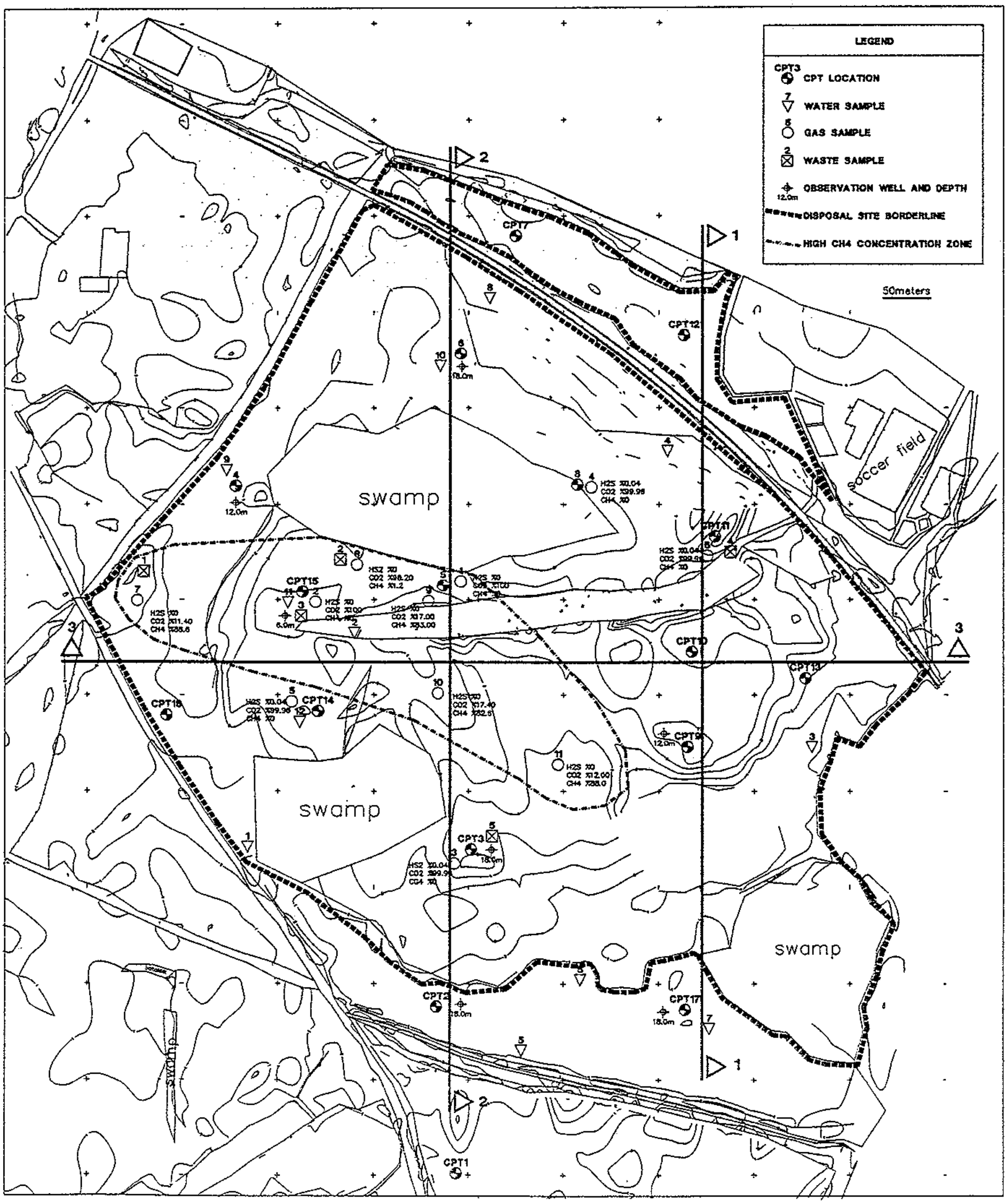

Figure 1. Plan of the solid waste disposal site

2.1. Cone penetration testing and sampling

At the initial stage of the investigations the topography of the storage area has been determined and the volume of the waste has been estimated to be 817,000 m^3. Cone Penetration Testing has been performed at 17 locations within the area. In the light of previous experiences in the region and using obtained data, a proper geotechnical model has been developed (Durgunoğlu et al.,1995).

