DESIGN DEVELOPMENT OF A LANDFILL LEACHATE PRETREATMENT PLANT

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ABSTRACT

This paper describes the development of the design of a landfill leachate pretreatment plant located in the Northeastern U. S. The pretreatment process is designed to remove heavy metals (mainly iron, manganese and zinc) before discharge to the local wastewater treatment plant. The main reaction is carried out in a solids contact clarifier in which lime and polymer are added to chemically coagulate and precipitate heavy metals. The clarified effluent is neutralized by acid addition prior to discharge to the municipal sewer. The metal-laden sludge is dewatered with a filter press to approximately 45% solids and then buried at the landfill. Construction of the pretreatment plant was completed in December 1988 and the plant has been in operation since then successfully meeting the city's sewer pretreatment requirements. This paper presents the design criteria of the pretreatment processes as well as raw leachate data, treatability test results and Extraction Procedure Toxicity data on the sludge produced from the treatment process.

BACKGROUND

The landfill is located adjacent to a large river about 2 miles southwest of the city center and is bounded by the river on three of its sides.

The existing landfill encompasses approximately fifty-five (55) acres and since opening in late 1982 has accepted municipal solid waste (MSW). In addition, rejected materials from the on-site refuse derived fuel (RDF) processing facility and residual ash from a nearby RDF Boiler facility are also disposed at the landfill. In the future, a portion of the existing site will be dedicated for ash disposal.

The existing landfill cells have a groundwater dewatering system, a liner and a leachate collection system. Leachate is collected above the liner, and conveyed to leachate holding tanks by gravity sewers. Prior to construction of the leachate pretreatment plant, the leachate was discharged to the city sewer on an interim basis and subsequently treated at the city's wastewater treatment plant.

LEACHATE CHARACTERISTICS

Characteristics of the leachate generated from the landfill have been monitored periodically, with data going back to 1984, including complete priority pollutant scans. The leachate characteristics are presented in Table 1 and indicate moderately high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) concentrations and relatively low metals concentrations, except for iron and zinc.

TABLE 1 LANDFILL LEACHATE QUALITY DATA PRIOR TO 1987

	CONCENTRATION (mg/l)			
PARAMETER	HIGH VALUE	LOW VALUE	AVERAGE	CITY SEWER LIMIT
BOD	6300	1400	3800	400
COD	9400	2100	5029	600
Total Solids	10000	4444	6167	5000
Chlorides	---	270	2388	---
Iron	980	---	>50	10
Silver	0.028	<0.02	<0.02	1.2
Cadmium	0.02	<0.02	<0.02	0.2
Chromium	0.9	0.089	0.302	8.4
Copper	0.075	0.02	0.053	6.4
Nickel	1	<0.04	0.376	2.2
Lead	0.5	0.1	0.23	1.1
Zinc	11.5	0.209	4.67	3.5
Volatile Organics	8.576	0.857	---	N.S.[1]
Semi-Volatiles	>88.7	9.3	---	N.S.
pH (in pH units)	6.2	5.7	---	6.0-9.0

[1] NS indicates No Standard existed prior to 1987.

TABLE 2 LEACHATE QUALITY DATA SINCE 1987

	CONCENTRATION (mg/l)*				
	9/2/87	1/29/88	4/14/88	Ave.	Sewer Limits
pH	6.0	6.2	NA**	6.1	6.0-9.0
Cyanide, Total	<0.010	<0.010	<0.010	<0.010	0.4
BOD	4800	3200	150	2716.7	400
COD	NA	NA	NA	---	600
Solids, Total Suspended	110	1280	94	494.7	5000
Sulfate	160	72.7	68.5	100.4	250
Total Volatiles (EPA Method 624)	2.612	1.255	0.263	1.377	
Acid Extractable & Base/ Neutral Compounds (EPA 625)	0.978	BDL	BDL	0.326	
Pesticides & PCB's (EPA 608)	BDL	BDL	BDL	BDL	
Total Toxic Organics (sum of above three analyses)	3.590	1.255	0.263	0.568	4.0

* BDL indicates below minimum detection limit.
** NA indicates parameter was not analyzed for.

