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Project Summary

Performance Evaluation at a Long-Term Food Processing Land Treatment Site

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The objective of this project was to determine the performance of a full-scale, operating overland flow land (OLF) treatment system treating non-hazardous waste. Performance was evaluated in terms of treatment of the applied waste and the environmental impact of the system, particularly on surface and ground water quality. Performance data were obtained from the Campbell Soup (Texas), Inc. OLF system in Paris, TX, which has been in operation for over 24 years. Field samples of soil, wastewater, OLF runoff, and ground water collected during the project and long-term process records maintained by Campbell Soup were used as part of the evaluation. The long-term operation and performance data indicated that the OLF system consistently achieved a very high level of treatment and pollutant removal, from a surface discharge standpoint. Removals of BOD_5, COD, TOC, and TSS have been consistently high with mean individual pollutant removals of >92% (mass basis) and >93% (concentration basis). Total nitrogen removals were between 84 and 89%. Effluent mass discharges have remained well within the regulatory limitations for suspended solids and BOD_5 over the 24 years that the site has been in operation. Although the accumulation of zinc and nickel was evident, the cumulative soil concentrations (200 kg/ha and 85 kg/ha) were well below EPA recommended limits (1,120 kg/ha and 560 kg/ha) and several hundred years of continued site use may be expected at present average loading rates (3 kg/d and 0.2 kg/d). The OLF site was underlain by several meters of a heavy inorganic clay (Bonham Formation). A semiconfined aquifer, partially confined from above by the Bonham Formation clays and slowly recharged by downward leakage of treated wastewater and precipitation through the Bonham Formation exists below the OLF site. The aquifer is confined from below by the dense, fissile shale of the Eagle Ford Group. Ground water below the OLF site was moderately saline due to the presence of sodium, calcium, magnesium, chloride, and sulfate. No purgeable or extractable organics were detected. Geochemical data indicated that sulfate-chloride facies were dominant for the ground water collected at three monitoring wells at the OLF site and for lysimeter data collected in 1968. A pattern of increasing ionic composition over time (1968 to 1989) with relatively small changes in ionic ratios suggested a trend toward the dissolution (due to the infiltration of large volumes of treated wastewater) and concentration of naturally present minerals (in the soil) in the relatively slow moving groundwater.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Resource Conservation and Recovery Act (RCRA) Amendments of 1984 require the U.S. Environmental Protection Agency (EPA) to assess the adequacy of current federal programs to protect human health and the environment from mismanagement of non-hazardous and unlisted hazardous wastes. Because the land disposal options of concern for listed hazardous wastes include landfills, land treatment, waste piles, surface impoundments and salt domes, the EPA evaluation of RCRA Subtitle D unlisted wastes includes these options. As a result, information is needed to support EPA activities related to the evaluation of Subtitle D wastes.

The EPA Office of Solid Waste (OSW) has assessed the extent of land disposal for Subtitle D industrial wastes. The assessment indicated that at least 145 million metric tons of industrial non-hazardous waste (35% of all such waste) are managed by on-site landfills, surface impoundments and land application. The OSW assessment also indicated significant missing information, especially data related to the performance achieved when such disposal options are used. Much of the available data were over 10 years old and little information existed on the impact that such operating land disposal options have on human health and the environment.

Objectives

The primary objective of this project was to determine the performance of a full-scale, operating overland flow (OLF) land treatment facility treating non-hazardous waste. Performance was to be evaluated in terms of pollutant reduction and removal from the applied waste and the environmental impact of the system, particularly surface and groundwater quality. Performance data were to be obtained from a land treatment system that had been operating for an extended period of time to permit the evaluation of long-term performance trends.

OLF Site Description

The Campbell Soup (Texas), Inc. OLF treatment system located in Paris, Texas, was utilized for all research described in this report. The plant processes about one billion cans of soup per year and employs about 1,600 people. The site has about 364 hectares (700 ac) that are being used for the land treatment of vegetable processing wastewater by the OLF method. About 16,000 cubic meters/day (4.25 mgd) are handled in this manner. Only the vegetable processing and can preparation wastewaters are applied to the site. All sanitary wastewaters from the plant are discharged to the Paris, Texas, municipal wastewater treatment plant. In addition, all storm water and can cooling water are handled separately and discharged directly to surface streams.

The size of the land treatment system has increased over the years. The original site (1964) consisted of 120 ha (300 ac). Three expansions have occurred: each of approximately 80 ha (200 ac). The expansions resulted in a total of 365 ha (900 ac) being included in the OLF system. Not all of the site is available for wastewater treatment and over 485 ha (1,200 ac) comprise the entire site.