A typical cross section of the waste and the subsoil is shown in Figure 2. The average thickness of the waste is determined to be ~3.0 meters, in some regions reaching the maximum thickness of 5.0 meters. Silty clay is located at the top on a continuous sublayer of silty sand. Below these a considerably thick clay layer and sandy clay overlying the bearing layer of clayey gravel located at a depth of 27.0-30.0 meters from surface is present, as seen in the cross section.

Erratically distributed sand and gravel lenses are present within the subsoil, creating vertical and horizontal connection between soil layers and increasing the rate of seepage within the subsoil. Such a geological formation is typical of the area, i.e., alluvial deposits of Gediz River.

In addition to conventional measurement of cone resistance and sleeve friction, conductivity of the soil has been measured with the CPT device to determine the extent of contamination within the subsoil. The presence of ions in the contaminated soil increases the electrical conductivity of the soil. Therefore the increase in the electrical conductivity is a measure of the extent of contamination within the subsoil.

A typical conductivity measurement at a CPT test is given in Figure 3. It is seen from the conductivity measurement that the first eight meters of the soil exhibits a relatively high electrical conductivity indicating the zone of contamination which extends to the clay strata within the subsoil.

The extent of the contamination plume and the content of gas generated from the decomposition of solid waste has to be determined in order to perform a proper remedial design. Water and gas samples have been taken at test locations from various depths of the subsoil with a special sampling equipment connected to the penetration device. The sampler is driven into the soil with the penetrometer, the filter is opened and with the aid of a peristaltic pump located at the ground surface the waste or gas (whichever is present at that location) is transferred into proper storage units.

The advantage of such sampling procedure over the methods associated with drilling is that the water or gas sample is characteristic of the certain depth at

