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Compost Sites

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INVESTIGATION OF GROUNDWATER IMPACTS
AT YARD WASTE COMPOST SITES

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INVESTIGATION OF GROUND WATER IMPACTS AT YARD WASTE COMPOST SITES

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Abstract

Yard waste composting facilities have steadily expanded in the state of Wisconsin. There is some concern regarding these types of facilities because, under certain circumstances, water percolating through yard wastes can generate a leachate that could potentially impact surface water and/or ground water quality. To quantify these potential impacts, the WDNR began a detailed study of two selected yard waste compost sites in Wisconsin.

Groundwater monitoring wells were installed at two operating compost facilities and sampled over the course of the study. Leachate samples were collected at the two study sites and at two other yard waste compost facilities.

The ground water sampling results indicate that downgradient wells at both sites contain elevated levels of nitrate and several other indicator parameters. Results of the leachate sampling yielded relatively high concentrations of many compounds, including ammonia and heavy metals such as lead and chromium.

Introduction

As in many other states throughout the U.S., the number of yard waste composting facilities being sited in the State of Wisconsin has rapidly increased in the past few years. Currently there are approximately 135 approved yard waste composting sites with capacities of between 50 and 20,000 cubic yards (yds³) in Wisconsin, and new sites are continually being licensed. The continued siting of new composting facilities has been driven in most part by the 1989 recycling and waste reduction law, Wisconsin Act 296. As of January 3, 1993 yard wastes have been banned from disposal at municipal solid waste landfills and incinerators unless the materials are burned for energy recovery. With this ban in place, communities and businesses were forced to come up with new ways to manage their yard wastes.

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Even though there is rapid growth in the number of facilities being sited, there remains very little published data indicating the potential environmental impacts from yard waste composting facilities. One purpose of this study is to add to the existing data base of information regarding compounds present in yard waste compost leachate and to evaluate whether these compounds are causing ground water quality impacts beneath and adjacent to these facilities. This aspect of the study is much needed as most composting studies to date have focused on analysis of leachate and surface waters to evaluate the potential for ground water impacts without ever actually sampling ground water quality near the site.

The other purpose of this study is to evaluate the appropriateness of yard waste composting facility regulations in the state of Wisconsin. A recent study (Varsa, 1994) found that regulations pertaining to yard waste composting sites vary considerably from state to state. There does not appear to be any sort of national consensus regarding the most appropriate requirements for siting or operating compost facilities.

Site Descriptions

To protect the identity of the study sites, each facility will be labeled, respectively, "Site A", "Site B", "Site C", and "Site D". Ground water monitoring wells were installed at Sites A and B, while sites C and D were used solely for the collection of supplemental leachate quality data.

Site A

Site A is a large, county operated yard waste composting facility that has approximately 15,000 yds³ of material on site at any given time. The site is located in southern Wisconsin (Figure 1) and serves as a composting site for several nearby municipalities. The site is unlined with no surface water run-off collection. The site slopes gradually to the north and drains into a large wetland complex. The subsurface geology consists of a thick silty sand glacial outwash deposit overlain by a silty clay loess deposit that averages about 6 feet thick. All of the wells at the site were completed in the sand outwash deposit. The water table ranged from 3 feet below the surface near the wetlands to 15 feet below the surface in the upgradient well near the road.

The yard waste is arranged into a series of large (10 to 15 feet high) piles. Waste accepted at the site is neither screened nor shredded prior to placement in a pile and it appears that the majority of the waste is composed of grass clippings. Once a pile is established, it is rarely disturbed and is usually left for a period of one to two years before being distributed to the public. Decomposition is primarily by anaerobic decomposition and large pools of black liquid can typically be found at the base of the piles.