The original fields have been in operation the longest, since the 1960's. The second set of fields began to be used in the early 1970's and in the late 1970's the third set of fields began to be used. This allowed the opportunity to evaluate soils that have received wastes for different time periods.

About 1.5 cm (hydraulic application rate) of wastewater are applied to the wetted acreage each day. Prior to application, the wastewater is screened to remove large solids, and grease is skimmed. The plant and the land treatment site operate all year. No storage is used. The wastewater is pumped directly from a 375-cubic meter sump (100,000-gallon) and is applied by spray nozzles that have a spray diameter of 30 m (150 ft). The overland flow slopes are about 55 m (170 ft) in length.,

The soils at site are clays and sandy clay loams. A semiconfined aquifer exists below the site. Depth to this aquifer from the ground surface varies between 5 m and 10 m (15 to 30 ft). The vegetation on the land treatment site is Reed canary grass and tall fescue. The crop is harvested 2 to 3 times per year and used as forage in the local area.

The Paris, Texas site was evaluated in considerable detail in the late 1960's. The early research focused on the surface hydrology and treatment performance of the system. These early studies served as sources of basic information and as "background" data. In addition, many of the Campbell Soup personnel and the RSKERL personnel who were involved in the earlier research were still active and were able to participate in this project. Thus, considerable "historical memory" and knowledge about the plant, available data and the operation of the OLF system was available to the project.

Campbell Soup agreed to cooperate as actively as possible in the study, to assist with the sampling that was performed and to provide the available historical operational and other data. This included available wastewater characteristic data, effluent monitoring data and weather data. The wastewater data represented the material from the sump and therefore the characteristics of the wastewater actually applied to the site. Such data had been collected approximately twice per month for 10 years. In addition, effluent monitoring data have been collected three times a week for 10 years and daily climatological data covering a 15-year period were available.

Raw Waste Characteristics

Comprehensive records of raw waste characteristics and flow, covering the period between 1977 and 1988, were made available by Campbell Soup for this research. Composite samples were collected from the sump several times each month (two to three composite samples) and typically were analyzed for BOD_5, COD, oil and grease, TSS, VSS, chloride, and sulfate.

Application rates (wetted area basis) have varied substantially over the 24 years of operation; however, statistical analyses of the cumulative raw data revealed that waste characteristics and mass loading were relatively constant over the 10-year period of record.

The sump wastewater characteristics for the 10-year period between 1977 and 1988 are summarized in Table 1. Comparison of several of these parameters with values reported from the 1960s indicated that most values from the 1960's data were within or very near the limits of 95% confidence intervals about the mean of the 1977-1988 data. In general, it appeared that waste characteristics have remained relatively constant without significant deviation from the mean over the life of the site. This constancy permitted direct comparisons to be made of process performance over the 25-year period of operation.

OLF System Performance

Because Federal and State regulatory limitations have been established for flow, BOD_5 and TSS loads discharged from the Paris, Texas site, an evaluation of the degree of compliance within these limits served as a convenient and common measure of system performance. Daily average waste loading values (monthly

Table 1. Long-Term Mean Wastewater Concentrations and Loading to OLF Site Period: 1977-1988

Wastewater Parameters	Mean Concentration, mg/L	Standard Deviation, mg/L	Mean Load kg/d	Standard Deviation, kg/d
BOD_5	550	210	8,950	4,100
COD	1,190	520	19,600	9,555
Oil/Grease	125	80	2,170	1,345
TSS	425	210	7,085	3,730
VSS	370	200	6,330	3,640
Cl^-	66	47	1,060	780
SO_4^{2-}	40	40	633	320
NH_4^+-N	0.7	0.7	13	9
Org-N	27	27	480	178
NO_3-N	0.33	0.33	6	10
NO_2-N	0.03	0.03	0.4	0.2
Total-P	6	6	91	39
Sodium	47	16	760	255
Potassium	24	12	390	195
Calcium	45	24	725	380
Magnesium	4.0	1.4	65	22
Iron	0.71	0.41	11	7
Manganese	0.04	0.03	1	1
Aluminum	0.72	0.63	12	10
Zinc	0.17	0.11	3	2
Strontium	0.08	0.08	3	1

means) over the period between 1974 and 1988 indicated that the water quality in Smith Creek (representing the combined flow of OLF runoff and natural stream flow from offsite) was continuously well below regulatory limits. A summary of these data (Table 2) illustrates the exemplary permit compliance achieved by the OLF system.