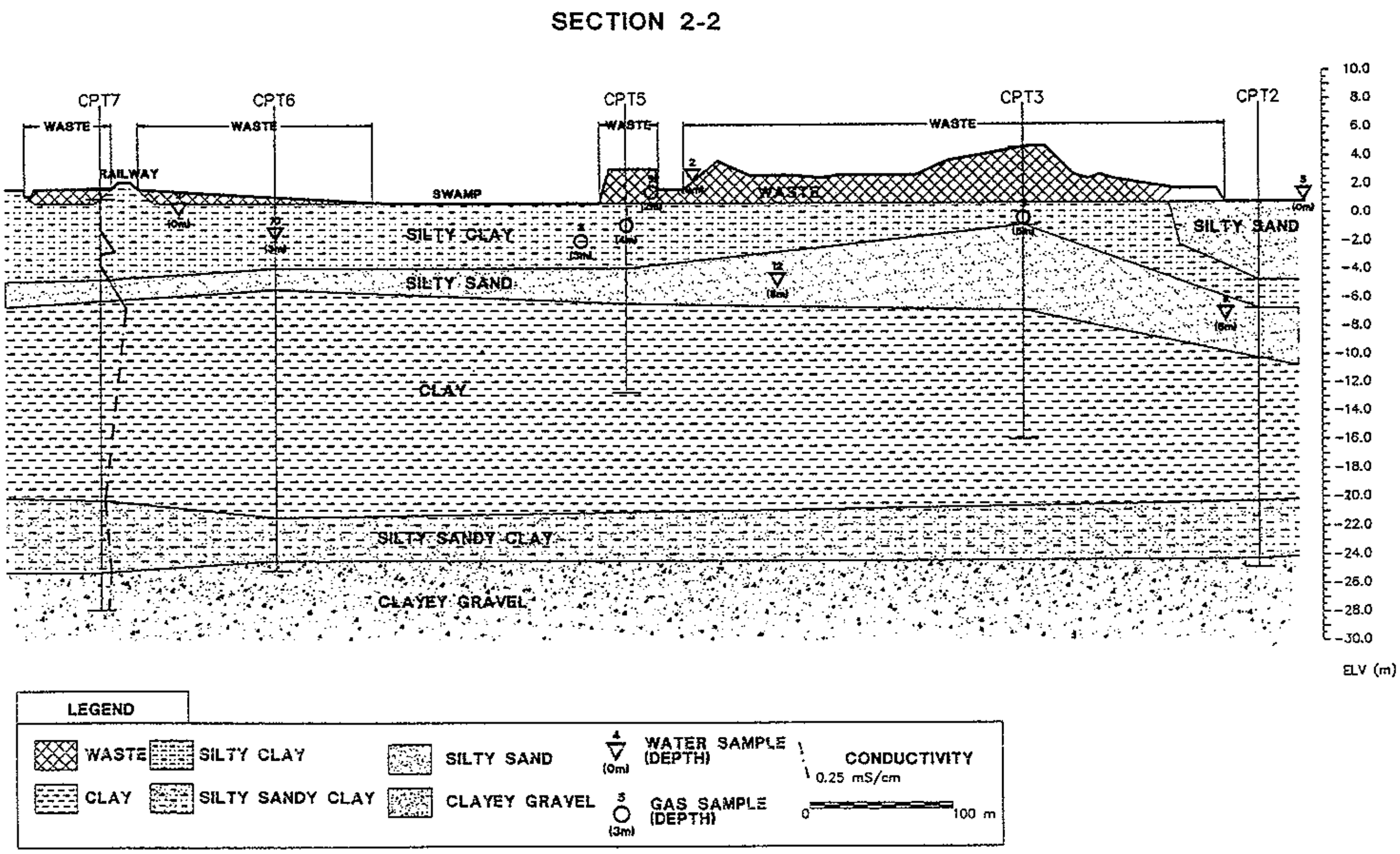

Figure 2. Typical geotechnical cross section

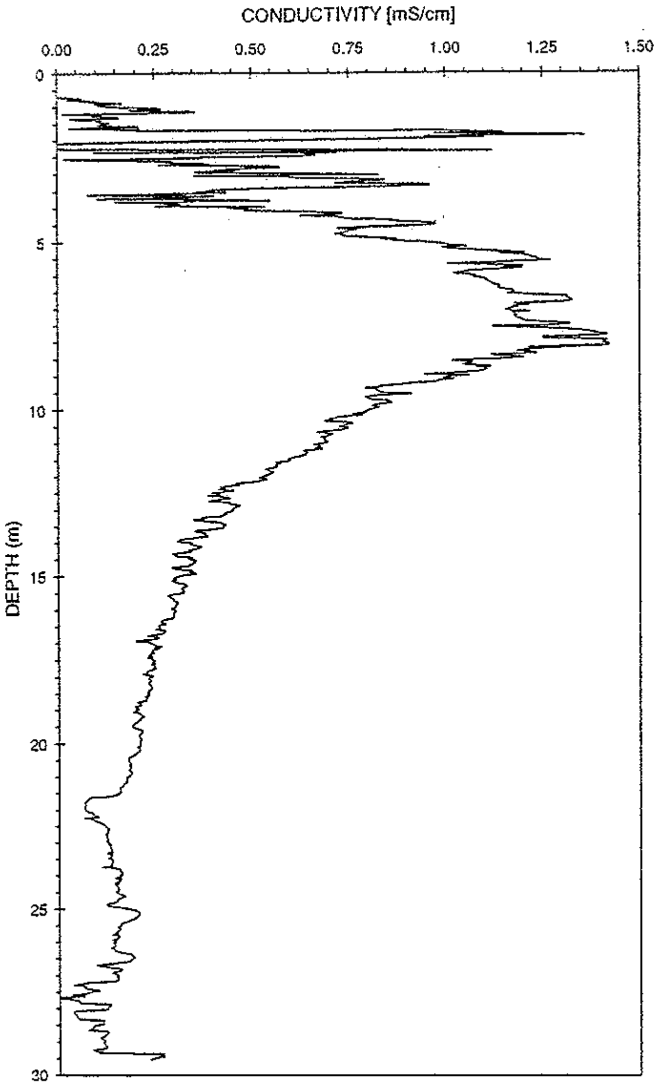

Figure 3. Conductivity measurement from a CPT sounding

which the sampler is located. Therefore with the aid of such an equipment, the variation of contamination with depth can be determined with only one penetration.