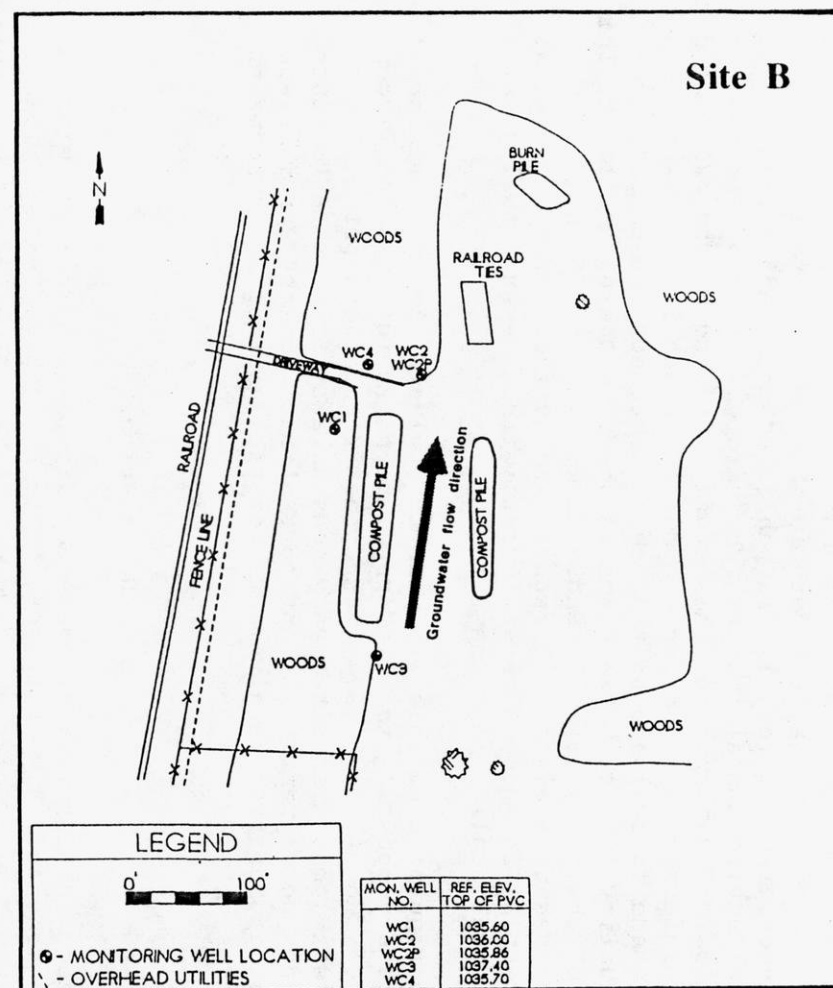
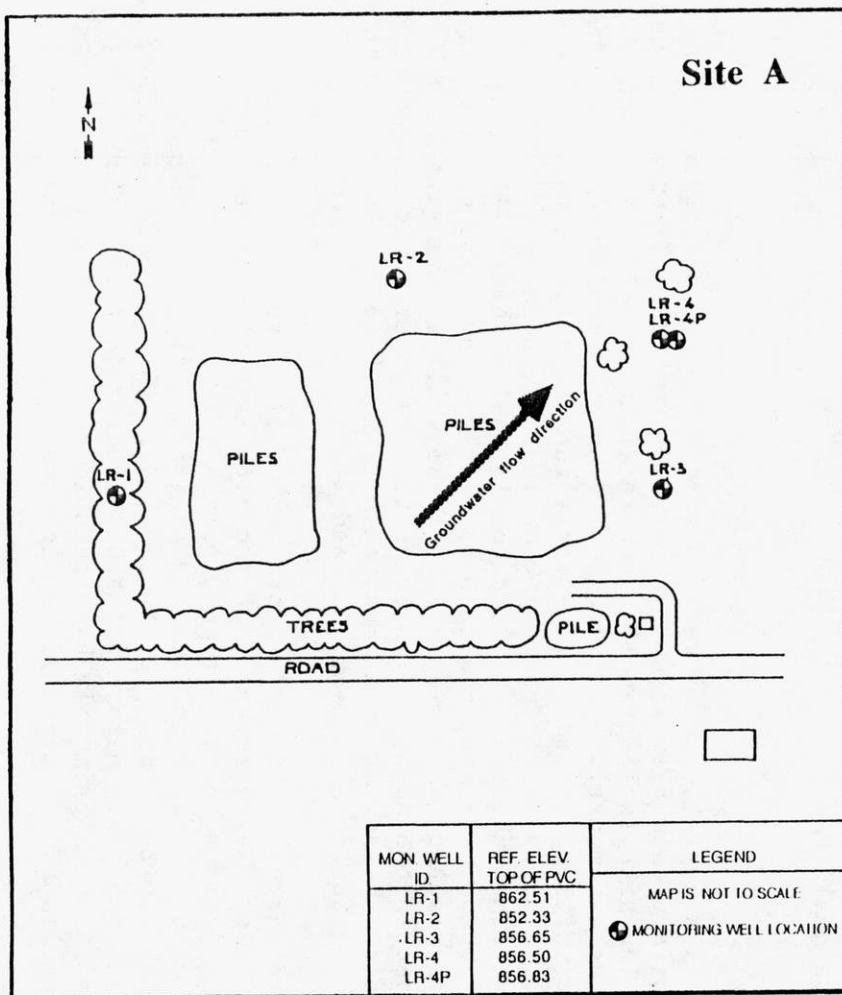


Figure 1, Maps of Study Sites

Site B

Site B is a medium-sized, privately operated yard waste composting facility in central Wisconsin (Figure 1) consisting of approximately 2500 yds³ of material collected from several small gardening services contractors and limited members of the public. The site is unlined and nearly level, but the sandy nature of the soils allows any liquids to infiltrate into the ground fairly rapidly. The sandy outwash deposit is approximately 20 feet thick and overlies a sandy clay deposit of weathered Precambrian bedrock. The monitoring wells are all screened in the outwash deposit and the piezometer is partially screened in the weathered bedrock. The water table is within 10 feet of the surface in all wells.

Waste material is placed into a pile, 100-200 feet long and 9-12 feet high. At the time of the study, there were two piles of this size on site, one pile being slightly older than the other. The piles are turned or moved infrequently, once or twice a year on average. The waste seems to consist mostly of grass and some leaves. Because of the sandy nature of the soils beneath the site, very little liquid accumulates at the base of the piles.

Site C

Site C is a large, municipally-run yard waste composting facility located in central Wisconsin. The site is unlined and fairly flat. Surface water drains to a low, marshy area near the site, but pools of dark liquid commonly form at the base of the piles. Because no wells were installed at the site, the subsurface geology is not known. Generally, the compost is segregated into a series of piles arranged in a rough circle. As a new load of waste material is brought in, each existing pile is moved to the next station and the oldest pile is taken away to be sieved and given away to the public. Exact timing may vary, but on average the piles are moved every few months. The piles are composed mostly of grass clippings and leaves.

Site D

Site D is a large, municipally-run yard waste composting facility located in eastern Wisconsin. The site is unlined, fairly flat and poorly drained. The surface soils appear to consist of low-permeability glacial till material, but, again, because only leachate samples were collected at this location, no detailed geologic investigation was performed. Waste materials consisting of leaves, grass and garden debris are arranged in one of two very large piles. The piles are rarely, if ever, turned and the waste material is allowed to decompose anaerobically. Significant quantities of black leachate frequently collect around the base of the large static piles.

Investigative Methods

A hollow stem auger was used to install five wells at each of sites A and B. The wells were located so that one monitoring well was upgradient to the site and the other three water table monitoring wells were either down or sidegradient (Figure 1). In addition, a piezometer screened below the water table was installed adjacent to one of the downgradient monitoring wells. Well placement was determined by examining regional ground water flow maps. Split spoon samples were collected every five feet during drilling of each well to determine the subsurface geology.