Mass balances were made around the Paris, Texas land treatment site using daily upstream and downstream (Smith Creek) flow and concentration data; and daily raw waste flow and concentration data supplied by Campbell Soup. Because no monthly or seasonal trends were observed for either raw wastewater loading or in-stream loading in Smith Creek, the daily data were used for the mass balance calculations.

Since the actual land treatment site runoff was not measured, an assumption of the applied wastewater that was discharged as runoff was needed. Previous research has shown that the runoff percentage at the Paris, Texas site varied seasonally, between 44 and 72%; with 60% as the mean. In addition, variation in application rate, wetted acreage and soil properties could have also affected the runoff percentage. Therefore, it was assumed that a value of 60% was a suitable estimate for the percentage of runoff flow. As a result, the concentration values shown in Table 3 are not exact, but are estimates which provide an approximation of the overall system performance.

The data in Table 3 indicate that mass removal and concentration change percentages for all parameters are generally in excess of 90%. The data from 1969 show excellent agreement with the estimated values from the 1977-1988 period. Thus, it appears that process performance remained relatively stable and a high degree of efficiency was maintained over the entire 24-year life of the system.

Soils

Soil samples were collected at specific wastewater application areas and at one location onsite which had not been subjected to wastewater application. The soil properties within this "control" area provided a comparative measure for the evaluation of the long-term impacts of wastewater application on soils within the treatment area. In addition, where appropriate data were available, direct comparisons of soil properties were made between recently collected samples and previously published results for the Paris, Texas site. The soils were analyzed for organic carbon, pH, cation exchange capacity, 24 metals, and chloride and sulfate.

Several statistically significant ($p \leq 0.05$) trends were discerned for the total metal soil concentration data and the calculated pore water concentrations. With respect to the control area, accumulation of organic carbon, potassium, magnesium, zinc, and nickel in the soil at the wastewater application areas were evident, as well as leaching of calcium, sodium, and sulfate and possibly chloride, zinc, and nickel. Neither accumulation nor leaching of chromium was evident.

Although the accumulation of zinc and nickel was evident, the accumulation was so small that several hundred years of

Table 2. *Effluent Loads in Smith Creek and Permit Limitations*

Parameter[a]	Mean Load	95% Confidence Interval	Daily Ave. Max. Limit
BOD_5	80	$71 < x < 80$	606
TSS	445	$378 < x < 512$	2,270
VSS	190	$162 < x < 218$	NA

[a]*Units of load, kg/d.*
NA = Not appliable, no regulatory limit established for VSS.

Table 3. *Mass Balance Results for the Paris, Texas OLF Site*

Parameters	BOD_5	COD	TOC	TSS	T-N
Runoff concentration (mg/L)					
1977-1988 (calculated)[a]	6	43	15	32	2
1969 (measured)[b]	9	NA	23	16	3
Concentration reduction (%)					
1977-1988[c]	98	96	95	93	89
1969[d]	99	NA	NA	94	84
Mass removed (%)[e]					
1977-1988	99	98	97	94	96
1969	99	NA	NA	98	92

[a]*Mean values based on mass balance calculation results.*
[b]*Measured values reported from 1969.*
[c]*Mean values based on paired daily data:raw waste and runoff concentrations.*
[d]*Single values based on single values reported for raw waste and runoff concentrations.*
[e]*Values based on loading rates calculated from flow and concentration data.*

continued site use may be expected at present loading rates before the cumulative zinc and nickel soil concentrations would approach action levels recommended by EPA for agricultural lands.

Hydrogeology

The Paris, Texas area is underlain by hundreds of meters of sediments laid down from the Paleozoic through the Quarternary eras. A continuing cycle of advance and retreat of ancient seas resulted in periods of sediment accumulation alternating with periods of erosion. The Austin Chalk Group outcrops at the Campbell Soup (Texas) Inc. OLF site. The Bonham Formation, within the Austin Group, is a heavy clay with marl about 6- to 15-m thick at the site. The Bonham Formation is underlain by the Eagle Ford Group. The Eagle Ford Group is composed primarily of dark, fissile shale. The contact between the Eagle Ford and Austin Groups is characterized by an erosional surface and is unconformable.

The results of the hydrogeologic investigation indicated that an aquifer existed below the OLF site. Data limitations prevented the definitive classification of the aquifer, i.e., either semi-confined, confined or unconfined.