Also presented in Table 1 are the city's Sewer Limits. The data indicate that the average concentration of BOD, COD, Total Suspended Solids, iron, and zinc exceed the city's Sewer Limits.

In general, refuse leachate typically contains high concentrations of BOD and COD, low levels of dissolved metals and exhibit acidic characteristics. Depending on the types of the wastes received, a variety of metals, synthetic organic chemicals and oils may appear in the leachate. Even in the absence of industrial wastes, some organic chemicals from discarded household refuse can be expected in the leachate. Ash leachate also typically contains low levels of dissolved metals but exhibits basic characteristics.

MSW landfill leachate strength, as quantified by BOD and COD, is related to the amount of precipitation percolating through the waste, the age and composition of the waste, the quantity of waste and the landfill design and operations. Leachate strength typically increases in initial years of operation, but then stabilizes and decreases in subsequent years of operation.

More recent data indicative of present conditions at the landfill are presented in Tables 2, 3, and 4. The data indicate that the concentrations of BOD, Total Suspended Solids, and volatile organics are reducing with time.

The concentration of Total Toxic Organics (TTO) is also presented in Table 2. The concentration of TTO compounds can be obtained by adding the cumulative concentrations of the following U.S. EPA analytical methods [1].

(a) Method 624—Volatiles

(b) Method 625—Acid and Base/Neutral Extractables

(c) Method 608—Organochlorine Pesticides and PCBs

Total Toxic Organics became an important parameter with the passage of the Metal Finishing Discharge Standards, promulgated by the U.S. EPA in July 1983 [2]. The standards imposed severe restrictions on the concentration of TTO which could be discharged to a municipal sewer system, as well as to surface waters. The recent data show that the levels of TTO are below the city's sewer limit of 4.0 mg/L.

Leachate metals analyses since 1987 are presented in Table 3. The data show high concentrations of iron and zinc which exceed the city's sewer limits. Although manganese was not analyzed in the tabulated sample rounds, it was later found that manganese is typically in the 20–50 mg/L range, thus exceeding the city's sewer limit. Table 4 presents the volatile organic analyses (i.e., results of the U.S. EPA Method 624). The organic compounds repeatedly found in appreciable

TABLE 3 LEACHATE METALS ANALYSES SINCE 1987 CONCENTRATION (mg/L)

METAL	CONCENTRATION (mg/l) 9/2/87	1/29/88	4/14/88	Ave.	Sewer Limits
Antimony	<0.025	<0.025	<0.025	<0.025	N.L
Arsenic	0.023	0.14	0.009	0.0573	0.7
Beryllium	0.058	<0.010	<0.010	0.026	N.L
Cadmium	<0.005	0.17	<0.010	0.062	0.2
Chromium	0.20	0.46	<0.020	0.227	8.4
Copper	<0.02	0.20	<0.020	0.08	3.0
Lead	<0.005	0.15	<0.005	0.053	0.6
Mercury	0.0080	<0.0010	<0.0005	0.003	0.1
Nickel	0.15	0.14	<0.020	0.103	2.2
Selenium	<0.010	<0.10	<0.010	<0.04	N.L
Silver	<0.02	<0.020	<0.010	<0.017	1.2
Thallium	<0.050	<0.010	<0.010	<0.023	N.L
Zinc	5.8	2.9	0.063	2.92	3.5
Iron	650	580	19	416	10
Manganese	N.A	N.A	N.A	N.A	5

N.L indicates no limit has been established.

N.A indicates that the metal was not analyzed for.