Ground water quality sampling took place over a one year period beginning with April, 1993 and ending with April, 1994. Each well and piezometer was sampled on 5 separate occasions and the sampling events were all at least 2 months apart.

Ground water samples were collected by utilizing a clean, bottom emptying bailer. After the samples were collected, the metals and inorganic samples were run through a 0.45 micron filter and all samples were acidified to preserve them for shipping. Field blanks and duplicates were taken during all sampling rounds. All analyses were conducted by the Wisconsin State Laboratory of Hygiene (SLOH). Tables 1 and 2 contain a detailed list of the parameters analyzed for the study.

Leachate samples were also collected over the study year period, usually coincident with ground water sampling events. The number of leachate samples collected varied considerably because sample collection was dependant on the availability of ponded leachate at the facility. At Site A, ponded leachate was present throughout the year in fairly large quantities, so a total of 11 samples from 4 different sampling events were collected. Only one sample was collected at Site B, however, due to the fact that the sandy soils allowed leachate to infiltrate into the soil very rapidly. A total of 6 samples were obtained at Site C on two different sampling events and 3 samples were collected at Site D from two different sampling events.

The leachate collection procedure consisted of dipping a clean sample jar into the ponded liquid nearest the compost pile and allowing it to fill with liquid. The liquid was then decanted into sample jars and shipped to the SLOH for analysis. All analytical results were reported as totals. The leachate samples were analyzed for the same parameters as the ground water samples with the addition of Biological Oxygen Demand (BOD). Table 5 contains a detailed list the parameters included in the study.

At sites where more than one leachate sample was collected, an attempt was made to collect leachate sample at consistent locations. This procedure worked fairly well at the sites with large, static piles that were seldom disturbed, such as at Sites A and D, but was more difficult at sites where the compost piles were moved. The

variability in the location of leachate pools also made it somewhat difficult to keep the sampling points totally consistent.

Sampling Results

For comparison purposes, all ground water and leachate quality data was compared to the ground water quality standards established by the State of Wisconsin under NR 140 of the Wisconsin Administrative Code. These ground water standards are based on a list of Enforcement Standard (ES) contaminant levels that are equivalent to the U. S. Environmental Protection Agency's Maximum Contaminant Levels (MCLs).

Ground Water

The five rounds of ground water samples collected from monitoring wells at Site A and Site B were analyzed for a variety of parameters including metals, inorganics and nutrients. In addition to these parameters, each well at both sites was sampled once in June of 1993 for the presence of pesticide compounds. Each sample was analyzed for the following commonly used pesticides: 2,4-D, diazinon, malathion, chlorpyrifos, dacthal, captan, alachlor, atrazine, cyanazine, methoxychlor, dicamba, chlorodane, and aldrin.

Site A

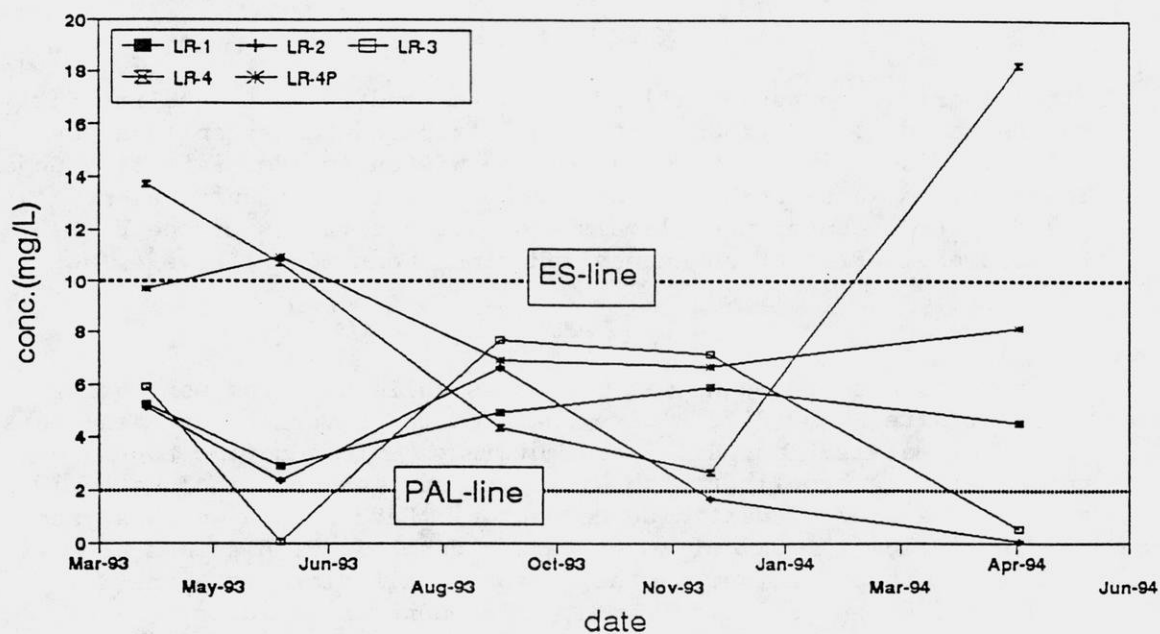
Nitrate+Nitrite as N was detected in every well and at each sampling event, but downgradient well LR-4 frequently had the highest reported levels of this compound. The highest reported nitrate level at this site was 18.3 milligrams per liter (mg/L) which was recorded at well LR-4. At LR-1, the upgradient well, nitrate levels varied between 2.93 mg/L and 5.9 mg/L. The WDNR's Enforcement Standard (ES) level of 10 mg/L was exceeded 3 times in well LR-4 and once at piezometer LR-4P (Figure 2).