2.2. Laboratory testing

Chemical analyses have been performed on 12 water samples taken from various locations and depths in the area. The results of the analyses have been summarized in Table 1. Some criteria are also given for comparative purposes.

Concentrations measured in water samples are within the range and above the values given in column (b) which shows the concentration ranges measured in leachate from solid waste disposal sites in Wisconsin (Avcı et al., 1994). Especially, the chloride concentration is very high and reaches to 34000 mg/l in average. Such a concentration is an important measure of contamination in the subsoil and ground water.

Chemical oxygen demand (COD) has been measured to be 3450 mg/l in average. This value is far above the value 600 mg/l given in column (a) as waste water standard and is within the range given in column (b) as an example of leachate water.

It is seen from the comparison of the listed values of certain chemicals that groundwater has been contaminated with the leachate generation. Such a contamination makes it impossible to provide the drinking and domestic water from groundwater sources in the area which is planned to be developed for housing purposes. The high concentration of sulfate in the groundwater makes it necessary to take precautions against corrosive effects of the groundwater for the safety of underground concrete structures (foundation, piles) planned to be built near the area. Observation wells have been installed at CPT locations to monitor the groundwater flow. These may also be used for future sampling purposes.

The content of H_2S, CO_2 and CH_4 have been investigated in 11 gas samples taken from various locations of the site, especially from the waste itself. Carbondioxide (CO_2) is present in all samples. Except for 4 samples, the ratio of CO_2 is determined to be approximately 100%. Methane (CH4) has been measured in 6 samples. The concentrations measured exceed 80% in 4 of the samples tested.

In addition, the organic content of the waste has been determined to be 23-37%, indicating that although decomposed to a great extent, the waste is still a possible source of gas generation in anaerobic conditions. Therefore, a gas collection and removal system has to be constructed for the removal of generated gas to eliminate possible problems on nearby housing and plants.

3. REMEDIAL PROJECT

The solid waste distributed over a large region within the storage area and approximated to be 817,000 m^3 in volume, is planned to be compacted and stored in a smaller area. The solid waste disposal site partially occupying the extension zone of Mavişehir Housing Development will be limited in extent and remaining portions will be opened to housing development gaining extensive amount of land.

Stability and settlement analyses have been performed to eliminate the problems foreseen to be associated with the compacted waste disposal site. The geometrical configuration and height for the waste are optimized with the evaluation of these analyses.

Table 1. Analyses of Water Samples and Comparison with Available Criteria

Parameters	Various Criteria a	b	c	Average of Samples
pH	6.5-10	5.4-7.2		7.93
Chloride mg/l	100	180-2651		33800
Total Phosphorus mg/l	15	0.1-117		1.40
Cadmium mg/l	2	B*-0.07	0.001	0.496
Total Cyanide mg/l	10			0.252
Total Chrome mg/l	5	B-1.0	0.05	0.313
Zinc mg/l	10	B-54	5	0.283
Chemical Oxygen Demand mg/l	600	1120-50450		3450
Total Nitrogen mg/l	75	4.7-1470		72
Sulfate mg/l	1000	8.4-500		2410
Lead mg/l	3	B-1.11	0.05	0.41
Oil mg/l	50			1780
Total Precipitating Solids mg/l				27.3
Total Solids in Suspension mg/l	350	2180-25873		755
Total Dissolved Solids mg/l		28-2835		105450

* B : below measurement limit
a : Waste water standards for storage units discharging to sea
b : Content range of chemicals present in solid waste disposal sites in Wisconsin, USA, (Avcı et al., 1994)
c : Standards for drinking water in Turkey

A proper drainage system has been designed for leachate collection with the evaluation of hydrogeological data. A gas collection system consisting of horizontal and vertical pipes has been designed to remove the gas generated from the solid waste.