TABLE 4 LEACHATE VOLATILE ORGANICS ANALYSES SINCE 1987

CONSTITUENTS[1]	CONCENTRATION (ug/l) 9/2/87	1/29/88	4/14/88	Ave.
Chloromethane	<25	<15	<10	<16.7
Bromomethane	<25	<15	<10	<16.7
Vinyl Chloride	<25	<15	<10	<16.7
Chloroethane	<25	<15	<10	<16.7
Methylene Chloride	1495	840	220	851.7
Trichlorofluoromethane	<25	<15	<10	<16.7
1,1-Dichloroethylene	<25	<15	<10	<16.7
1,1-Dichloroethane	292	103	<10	135
Trans-1,2-Dichloroethylene	41	19	<10	23.3
Chloroform	<25	<15	<10	<16.7
1,2-Dichloroethane	<25	<15	<10	<16.7
1,1,1-Trichloroethane	241	63	13	105.7
Carbon Tetrachloride	<25	<15	<10	<16.7
Bromochloromethane	<25	<15	<10	<16.7
1,2-Dichloropropane	<25	<15	<10	<16.7
Trans-1,3-Dichloropropane	<25	<15	<10	<16.7
Trichloroethylene	48	20	<10	26
Dibromochloromethane	<25	<15	<10	<16.7
Cis-1,3-Dichloropropane	<25	<15	<10	<16.7
1,1,2-Trichloroethane	<25	<15	<10	<16.7
Benzene	<25	<15	<10	<16.7
2-Chloroethylvinylether	<25	<15	<10	<16.7
Bromoform	<25	<15	<10	<16.7
1,1,2,2-Tetrachloroethylene	43	<15	<10	22.7
1,1,2,2-Tetrachloroethane	<25	<15	<10	<16.7
Toluene	397	190	30	205.7
Chlorobenzene	<25	<15	<10	<16.7
Ethylebenzene	55	20	<10	28.3
TOTAL VOLATILES	2612	1255	263	1377

[1] Only volatile organic compounds on EPA's Total Toxic Organics List are presented.

quantities are: methylene chloride, 1,1-dichloroethane, trans-1,2-dichloroethylene, 1,1,1-trichloroethane, trichloroethylene, 1,1,2,2-tetrachloroethylene, toluene, and ethyl benzene.

PROPOSED TREATMENT PROCESS

Examining the leachate data and the city's sewer limits, presented in Tables 1–4, it became clear that the leachate would require treatment for BOD, COD, TSS, metals (primarily iron, manganese, and zinc), and possibly TTO. However, there were some considerations which affected the selection of a treatment process. The city sewer ordinance allowed the limits on BOD, COD, and TSS to be exceeded provided that the discharger pay a surcharge to the city. These parameters will be treated for in the city's wastewater treatment plant (WWTP). Based on the data prior to 1987, treatment for TTO removal would be required, but the recent data indicated that TTO was within the city limits. Thus, there was no need to treat for TTO removal.

Considering the above, it was determined that the most cost-effective treatment alternative was to provide metals removal, neutralization, and discharge of the pretreated effluent to the city sewer system. Treatment for reduction of BOD, COD, and TSS would not be provided since these parameters would be treated for at the city's WWTP. Concerning the TTO limit, after consultation with the regulatory agencies, it was agreed that since the recent TTO data was below the sewer limit, pretreatment for TTO removal would not be required.

The final recommended process schematic of the pretreatment system is shown in Fig. 1. The leachate is pumped from two underground, fiberglass storage tanks to a solids contact clarifier where lime and polymer are added. The main reaction, caused by the lime, is chemical precipitation in which dissolved metals (in anionic form) are converted to insoluable metal hydroxides. The polymer is used as a flocculating aid to help agglomerate fine floc particles and thereby create a faster settling floc as well as a clearer supernatant (effluent). Air addition was considered to convert iron from the ferrous to ferric state and thereby enhance the precipitation reaction. However, this option was ruled out because of possible release of odors. The solids contact clarifier is divided into three zones to accomplish the above physical and chemical reactions: a rapid mix zone, a flocculation zone, and a clarification