The available data, however, suggest that the aquifer was semiconfined and that the erosional contact between the Eagle Ford and the Austin Groups may serve as a transmission zone for groundwater within the relatively impermeable clays of the Bonham Formation.

Groundwater level data indicate that the general flow direction is to the northwest with a hydraulic gradient of approximately 0.004m/m. Measured hydraulic conductivity values within this zone (k between 10^{-4} and 10^{-3} cm/s) were substantially greater than typical values for unweathered marine clay and shale (k between 10^{-11} and 10^{-8} cm/s). However, the calculated values were well within the range of hydraulic conductivities reported for fractured rocks as well as for clean sand (k between 10^{-4} and 10^{-3} cm/s). These results indicated that fractures in the Eagle Ford shale and sandy laminae at the weathered contact zone between the Eagle Ford and the Austin Chalk Groups represents a path for the movement of semiconfined groundwater below the Paris, Texas site.

Groundwater Quality

Monitoring wells, MW-1 and MW-2, were sampled approximately twice yearly between 1987 and 1989 to identify the quality of groundwater located within the erosional contact of the Austin and Eagle Ford Groups at the Campbell Soup site. A total of 22 samples were analyzed. The samples were collected on six dates at MW-1 and MW-2, i.e., 11 samples per well. A total of 4 samples from a third well, MW-3, were analyzed. Selected water quality parameters for samples collected from the three monitoring wells are summarized in Table 4.

No extractable organic compounds and purgeable organic compounds were detected in the ground water from any of the wells at any time. Therefore, these constituents were not included in Table 4. The groundwater samples from all 3 wells were moderate to very saline, with TDS values between 7,000 and 13,000 mg/L. The salinity was primarily due to the presence of the following dissolved ions: chloride, sulfate, sodium, calcium, and magnesium. TOC values were low (< 10 mg/L) at all wells and this condition is typical for a groundwater which has not been subjected to contamination by organic material.

Table 4. Groundwater Quality at Campbell Soup Site: Mean Values and Standard Deviation[a]

Constituent[b]	MW-1	MW-2	MW-3
Calcium	472 ± 42	525 ± 32	496 ± 6.5
Magnesium	247 ± 65	129 ± 38	169 ± 49
Manganese	0.52 ± 0.11	1.79 ± 0.18	4.20 ± 0.18
Nickel	0.03 ± 0.02	0.03 ± 0.02	0.35 ± 0.0
Potassium	7.9 ± 1.7	8.8 ± 1.55	13.5 ± 3.7
Sodium	2,870 ± 452	2,026 ± 415	1,623 ± 623
Zinc	0.02 ± 0.01	0.02 ± 0.01	1.61 ± 0.21
Chloride	2,151 ± 322	1,856 ± 440	1,200[c]
Sulfate	5,268 ± 834	3,441 ± 76	3,100[c]
Alkalinity as $CaCO_3$	610 ± 42	655 ± 7	27 ± 10
TOC	< 10	< 10	NA
pH	6.9 - 7.2	6.8 - 7.0	4.9 - 5.4

[a]Mean values and standard deviation.
[b] All units in mg/L, except pH.
[c]Single analysis performed.
[d]Range provided for pH.

Several graphical techniques were used to visually examine the similarity in water quality among the three monitoring well locations and lysimeter data collected at the site in 1968. Schoeller plots of major-ion concentrations indicated that water collected from all three monitoring wells exhibited similar ionic composition ratios (Figure 1). Ionic ratios (Figure 2) of major ions in groundwater data collected from lysimeters at the site in 1968 exhibited excellent agreement with comparable ionic ratios for more recent samples (MW-2, 1987-1989). The pattern of increasing ionic composition with relatively small changes in ionic ratios strongly suggested a trend towards the concentration of dissolved minerals in the relatively slow moving groundwater.

The geochemical data indicated that sulfate-chloride facies were dominant for groundwater at all three monitoring wells (MW-1, MW-2, and MW-3) and for the lysimeter data collected in 1968. Thus, the similarity of water quality among well locations as well as the similarity in the pattern of geochemical evolution over the past 24 years was suggested.

The infiltration of treated wastewater, development of semiconfined aquifer, the dissolution of soluble minerals from the soil and resultant effects on the quality of gorundwater below the site were strongly suggested by the ground water geochemical data, soil data, the expected rate of infiltration, field hydraulic conductivity and water level measurements, and the magnitude of the volume of wastewater applied.