Ammonia levels were generally low in all wells with concentrations ranging from below the detection limit (0.005 mg/L) to 0.11 mg/L in well LR-3.

Sulfate was detected at consistently elevated levels in downgradient well LR-4, ranging from a low of 120mg/L to a high of 340 mg/L. The ES for sulfate in ground water (250 mg/L) was exceeded at LR-4 on two separate sampling rounds. In contrast, the upgradient well, LR-1, had reported sulfate levels of between 28 and 46 mg/L. Well LR-2 had levels similar to well LR-1 and wells LR-3 and piezometer LR-4P had slightly elevated sulfate levels.

Chloride levels were significantly elevated in all sidegradient and downgradient wells in comparison with upgradient well LR-1. Chloride values in LR-1 ranged from between 6.9 and 13 mg/L, but ranged from between 22 and 170 mg/L in the side and downgradient wells. Monitoring well LR-3 appeared to be the most impacted well with respect to chloride.

NO₂+NO₃ as N in Groundwater at Site A



NO₂+NO₃ as N in Groundwater at Site B

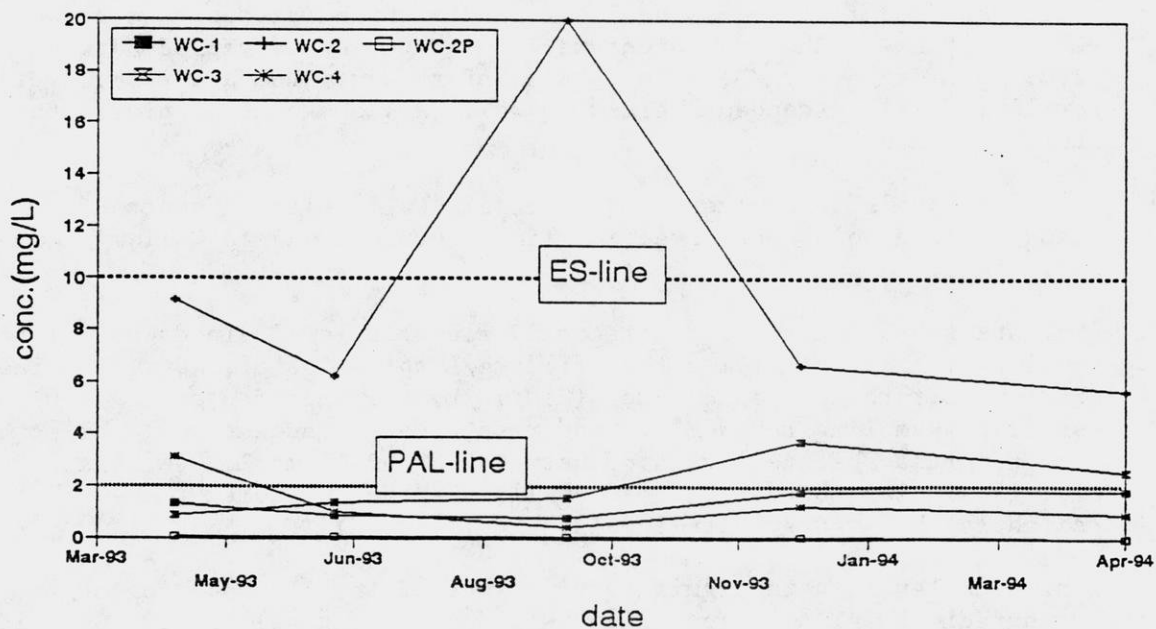


Figure 2

All monitoring wells were analyzed twice for copper and chromium and at least once for lead and cadmium. Only trace amounts of these metals were detected and there did not appear to be any significant difference between upgradient and downgradient wells. Except for one low detect in well LR-2, iron was not detected in any well. Zinc was sampled at each well, but the results were erratic and no discernable trends were noted.

The pH of the ground water in the wells was consistently above 7 and did not vary significantly between wells.

A few other parameters, including Total Dissolved Solids (TDS) and hardness, were slightly more elevated in well LR-4 when compared to concentrations in other on site wells.

The pesticide analyses resulted in two low level detects. Atrazine was detected at 0.13 micrograms per liter (ug/L) in upgradient well LR-1 and at 0.52 ug/L in piezometer LR-4P. No other pesticide compounds were detected.

Site B

As at Site A, nitrate+nitrite as N was detected in all wells at each sampling event. A downgradient monitoring well, WC-2, consistently had the highest nitrate levels during every sampling round with levels ranging from 5.63 mg/L to a high of 20 mg/L with a mean concentration of 8.2 mg/L. In contrast, the upgradient monitoring well, WC-3, had levels ranging from 0.865 to 3.7 mg/L with a mean concentration of 2 mg/L. The lowest concentrations of nitrate were found in piezometer WC-2P with concentrations that hovered around the level of detection (0.007 mg/L). The ES for nitrates (10 mg/L) was exceeded only once during the study at well WC-2 (Figure 2).

Again, ammonia concentrations were generally low through out the site. However, the ammonia levels in downgradient well WC-2 were significantly higher than the concentrations in other wells with one reading as high as 3.5 mg/L. Ammonia levels in the upgradient well WC-3 never exceeded 0.032 mg/L.

The sulfate levels were generally lowest in piezometer WC-2P, but the sulfate levels in the monitoring wells did not differ significantly between wells. Sulfate levels ranged between 16 and 41 mg/L, with the highest sulfate reading actually occurring at the upgradient well, WC-3.

As at Site A, the chloride levels were significantly higher in the immediately downgradient well, WC-2, when compared to concentrations in the upgradient well. Chloride levels in WC-2 ranged from 15 to 38 mg/L, in contrast to the levels in upgradient well WC-3 which had chloride concentrations ranging from below the detection limit of 1 mg/L to 8.3 mg/L. All other wells had low level chloride detects that never exceeded 14 mg/L.