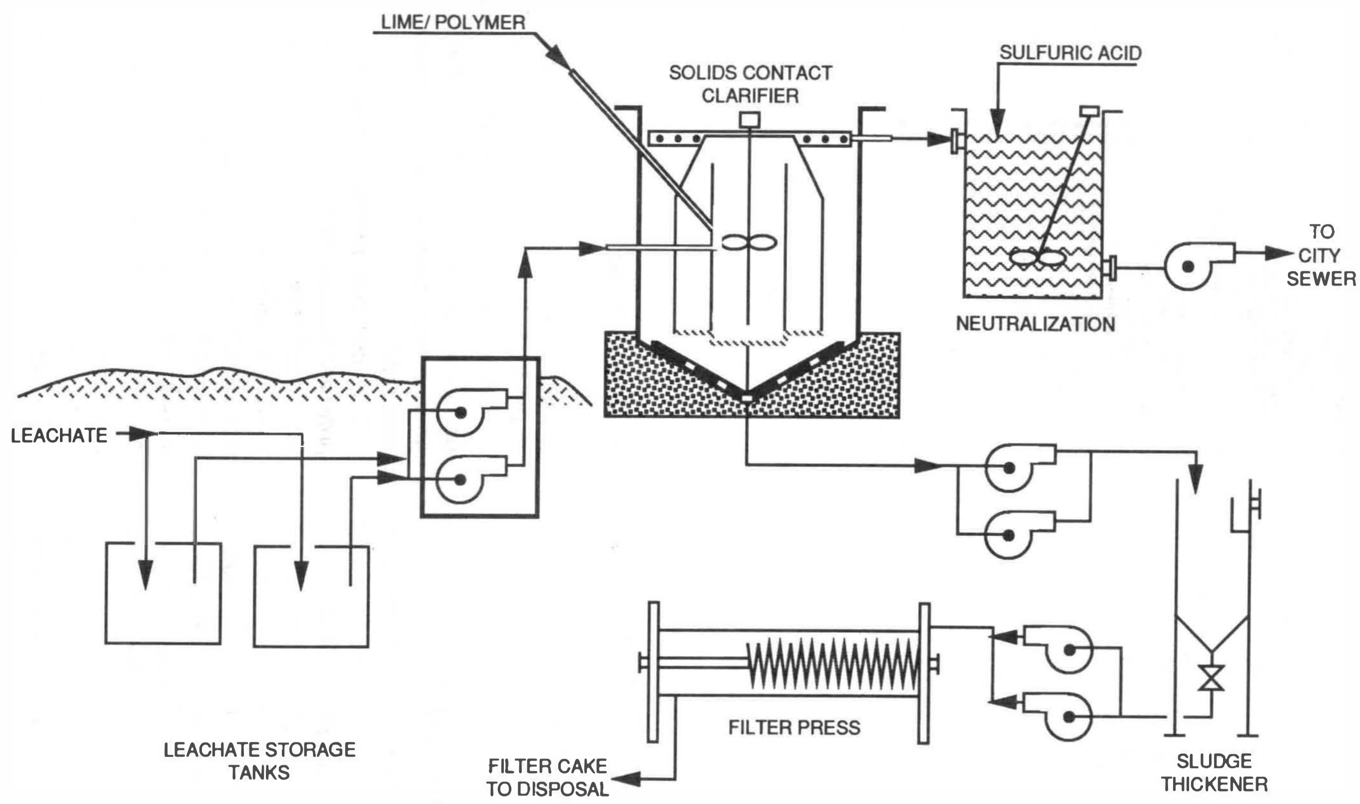

FIG. 1 RECOMMENDED PRETREATMENT SYSTEM

TABLE 5 TREATABILITY STUDY — FIRST SET OF TESTS

In each of the following tests, hydrated lime $Ca(OH)_2$ and a cationic polymer were rapid mixed for approximately 3.5 minutes with 1000 ml of leachate and then let settle. The tests were performed to observe the effect of different lime and polymer dosages on supernatant quality and metals concentrations, sludge settling rate, and sludge quantity. Settling time listed below is the elapsed time after rapid mixing to achieve approximately 800 ml of clear supernatant and 200 ml of settled sludge.

Date of Test	Sample ID	Test Conditions	Results
4/30/88	Jar 1	Low lime (1.0 gm) Low polymer (0.02 gm)	Cloudy supernatant, slow-settling suspension, low sludge quantity (50 ml)
4/30/88	Jar 2	Low lime (1.0 gm) High polymer (0.05 gm)	Cloudy supernatant, non-settling suspension, low sludge quantity (50-70 ml)
4/30/88	Jar 3	Medium lime (2.0 gm) High polymer (0.05 gm)	Clear supernatant, rapid-settling sludge, settling time = 2 min., high sludge quantity (180 ml at 0.93% solids), pH of supernatant = 7.4
4/30/88	Jar 4	High lime (4.0 gm) No polymer	Very clear supernatant, slow settling sludge, settling time = 36 min., high sludge quantity (200 ml at 1.90% solids), pH of supernatant = 11.6
4/30/88	Jar 5	Med-High lime (3.0 gm) High polymer (0.076 gm)	Very clear supernatant, slow settling sludge, settling time = 32 min., high sludge quantity (210 ml at 1.43% solids), pH of supernatant = 8.35, supernatant metals conc. in mg/l:

iron	=	39.0
mangenese	=	3.7
antimony	=	<0.025
arsenic	=	0.012
beryllium	=	<0.010
cadmium	=	<0.010
chromium	=	0.024
copper	=	<0.02
lead	=	<0.05
mercury	=	<0.0005
nickel	=	<0.023
selenium	=	<0.010
silver	=	<0.020
thallium	=	<0.010
zinc	=	<0.020

TABLE 6 TREATABILITY STUDY — SECOND SET OF TESTS

The second set of treatability tests were performed similar to the first set. (Hydrated lime and cationic polymer were added to 1000 ml of leachate, rapid mixed for 3.5 minutes, and then let settle). This set of tests was performed to observe the effect of pH on metals removal. The pH of the supernatant and iron and manganese concentrations (in mg/l) of the supernatant are listed below.

Date of Test	Sample ID	Tests Conditions	Results
6/7/88	1	High lime (3.4 gm) High polymer (0.076 gm)	pH = 10.6 iron = 1.37 manganese = 0.13
6/7/88	2	High lime (3.6 gm) High polymer (0.076 gm)	pH = 10.1 iron = 2.62 manganese = 0.33
6/7/88	3	High lime (3.4 gm) High poilymer (0.076 gm)	pH = 9.5 iron = 5.25 manganese = 0.69
6/7/88	4	High lime (3.8 gm) High polymer (0.076 gm)	pH = 11.0 iron = 1.46 manganese = 0.053

zone. The overflow from the solids contact clarifier goes to a neutralization tank where sulfuric acid is added to lower the pH to between 6 and 9. The clear effluent is then pumped to the city sewer.

The metal hydroxide sludge (and excess lime) settle to the bottom of the solids contact clarifier where a rake mechanism helps to concentrate and move the sludge to a center collection well. The sludge is then pumped to a sludge storage tank which serves to thicken as well as store the sludge for subsequent de-watering. The thickened sludge is then pumped to a filter press which dewaters the sludge to a 35–45% solids cake. The cake is hauled to a landfill disposal site. Based on the above conceptual design, treatability studies were performed to confirm and further develop the process design.

TREATABILITY STUDY

Two sets of wastewater treatment studies were performed. The results are presented in Tables 5 and 6. The first set of tests was performed to observe the effect of different lime and polymer dosages on supernatant quality and metals concentration, sludge settling rate, and sludge quantity. The results in Table 5 show that a medium to high lime dosage of 3.0–4.0 g per 1000 ml of leachate produces a very clear supernatant, but a relatively slow settling sludge. The quantity of sludge after 35 min of settling is approximately one fifth (200 ml of sludge) of the original sample volume. The solids concentration of the settled sludge is approximately 1.43–1.90% solids. Based on these results, for the average design flow of 15,000 gal/day (57 m^3/d); approximately 375–500 lb/day (170–227 kg/d) of lime will be required and 1100–1400 lb (499–635 kg) of dewatered cake at 35% solids will be produced. Note that at pH of 8.35, the concentration of iron in the supernatant exceeded the city sewer limit of 10 mg/L. All the other metals were at levels below the city sewer limits.

In the second set of tests, the effect of pH on the concentration of iron and manganese in the supernatant was investigated and the results are presented in Table 6. The results show that at pH levels of 9.5 or greater the concentrations of iron and manganese are lowered to below the city sewer limit. The lowest concentrations of iron and manganese were achieved at the highest pH tested 11.0. In conclusion, the treatability studies show that lime precipitation can reduce the concentration of metals in the leachate to below the city sewer limits, provided the pH is raised to 9.5 or greater.