Conclusions

Raw Waste Characteristics

1. Over a 10-year period between 1977 and 1988 the main characteristics (BOD_5, COD, chlorides, sulfates and solids mass loadings) of the raw wastewater exhibited normal distributions.

2. Statistical comparison of raw wastewater quality between recent and old data indicated long-term consistency with respect to flow and pollutant concentrations.

3. Individual metal loadings were variable over a 12-month period.

OLF System Performance

4. Seasonally heavy precipitation (>7.5 cm/month) resulted in small increases in TSS mass discharges (200 kg/d to 500 kg/d) within Smith Creek. These increases were well below regulatory mass loading limitations (values) and no statistically significant correlation ($p \leq 0.05$) was found between the TSS loading and precipitation.

5. Small increases in TSS loading in Smith Creek during periods of heavy precipitation were due to upstream (off-site) sources rather than losses form the OLF site.

6. The long-term operation and performance data indicated that the system consistently achieved a very high level of treatment, from a surface discharge standpoint. In-stream concentrations of BOD_5, COD, TOC and TSS indicated that mean removals were greater than 93%. Total nitrogen removals were between 84 and 89%. Effluent mass discharges have remained well within the regulatory limitations for solids and BOD_5 over the past 24 years. Percent removals (mass basis) for BOD_5, COD, TOC and TSS have been consistently high (>92%) over the 24-year life of the site.

Soils

7. With respect to a control area, accumulation of organic carbon, potassium, zinc and nickel in the soil at the wastewater application areas was evident, as well as leaching of calcium, sodium, and sulfate. Neither accumulation nor leaching of chromium, magnesium, and chloride was evident.

8. Although the accumulation of zinc and nickel was evident, the rate of accumulation was small and several

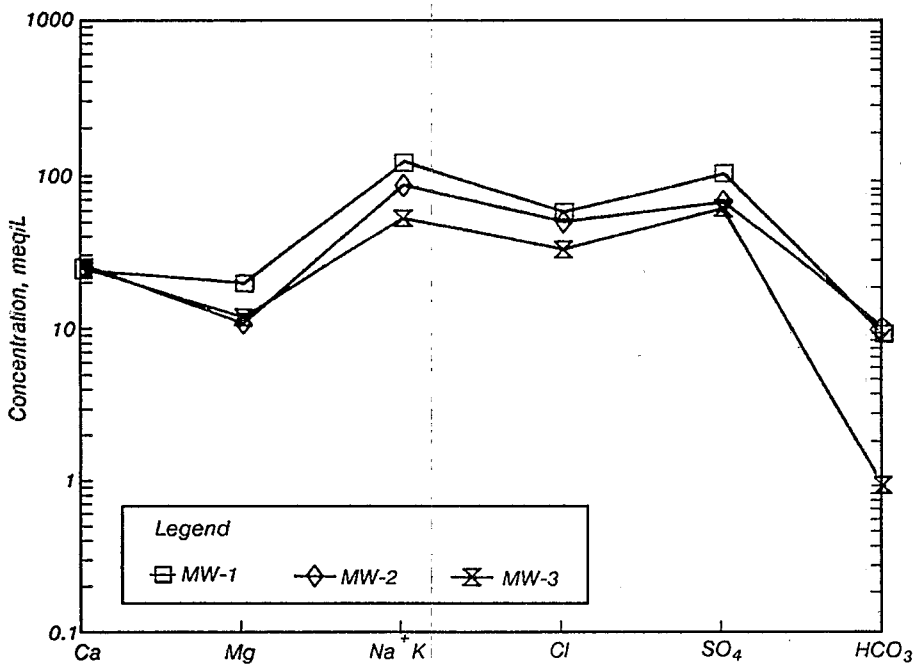

Figure 1. *Schoeller diagram for mean ionic concentrations (major ions) at 3 monitoring wells.*