There were some low level detects reported for chromium and copper, but there did not appear to be any significant difference between upgradient and downgradient wells. Lead was not detected in any sample. Iron was detected in all wells and iron concentrations were always highest in piezometer WC-2P.

No pesticides detects were reported in any of the wells.

Leachate

Leachate samples were collected at Sites A, B, C, and D and analyzed for a variety of inorganic parameters, metals, nutrients, and pesticides. The analytical results are summarized in Tables 3 and 4. Minimum, maximum and mean values for the leachate samples are presented in Table 5. The leachate testing results varied widely between sites and even between sampling events at the same location.

There are several different factors that could have contributed to the lack of consistency in the leachate results. As explained earlier, the sample locations were seldom exactly in the same place during any given sampling event because of pile movement. Also, the nature of the leachate generated varied with the age of the pile, the amount of precipitation prior to sample collection and the time of year the sample was taken. Even though the samples are referred to as leachate, the pools of liquid were influenced to varying degree by surface runoff and direct dilution from precipitation.

Nitrate+nitrite as N levels tended to be fairly low, ranging between 0.023 mg/L to 37.2 mg/L with a mean value of 2.2 mg/L. However, the ammonia levels tended to be very high ranging from a low of 0.037 mg/L to a high of 424 mg/L with a mean of 74.2 mg/L. The total phosphorus was also fairly high with a concentrations ranging from 0.61 mg/L to 452 mg/L with a mean value of 58.0 mg/L.

The sulfate and chloride levels were also high when compared to the Wisconsin ground water standards. The highest recorded sulfate value of 880 mg/L was over 3 times the ES of 250 mg/L. The mean sulfate value of 194 mg/L also approached the ES concentration. The highest chloride value of 1540 mg/L was over 6 times the ES of 250 mg/L and even the mean value of 405 mg/L was nearly twice the ES concentration.

Chromium and lead were analyzed in three leachate samples from Site A and twice from Site C. Chromium concentrations ranged from 4 to 23 ug/L and chromium was detected in all samples with the exception of one from Site C. The mean value of 11.9 ug/L was well below the ES for chromium in ground water of 100 ug/L. However, the lead levels ranged from 11 to 150 ug/L and exceeded the ES for lead in ground water of 15 ug/L a total of 6 times. Even the mean value of 53.5 ug/L was over 3 times the ES concentration. Iron levels were also consistently above the ES of 0.3 mg/L.

Pesticides were analyzed in leachate samples at Sites A, C, and D. No pesticide detects were reported at Site A or Site D. Site C had

two low level pesticide detects one for atrazine at 0.13 ug/L and one for 2,4-D at 1.8 ug/L. Neither of these pesticide levels approach the ES levels, 3 ug/L and 70 ug/L, respectively, for these compounds in ground water.

Discussion

In general, the analytical results indicated that medium-to-large sized, unlined yard waste composting facilities that allow organic wastes to decay anaerobically, generate leachates that have an impact on ground water quality. This conclusion is not entirely surprising as many authors (Helfrich, 1992, Kovacic, et. al., 1992, and Cole, 1994) have acknowledged that the potential for the generation of an enriched leachate exists when organic materials decay anaerobically. The leachate quality results of this study were compared to the results of a study done by Helfrich (1992)(Table 5) on yard waste that was allowed to decay anaerobically under controlled conditions. The results show that the leachate from the study sites are well within the range of values found by Helfrich for anaerobic decay conditions.

The most obvious ground water quality impact revealed during the course of the study was the increase in nitrate levels in wells downgradient of the composting facilities. The downgradient wells at both sites had nitrate levels that were consistently higher than nitrate levels at the upgradient wells. The nitrate levels in the downgradient wells were, at times, 3 to 12 times higher than the levels detected in the upgradient wells. The WDNR's enforcement standard for ground water quality with respect to nitrates was exceeded on four occasions at three separate downgradient wells during the course of the study.

The leachate data can be used to verify that the yard waste compost is contributing to the elevated nitrate levels in the ground water. Nitrate levels in the leachate were generally low, between 0.023 and 37.2 mg/L with a mean value of 2.2 mg/L. However, the ammonia concentrations in the leachate tended to be very high with levels as high as 424 mg/L with a mean value of 74.2 mg/L. Conversely, the ammonia concentrations in the ground water wells tended to be very low, with values that never exceeded 3.5 mg/L.

Clearly what is happening is that ammonium (NH_4) ions in the leachate are interacting with the soil and the atmosphere to transform into the nitrate and nitrite (NO_3 and NO_2) compounds found in the ground water analyses. Hem (1992) detailed how reduced forms of nitrogen in surface waters are commonly transformed into nitrate. Hem also cites a study where waters high in ammonia were quickly oxidized in the atmosphere to form nitrate and nitrite. Nitrogen in reduced or organic forms can also be reduced by soil bacteria to form nitrate compounds. The low levels of nitrate in the leachate could be caused by the relatively low initial nitrogen content of yard waste (Kovacic, et. al., 1992) or by the reduction of nitrates into nitrous oxide or nitrogen gas under anaerobic conditions (Hem, 1992).

The fact that both exposure to air and the action of soil bacteria contribute to the conversion of ammonia to nitrate is supported by the ground water analyses. Ammonia was only detected at extremely low levels in all wells with one notable exception, well WC-2 at Site B. The fact that the downgradient well at Site B showed elevated levels of ammonia while the downgradient well at Site A showed none can be attributed to the fact that Site B was underlain by very sandy soils that allowed the leachate to infiltrate into the ground water very quickly. This allowed for very little interaction between the leachate and the air or soil. Site A, on the other hand, had clay soils and large pools of leachate that optimized the interaction between leachate and the environment.