Additional tests were run to determine if there was any advantage to using caustic (sodium hydroxide) instead of lime as the precipitant. In general, these tests showed that with caustic much less sludge is produced, approximately one third as much as in the lime precipitation case. The sludge volume using caustic was approximately 70 ml versus 200 ml of sludge using lime, based on a initial 1000 ml sample of leachate. However, the floc from caustic addition was very fine and very slow settling. The above sludge volume in the caustic case was achieved after several hours of settling versus 35 min for the lime case. In addition, the supernatant for the caustic case was murky and turbid from suspended floc particles versus the crystal clear supernatant in the lime case. Therefore, due to the superior settling characteristics of the lime sludge and greater assurance of meeting the effluent criteria on metal concentrations, it was decided to use lime instead of caustic as the precipitant.

FINAL DESIGN AND CONSTRUCTION

Based on the results of the treatability studies, design criteria for the leachate pretreatment plant were developed. The criteria served as the basis of the final design of the pretreatment facility and are presented in Table 7.

The plant was designed to treat the average daily flow 15,000 gpd (57 m^3/d) in one 8 hr shift. Future and peak flows would be handled by increasing the operating hours. The solids contact clarifier is conservatively sized based on a clarifier overflow rate of 0.40 gallons per minute per square foot (gpm/ft^2) (16 L/min/m^2). Typical surface loading rates for settling light metallic floc suspensions vary from 0.35 to 0.83 gpm/ft^2 (14–34 L/min/m^2), according to water treatment texts [3, 4]. The 12 ft (3.66 m) diameter solids contact clarifier is the smallest, standard commercially available unit, and it was selected to avoid the additional expense of a smaller, custom-designed unit. The lime is added to the solids contact clarifier as a 5–10% slurry. The lime is purchased in hydrated form in 50 lb (23 kg) bags.

The sludge storage tank is conservatively sized to allow about three days of thickened sludge storage capacity, assuming a 4% solids concentration. This allows dewatering operations to be scheduled about two times per week. The 12 ft^3 (0.34 m^3) filter press is amply sized to handle about one day's sludge production in one filter press cycle. Note that sludge production and final cake solids are very variable and largely dependent on the TSS level of the influent leachate.

TABLE 7 DESIGN CRITERIA FOR RECOMMENDED LEACHATE PRETREATMENT PLANT

I.	DESIGN BASIS	
	Leachate Daily Flows - Average	15,000 gpd (57 m^3/d)
	- Average (future)	30,000 gpd (114 m^3/d)
	- Maximum	50,000 gpd (189 m^3/d)
	Plant Design Flow Rate 6.25 hr/day operation for average flow 12.5 hr/day operation for future average flow 20.8 hr/day operation for maximum flow	40 gpm (151 L/min)
	Plant Operations (includes time for start-up and shutdown) One 8-hr shift per day for average flow Two 8-hr shifts per day for future average flow Three 8-hr shifts per day for maximum flow	
	Total Metals Content (excluding iron)	2-13 mg/l
	Iron Content	200-1000 mg/l
II.	SOLIDS CONTACT CLARIFIER	
	Design Flow	40 gpm (151 L/min)
	Minimum Hydraulic Detention Time in Flocculation Zone	30 minutes
	Chemical Use at Average Leachate Flow of 15,000 gpd (57 m^3/d)	
	- Hydrated Lime (slurry 5% to 10%)	375 lbs/day (170 kg/d)
	- Polymer	9.5 lbs/day (4.3 kg/d)
	Clarifier Overflow Rate	0.40 gpm per sq. ft. (16 L/min/m^2)
	Effluent Criteria	
	Parameter	**Maximum Effluent Conc. (mg/l)**
	Iron	10.0
	Silver	1.2
	Cadmium	0.2
	Chromium	8.4
	Copper	3.0
	Nickel	2.2
	Lead	0.6
	Zinc	3.5
	Mercury	0.1
	Manganese	5.0
	Arsenic	0.7
	pH	6-9
III.	SLUDGE STORAGE TANK	
	Number of Units	1
	Capacity	4500 gal. (17.033 L)
	Total Storage Capacity	1-1/2 days
	Thickened Sludge Quantity from	1400 gal. (5299 L) @ 4% solids
	to	700 gal. (2650 L) @ 8% solids
IV.	FILTER PRESS	
	Type	Plate and Frame
	Capacity	12 cu. ft./cycle-day (340 L/cycle-d)
	Number of Plates	24
	Size of Plates	31 inches by 31 inches (790 mm × 790 mm)
	Quantity of Sludge Cake	12 cu. ft./day (0.34 m^3)
	Cake Solids	35 - 45%
V.	NEUTRALIZATION TANK	
	Hydraulic Detention Time	10 minutes
	Acid Use.	11 gal./day (42 L/d) of 93% H_2SO_4
	Effluent pH	6-9
VI.	EFFLUENT PUMP	
	Number of Units	2
	Design Flow	40 gpm (151 L/min)
	Discharge	To sewer system