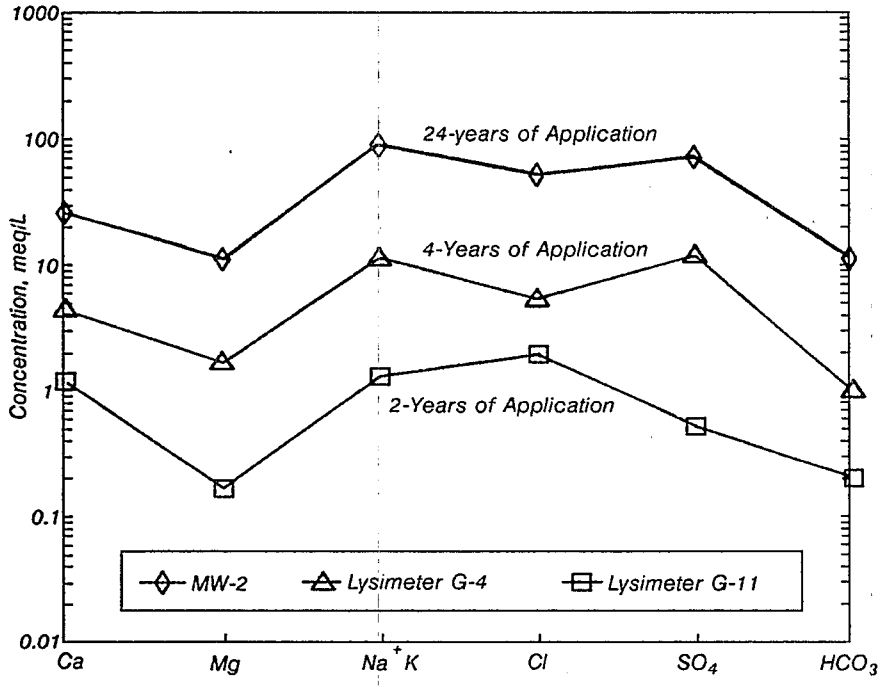

Figure 2. *Schoeller diagram for mean ionic concentrations (major ions) over 24 years.*

hundred years of continued site use may be expected at present loading rates.

Hydrogeology

9. The results of the hydrogeologic investigation indicated that an aquifer exists below the OLF site. The data suggested that the aquifer was semi-confined.

10. The results indicated that the erosional contact between the lower confining unit (Eagle Ford Group) and the aquifer (Bonham Formation within the Austin Group) may serve as a transmission zone for groundwater within the relative impermeable clays of the Bonham Formation. Measured hydraulic conductivity values (average k between 10^{-4} and 10^{-3} cm/s) within the erosional contact zone between the Eagle Ford and Austin Groups were substantially greater than typical values for unweathered marine clay and shale (k between 10^{-11} and 10^{-8} cm/s).

11. Groundwater level data indicated that the general flow direction was to the northwest with a hydraulic gradient of approximately 0.004 m/m.

Groundwater Quality

12. Twenty-six groundwater samples collected from three monitoring wells between 1987 and 1989 were analyzed. The waters were moderately saline (TDS between 7,000 and 13,000 mg/L) due to the presence of Na^+, Ca^{2+}, Mg^{2+}, Cl^-, and SO_4^{2-}. No purgeable or extractable organics were detected.

13. Statistical analysis of the groundwater data indicated that, for the major ions present, groundwater quality at each well remained uniform over the three-year sampling period. Statistically significant differences ($p = 0.05$) in water quality (including calcium, magnesium, manganese, sodium, and sulfate) between the well locations were found.

14. State records indicated that no well casings in Lamar County were screened within the contact zone of the Austin Chalk-Eagle Ford Groups. In addition, no springs which issued from the Bonham Formation were identified within Lamar County or any adjacent counties.

15. The major-ion chemistries (expressed as ionic ratios) of the groundwater samples collected from the confined aquifer were similar at all three monitoring wells. The major-ion composition data suggested the groundwater below the site have undergone similar patterns of geochemical evolution.

16. Ionic ratios of major ions in groundwater data collected from lysimeters at the site in 1968 closely agreed with comparable ionic ratios for more recent samples (1987-1988). The pattern of increasing ionic composition with relatively small changes in ionic ratios strongly suggested a trend towards the concentration of dissolved minerals in the relatively slow moving groundwater.

17. The geochemical data indicated that sulfate-chloride facies were dominant for groundwater at all three monitoring wells (MW-1, MW-2 and MW-3) and for the lysimeter data collected in 1968. Thus, the similarity of water quality among well locations as well as the similarity in the pattern of geochemical evolution over the past 24 years were strongly suggested.

18. The moderately saline aquifer below the OLF site was apparently the result of the enhanced leaching of naturally present, soluble soil minerals due to the infiltration of large volumes (based on estimated percolation rates) of treated wastewater over the past 24 years.

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The complete report, entitled "Performance Evaluation at a Long-Term Food Processing Land Treatment Site," (Order No. PB 90-195 389/AS; Cost: $23.00, subject to change) will be available only from:
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5285 Port Royal Road
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