Most of the nitrate problems can be related to the fact that the study sites accepted nutrient-rich grass clippings and allowed these wastes to decay anaerobically. Numerous studies (Cole, 1994, Varsa, 1994, Richard, et. al., 1990 and Helfrich, 1992) have shown that when yard waste composting is managed under controlled conditions that encourage aerobic decomposition and restrict the amount of grass waste, excessive nitrate and ammonia production does not occur.

Chloride levels in the downgradient wells at both study sites were much higher than levels in upgradient wells. A similar situation was noted in a study done by Varsa (1994). He attributed the increases to high levels of chloride in the compost runoff and chloride's low susceptibility to adsorption. Leachate samples taken from all four sites indicated high levels of chloride. Chloride in the leachate may originate from road salt picked up by vacuum collection trucks along with leaf litter. Another possible source is from plants that have adsorbed chloride from the soil. As these plants decompose in the compost piles, the chloride could then be released to the leachate.

The sulfate levels recorded at Site A indicated that sulfate levels were up to 10 times higher in the downgradient well LR-4 than the levels found in upgradient well LR-1. At Site B, however, the sulfate concentrations were about the same in all wells and no significant increase in sulfate concentration was noted in any downgradient wells. This can be explained by looking at the leachate analyses for each site. Site A had some of the highest sulfate levels of any site with one recorded concentration of 880 mg/L. Site B leachate had relatively low amounts of sulfate, around 65 mg/L.

Chromium and lead concentrations were found in almost all leachate samples and some of the metal concentrations were quite high, well above Wisconsin's ground water quality standards. Previous studies have shown the presence of heavy metals in yard waste compost leachate. Lead levels ranging from 15 to 512 ug/L were detected in the leachate from a leaf composting operation in New Jersey (Strom, 1986). Cole (1994) cites a study done by Kee (1962), that found the water-solubility and mobility of several types of metals is greater under conditions of low oxygen and low pH. These conditions exist within large piles of organic materials that are allowed to decay anaerobically, such as at Sites A and D. The most obvious source for

these metals is in the manner that yard waste is collected by municipalities. Leaves collected at curbside by vacuum truck or swept into trucks could also collect gutter debris laden with lead and chromium from automobiles.

In contrast, significant levels of chromium and lead were not detected in any of the monitoring wells at either Site A or B. This suggests that the metals rapidly oxidize as they come into contact with the atmosphere or they are attenuated by compounds in the soil before they can leach into the ground water.

The results of pesticide sampling indicates that the potential for pesticide contamination of ground water as the result of yard waste composting is extremely low. Very low levels of atrazine were detected in two wells at Site A and at none of the wells at Site B. One impacted well at Site A was upgradient to the site and the other well was a deep piezometer. This, added to the fact that atrazine is typically only used by farmers under controlled conditions, would indicate that the atrazine contamination probably originated from an off-site source.

In the leachate analyses, only two samples, both from Site C, had any measurable pesticide concentrations. One compound, 2,4-D, a very common broadleaf herbicide used by homeowners, was found at a low concentration of 1.8 ug/L. The ground water ES for this compound is 70 ug/L. Helfrich (1992) found similar levels of 2,4-D in yard waste compost leachate. The other compound detected was a low level of atrazine.

An interesting result of this study is that there appears to be a definite correlation between the contaminant concentrations and the level of anaerobic decomposition at a facility. Generally, the lowest leachate compound concentrations were found at Site C (Table 4), where the wastes were occasionally moved and aerated. The highest leachate compound values were found at Sites A and D (Tables 3 and 4), where the piles were seldom, if ever, turned and anaerobic decomposition dominated.

Conclusions

There are definite, measurable impacts to ground water quality in the form of elevated levels of nitrates, chloride and sometimes sulfate at large, unlined yard waste compost sites where materials are allowed to decompose anaerobically. These impacts can occur under several different environments and with waste masses that range from 2000 yds³ to 15,000 yds³.

The leachate at these sites typically contain levels of chromium and lead that exceed the Wisconsin ground water quality standards, but pesticide concentrations tend to be very low. The leachate also contains high levels of ammonia and total phosphorus that could be

detrimental to surface water quality if allowed to reach a stream, lake or impoundment.

It appears that production of many of the contaminants present in yard waste compost leachate could be lessened or eliminated by actively managing the compost to allow the waste to decompose under aerobic conditions. However, further studies are needed to determine the ground water impacts and leachate quality of unlined composting facilities that encourage aerobic decomposition.

Further studies are also needed to determine whether or not lining of yard waste compost sites can mitigate all potential ground water contamination problems from large sites that allow anaerobic decomposition to predominate. This study examined one site, Site A, that was sited on a clay deposit and found that the clay did not prevent the ground water quality from being significantly impacted. The leachate results from Sites A and D would seem to indicate that the presence of a clay layer beneath sites that allow large, seldom turned static piles may actually promote anaerobic decomposition by keeping the wastes saturated for longer periods of time.