3.1. Gas collection system

The gas generation in solid waste disposal sites is divided into four stages. In the first stage named 'aerobic media' O_2 decreases to zero from 20% and N_2 starts to decrease from 80%, whereas the amount of CO_2 starts to increase. In the second stage taking place in anaerobic media the amount of CO_2 rises to 70-75% and H_2 rises to 20%, whereas N_2 drops to 10%. In the following stage (anaerobic media - formation of instable methane) CO_2 decreases to 45% and CH_4 rises from zero to 55%, whereas N_2 and H_2 diminish to zero. In the last stage (Anaerobic media - formation of stable methane) the CO_2 and CH_4 balance in 45% and 55% while no other primary components are present except these.

High amount of methane (CH_4) and carbondioxide (CO_2) has been measured in the solid waste disposal site. This condition corresponds to the fourth stage mentioned above as anaerobic media - formation of stable methane. The gas potential of the site has been calculated using the formula below;

$$G_t = 1.868 \times C_0 \times (0.014 \times \vartheta + 0.28) \times (1-10^{-kt})$$

G_t = amount of gas generated until time t (m^3/ ton)

C_0 = organic carbon content (kg/ton-waste)
for domestic wastes this value varies between 170-220

ϑ = temperature (°C)
this value is around 25-35°C for solid waste disposal sites

k = reduction constant
0.035-0.040 for a period of 12-24 years for decomposition of organic waste in landfills

t = time (year)

In the above relation the carbon content (C_o) is taken to be 170 kg/ton-waste and average temperature (ϑ) is taken as 30 °C and the reduction constant (k) as 0.030. Amount of gas generation is determined to be ~500m^3/h for the ten year operation period. The gas will be collected with horizontal drainage pipes located on drainage blanket laid on the waste and removed to the burning unit.

3.2. Leachate collection and removal

Precipitation water penetrating into the waste dissolves organic and inorganic substances in the waste and contributes to the formation of leachate. Amount of precipitation, surface runoff, evaporation and groundwater level are the basic parameters determining the amount of leachate water. The leachate quantity is calculated using the meteorological data of the vicinity and a proper leachate collection and removal system has been designed.

The monthly meteorological data of the vicinity (precipitation, vaporization, temperature) for 1984-1994 period has been collected and the method proposed by Canziani and Cossu (1995) has been utilized in the determination of leachate production.

Only three months of the region are rainy and the quantity of water penetrating the top liner and membrane has been calculated to be less than 55 mm/month at the maximum precipitation period. The method proposed in the remedial project is to remove the leachate water into temporary storage basins and discharge into the municipal sewage system.

A leachate storage system consisting of leachate collection ponds has been proposed which will serve as a temporary storage unit until the collected leachate is pumped out by the municipality. Factors which effect the dimensions of these ponds include the amount of leachate produced (20, 30, 40, 50, 60 mm), the leachate removal frequencies (1,2,3,4 times a month) and the maximum cumulative rainfall between these removal times.

Minimum required pond dimensions for different combinations of the above stated factors are investigated. As a result, a pond of 5.0m x 5.0 m is determined to be suitable for the removal of leachate not more than once a week at the maximum precipitation period requiring that the leachate quantity within the tank does not exceed 1.7m. For this reason a leachate collection pool of 5.0 m x 5.0 m with sufficient depth has been proposed. The cross section of the leachate collection system and temporary storage pond is shown in Figure 4.

3.3. Stability and settlement assessment of the storage area

No bearing capacity problem is present for the compacted storage scheme. However, sliding surfaces which are critical in terms of slope stability are expected to develop at slopes. Therefore slope stability analyses have been performed for the disposal site.

The performed analyses include various piezometric configurations of short term and long term conditions. The results of the stability analyses are summarized in Table 2.