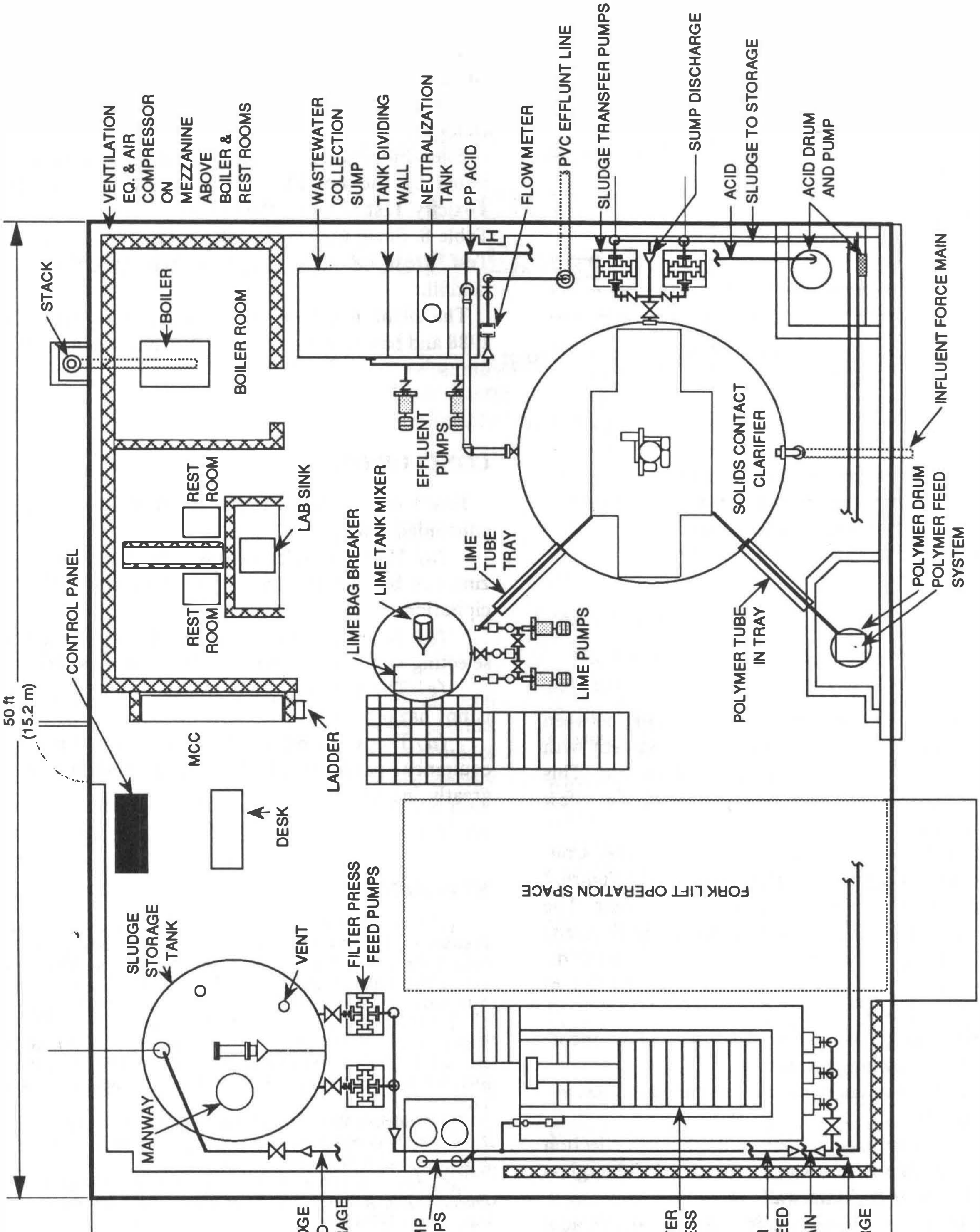

FIG. 2 PLAN VIEW OF LEACHATE PRETREATMENT PLANT

TABLE 8 RESULTS OF EXTRACTION PROCEDURE TOXICITY TEST

	Run 1	Run 2	Run 3	Maximum EP Concentration (mg/l)
Lime Dose (mg/l)	2,480	2,830	3,060	---
Suspended Solids After Lime Dose (mg/l)	17,000	5,700	5,300	---
Percent solids in Dewatered Sludge	46.6	20.6	26.0	---
Solids Production lbs./1,000 gallons (kg/1,000 Liters)	142 (17.1)	47.5 (5.69)	44.2 (5.30)	---
Sludge pH (units)	7.3	10.8	10.3	---
EP Results *				
Arsenic (mg/l)	0.008	BDL (1)	BDL	5.0
Barium (mg/l)	1.0	0.5	0.14	100.0
Cadmium (mg/l)	0.02	0.02	0.02	1.0
Chromium (mg/l)	0.03	0.04	0.04	5.0
Lead (mg/l)	0.20	0.24	0.21	5.0
Mercury (mg/l)	BDL	0.0021	BDL	0.2
Selenium (mg/l)	0.007	BDL	BDL	5.0
Silver (mg/l)	0.02	0.02	0.02	5.0
Zinc (mg/l)	0.92	0.09	0.17	---
Final EP pH (Units)	5.2	6.2	6.3	---
Acetic Acid Used (ml of 0.5 N)	400	400	400	---

* EP Toxicity Test run on equivalent of 100 grams of sludge at 35% solids content.

(1) BDL = Below Detection Limit.

The clarified effluent is neutralized to a pH between 6 and 9 using a single stage pH control system with a neutralization tank detention time of 10 min. This system is capable of controlling pH to within a few tenths of a pH unit.

The facility was designed and built in 1988. Construction was completed in December 1988. Figure 2 shows the floor plan of the pretreatment plant. The process equipment is compactly-arranged to fit inside a prefabricated, metal-wall building with overall dimensions of 40 ft × 50 ft × 24 ft in height (12.2 m × 15.2 m × 7.3 m in height).

The final design of the pretreatment plant incorporates the following features:

(a) All process tanks are covered to minimize release of odors.