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KEYWORDS

1. yard waste composting
2. leachate
3. ground water quality
4. nitrate
5. anaerobic decomposition
6. compost piles
7. ammonia
8. pesticides
9. aerobic decomposition
10. compost

Appendix
Data Summary

PARAMETER	LR-1 upgradient					LR-2 down or sidegradient					LR-3 downgradient				
	04/12/93	06/09/93	09/13/93	12/14/93	04/27/94	04/12/93	06/09/93	09/13/93	12/14/93	04/27/94	04/12/93	06/09/93	09/13/93	12/14/93	04/27/93
Nitrate+Nitrite-N(mg/L)	5.28	2.93	4.93	5.9	4.55	5.1	2.36	6.68	1.68	0.016	5.9	0.034	7.68	7.16	0.5
Ammonia-N(mg/L)	<0.1	0.026	<0.005	0.006	<0.005	0.046	0.088	0.014	0.012	0.025	0.054	0.11	0.075	0.066	0.019
Tot. diss. Phosph.(mg/L)	0.05	0.06	0.06	0.06	0.06	<0.02	0.03	0.02	0.03	0.05	0.03	0.05	0.05	0.06	0.04
Sulfate, diss.(mg/L)	33	46	28	31	34	30	43	31	31	30	56	57	58	60	64
Chloride, diss.(mg/L)	11	13	9	9	6.9	81	170	40	81	164	64	73	64	69	82.2
COD, diss.(mg/L)	9	7	<5	<5	<5	70	94	10	26	80	9	<5	<5	<5	<5
TDS(mg/L)	486	530	438	452	456	630	940	474	624	868	576	636	546	578	582
Cadmium, diss.(ug/L)				0.57	0.26				0.29	0.17				0.4	0.08
Chromium, diss.(ug/L)				3	3.4				<1	<1				<1	<1
Lead, diss.(ug/L)				<1	<1				<1	<1				1.1	<1
Copper, diss.(ug/L)				3.1	2.4				9	13				2.4	3
Iron, diss.(mg/L)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.19	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc, diss.(ug/L)	100	<10	11	42	35	15	12	<10	23	25	85	<10	24	20	12
Calcium, diss.(mg/L)	94	97	90	96	91	100	130	96	110	140	88	92	91	100	100
Magnesium, diss.(mg/L)	48	54	48	49	49	53	73	53	60	75	55	63	57	60	65
Hardness, diss.(mg/L)	430	460	420	440	430	480	620	460	530	650	450	490	460	500	510
Alkalinity, diss.(mg/L)	395	413	365	378	390	372	384	345	406	456	353	351	333	345	370
Cond., field(umhos/cm)	595	440	600	550	520	660	750	720	710	900	690	600	610	725	720
Cond., lab(umhos/cm)	814	836	740	773	772	988	1240	818	1000	1320	946	905	918	959	981
pH, lab, diss.(SU)	7.71	7.74	7.58	7.61	7.84	7.83	7.77	7.56	7.6	7.4	7.93	8.06	7.75	7.79	7.85
Temperature, field(C)	8.5	20	14	8.9	8	6	20	15	7.8	7	9.5	22	11	9	9.2
Depth to groundw. (ft)	12.7	10.5	10.05	12.26	12.55	3.65	2.4	3.32	4.64	4.4	7.5	5.92	7.05	9.24	8.8

empty cell indicates data not available

Table 1
Site A Groundwater Data

PARAMETER	LR-4 downgradient well					LR-4P downgradient well				
	04/12/93	06/09/93	09/13/93	12/14/93	04/27/94	04/12/93	06/09/93	09/13/93	12/14/93	04/27/94
Nitrate+Nitrite-N(mg/L)	13.7	10.7	4.38	2.71	18.3	9.7	10.9	6.96	6.71	8.17
Ammonia-N(mg/L)	<0.005	0.045	0.024	<0.005	<0.005	<0.005	0.026	0.013	<0.005	<0.005
Tot. diss. Phosph.(mg/L)	0.03	0.04	0.04	0.04	0.04	<0.02	0.02	<0.02	0.02	<0.02
Sulfate, diss.(mg/L)	320	190	120	160	340	110	120	73	67	69
Chloride, diss.(mg/L)	72	49	33	34	68.2	29	30	25	22	23.8
COD, diss.(mg/L)	44	7	6	<5	10	9	<5	7	<5	<5
TDS(mg/L)	1120	810	592	708	1130	650	726	522	518	520
Cadmium, diss.(ug/L)				0.13	0.07				0.23	<0.04
Chromium, diss.(ug/L)				1	<1				2.4	<1
Lead, diss.(ug/L)				1	<1				<1	<1
Copper, diss.(ug/L)				2.1	2.5				2.6	2.6
Iron, diss.(mg/L)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc, diss.(ug/L)	24	<10	13	21	11	87	<10	11	22	<10
Calcium, diss.(mg/L)	170	130	110	130	160	100	120	99	99	<1
Magnesium, diss.(mg/L)	100	82	61	69	110	54	65	53	51	<1
Hardness, diss.(mg/L)	840	650	520	610	850	480	560	470	460	<6
Alkalinity, diss.(mg/L)	433	380	356	401	443	375	394	352	353	354
Cond., field(umhos/cm)	1100	750	720	760	610	730	650	760	600	1100
Cond., lab(umhos/cm)	1540	1160	936	1080	1580	997	1020	851	842	854
pH, lab, diss.(SU)	7.71	7.95	7.67	7.65	7.6	7.82	7.81	7.69	7.76	7.68
Temperature, field(C)	9.8	20	11	8	9	9.5	21	10	8	8
Depth to groundw. (ft)	7.3	5.9	7	9.16	9.4	7.65	6.2	7.27	9.46	9.05