Short term and long term stability analyses show that a sufficient factor of safety is achieved as long as pore water pressure does not rise excessively. Therefore pore water pressure within the subsoil and waste has to be monitored during the compaction process. For this purpose, piezometric monitoring stations are recommended to be installed at 200 m intervals.

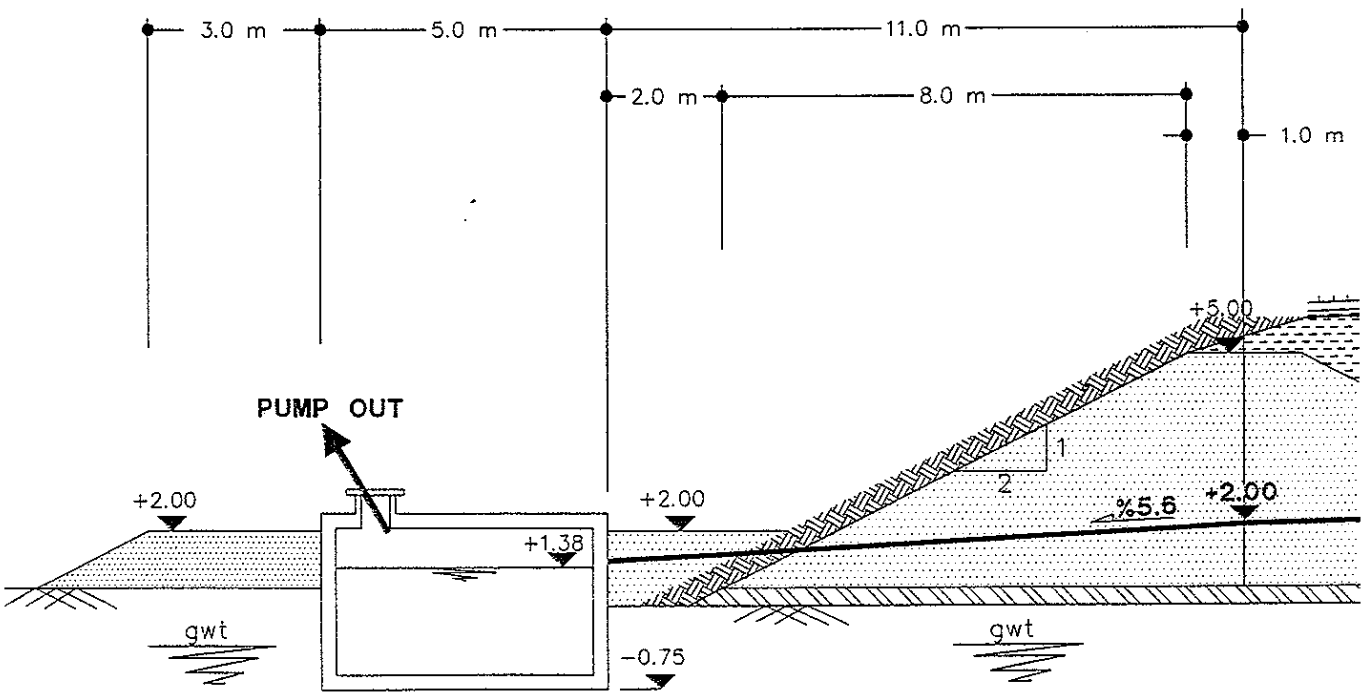

Figure 4. Leachate collection and removal system

Table 2. Stability analyses

Analysis	FS	ru	k	Result
short term	2.10	NA	statical	safe
long term	1.77	0.00	statical	safe
long term	1.57	0.10	statical	safe
long term	1.43	0.20	statical	safe
long term	1.04	0.40	statical	critical
long term	1.00	0.00	earthquake	safe

FS : factor of safety
ru : pore water pressure ratio
k : lateral earthquake acceleration (0.2g)

Total and differential settlements expected to occur in the natural subsoil under the weight of the waste are the main issues that should be taken into consideration in the design and functioning of impermeable liner, geotextile blanket and gas and leachate collection system.