(b) The neutralization tank and effluent collection sump are combined in a single, rectangular fiberglass tank with center dividing wall.

(c) For sludge transfer air-operated diaphragm pumps are used.

(d) To increase overall plant reliability, two pumps (one operating and one spare) are provided at all pump locations and spares of all major mechanical components, such as the solids contact clarifier turbine and rake drive mechanism, are provided.

(e) To comply with state water pollution control regulations, an oil-fired diesel engine driven generator was provided to supply emergency power in the event of an electrical power outage. An automatic transfer switch will activate the generator upon loss of power. The generator is located outside in a weather-proof enclosure.

The sludge cake produced from the process was tested by the US EPA Extraction Procedure (EP) Toxicity Test [5], and the test results are presented in Table 8. Since the sludge cake passes the EP Toxicity Test, it can be disposed of at a conventional sanitary landfill.

The plant has been in operation since December 1988 and has been consistently meeting the city's sewer limits.

CONCLUSIONS

Based on the findings presented above, it can be concluded that:

(a) Heavy metals such as iron, manganese, and zinc can be removed from the leachate by lime precipitation.

(b) A jar test treatability study is essential for selecting suitable process and design parameters.

(c) The sludge cake produced from the process is not hazardous.

(d) By providing redundant pumps and essential equipment parts, the plant's overall reliability can be greatly increased.

REFERENCES

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Key Words: Heavy Metals; Landfill; Leachate; Organic(s); Pretreatment; Sludge; Waste Control