It has been determined with the evaluation of CPT soundings and the geotechnical model, that the subsoil is susceptible to settlement. The settlements of the subsoil under embankment loading have been calculated and the results of the analyses are summarized in Table 3.

Immediate and consolidation settlements under 30, 60, 90 and 120 kPa surcharge loads, each corresponding to various compacted waste embankment heights in the proposed design are calculated. The average settlement under 30 kPa surcharge, corresponding to about 1.5 m waste height is 47 cm. It is seen that a major portion of the total settlement results from consolidation.

Due to the expected settlements, the construction process should be performed in accordance with the evaluation of the realized settlements. The realized settlements should be monitored systematically with proper instruments. The distribution of settlement within the compacted waste and the subsoil are proposed to be monitored with settlement columns in order to determine what portion of the total settlement consists of the compression of waste and subsoil.

Therefore, settlement monitoring stations of 100 m spacing are recommended to monitor the settlements during the compaction process. The settlements are expected to be completed within the period of construction due to the presence of sand and gravel lenses within the subsoil.

The amount of settlements is the main criteria limiting the height of the compacted waste. Therefore maximum waste height is optimized to be 4.0 m with the evaluation of present soft and compressible soil conditions.

Table 3. Settlement analyses for various levels of loading

CPT no	height of gwt (m)	height of waste (m)	Load (kN/m^2) total settlement (mm) 30	60	90	120	Load (kN/m^2) immediate settlement (mm) 30	60	90	120	Load (kN/m^2) consolidation settlement (mm) 30	60	90	120
01	1.5	1.0	569	920	1192	1417	10	19	28	35	559	901	1164	1382
03*	4.5	4.0	332	518	663	784	13	24	33	42	319	494	630	742
04*	1.5	1.0	660	1093	1433	1716	3	6	9	11	657	1087	1424	1705
05	4.0	3.5	239	405	538	650	6	11	15	19	233	394	523	631
06	2.5	2.0	525	858	1120	1338	4	7	10	13	521	851	1110	1325
07	3.5	3.0	298	516	692	843	5	10	15	19	293	506	677	824
08	3.5	3.0	359	592	743	928	7	14	19	25	352	578	724	903
09	5.5	5.0	455	779	1045	1273	2	4	6	7	453	775	1039	1266
10	5.5	5.0	371	626	838	1021	7	13	18	23	364	613	820	998
11	5.5	5.0	288	523	724	899	8	15	21	26	280	508	703	873
13	3.5	3.0	542	901	1187	1429	4	8	11	13	538	893	1176	1416
14*	3.5	3.0	372	606	790	943	8	14	20	25	364	592	770	918
15	3.5	3.0	492	820	1082	1303	5	9	13	16	487	811	1069	1287
16	2.0	1.5	438	677	852	991	5	9	13	16	433	668	839	975
17	1.5	1.0	669	1096	1430	1708	4	8	11	14	665	1088	1419	1694
average			472	783	1028	1239	5	10	15	18	467	773	1014	1221

* not included in the average value because the CPT sounding is not achieved until bearing layer

4. CONCLUSIONS

Detailed in-situ investigations, laboratory testing and office studies have been performed for the remediation of a closed solid waste disposal site, located in İzmir, one of the major cities of Turkey. The disposal site is located within one of the main extensions of the city and partially occupies the extension zone of a large scale housing development project. Studies have been conducted to enable the solution of the existing environmental problems with determination and assessment of geometrical, geotechnical and contamination parameters of the disposal site.

Extensive field testing has been performed with cone penetration testing to determine the geotechnical parameters of the waste and subsoil. Water and gas samples have been taken from the waste and subsoil with a special device connected to the cone penetrometer. Laboratory tests have been performed on the samples and the extent of contamination has been assessed.

With the evaluation of the geotechnical model and contamination data, an appropriate remedial project has been designed which will eliminate the present and future complications related to waste disposal.

A new storage geometry has been proposed to minimize the area of storage and the proposed design has been checked in terms of stability and settlement. A pore water pressure and settlement monitoring program has been established to monitor the relevant parameters that are important for the validity of the design assumptions.

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