empty cell indicates data not available

Table 1 (continued)
Site A Groundwater Data

PARAMETER	WC-1 down or sidegradient well					WC-2 downgradient well					WC-2P downgradient well				
	04/21/93	06/22/93	09/20/93	12/21/93	04/26/94	04/21/93	06/22/93	09/20/93	12/21/93	04/26/94	04/21/93	06/22/93	09/20/93	12/21/93	04/26/94
Nitrate+Nitrite-N(mg/L)	1.33	0.869	0.755	1.79	1.78	9.13	6.23	20	6.67	5.63	0.02	0.008	0.008	0.007	<0.007
Ammonia-N(mg/L)	0.014	0.026	0.023	0.01	0.005	0.96	1.45	3.5	0.381	0.091	0.124	0.125	0.139	0.118	0.124
Tot. diss. Phosph.(mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.15	0.16	0.2	0.2	0.19
Sulfate, diss.(mg/L)	18	18	19	17	16	23	22	30	33	26	<5	5	7	6	6
Chloride, diss.(mg/L)	3	2	5	4.6	1.9	38	19	68	16	15	5	3	8	4.9	2.8
COD, diss.(mg/L)	5	8	7	<5	5	16	8	36	11	11	6	<5	<5	<5	6
TDS(mg/L)	70	36	64	62	52	220	134	320	142	124	135	122	140	126	130
Cadmium, diss.(ug/L)					0.29					0.2					0.13
Chromium, diss.(ug/L)				1.3	5.8				<1	<1				2.2	<1
Lead, diss.(ug/L)				<1	<1				<1	1.8				<1	<1
Copper, diss.(ug/L)				<20	2				<20	3.1				<20	1.6
Iron, diss.(mg/L)	0.23	<0.05	0.19	0.08	0.24	0.08	0.06	0.06	<0.05	<0.05	2.1	2.5	3	2.9	3.3
Zinc, diss.(ug/L)	<10	12	10	10	22	25	40	39	43	18	<10	25	<10	43	15
Calcium, diss.(mg/L)	6.4	3.8	5.7	6.9	5.6	15	7.6	24	12	12	25	22	23	21	23
Magnesium, diss.(mg/L)	2	2	1	2	2	5	3	11	5	4	8	7	7	6	7
Hardness, diss.(mg/L)	25	16	20	24	21	59	32	110	50	47	92	84	89	79	88
Alkalinity, diss.(mg/L)	26	6	8	9	8	10	16	16	10	12	89	90	87	90	91
Cond. field (umhos/cm)	54	54	58	58	50	209	170	405	96	133	142	147	145	8	135
Cond. lab (umhos/cm)	116	69	81	96	79	300	216	511	224	192	192	178	188	180	186
pH, lab (SU)	6.93	6.02	5.88	6.02	5.81	5.58	6.44	5.7	5.71	5.75	7.17	7.22	7.03	7.13	7.1
Temperature, field(C)	7	14	12.5	4.8	9	9.8	19.5	14.7	5.5	10.1	11.8	16	12	7	11
Depth to groundw. (ft)	5.67	4.07	7.16	7.63	6.25	6.36	5.06	7.84	8.25	6.9	6.28	4.91	7.71	8.12	6.76

empty cell indicates data not available

Table 2
Site B Groundwater Data

PARAMETER	WC-3 upgradient well					WC-4 down or sidegradient well				
	04/21/93	06/22/93	09/20/93	12/21/93	04/26/94	04/21/93	06/22/93	09/20/93	12/21/93	04/26/94
Nitrate+Nitrite-N(mg/L)	0.865	1.38	1.56	3.7	2.57	3.11	1.01	0.449	1.24	0.928
Ammonia-N(mg/L)	0.014	0.032	0.013	0.024	0.029	<0.005	0.008	0.027	0.01	0.026
Tot. diss. Phosph.(mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sulfate, diss.(mg/L)	19	41	15	26	12	17	17	15	20	19
Chloride, diss.(mg/L)	<1	3	3	1.6	8.3	14	3	5	9.2	5.5
COD, diss.(mg/L)	10	33	<5	<5	<5	13	11	<5	<5	10
TDS(mg/L)	66	92	64	82	62	112	50	60	76	60
Cadmium, diss.(ug/L)					0.39					0.13
Chromium, diss.(ug/L)				1.3	<1				<1	<1
Lead, diss.(ug/L)				<1	<1				<1	<1
Copper, diss.(ug/L)				<20	1.6				<20	2.1
Iron, diss.(mg/L)	0.11	0.23	0.06	<0.05	<0.5	0.9	0.14	0.84	0.08	0.07
Zinc, diss.(ug/L)	<10	15	<10	<10	51	13	16	15	43	35
Calcium, diss.(mg/L)	8.1	12	7.1	12	7.3	8.6	5	3.7	6.4	5.3
Magnesium, diss.(mg/L)	3	5	2	4	2	3	2	2	3	3
Hardness, diss.(mg/L)	32	53	26	47	26	35	20	16	26	25
Alkalinity, diss.(mg/L)	17	8	15	12	8	9	7	9	9	6
Cond. field(umhos/cm)	57	103	60	78	210	88	60	50	63	62
Cond. lab(umhos/cm)	91	137	86	127	102	141	76	70	113	89
pH, lab(SU)	6.29	6.21	6.17	5.97	5.76	5.67	6.09	5.64	5.66	5.38
Temperature, field(C)	7	14	13.5	5	9	8	16	14	5	10
Depth to groundw. (ft)	6.58	7.1	7.93	8.55	6.58	6.1	4.65	7.95	8.15	6.58

empty cell indicates data not available

Table 2 (continued)
Site B Groundwater Data

PARAMETER	Leachate W				Leachate E				Leachate N		
	04/13/93	06/09/93	09/14/93	04/27/94	04/13/93	06/09/93	09/14/93	04/27/94	06/09/93	09/14/93	04/27/94
Nitrate+Nitrite-N(mg/L)	0.06	0.047	37.2	0.033	0.157	<1	<1	0.072	0.036	0.041	0.48
Ammonia-N(mg/L)	26.5	47.7	323	2.94	90.1	138	68.1	12.7	0.966	77	424
Tot. Phosphorus(mg/L)	12.3	16.9	31.2	16	63.8	26.3	26.3	240	8.58	20.8	452
BOD 5 day (mg/L)		<600	240			1900	350		860	680	
Sulfate (mg/L)	95	72	500	47	180	81	140	240	37	200	880
Chloride (mg/L)	340	360	243	215	470	200	38.5	585	260	77	1540
COD (mg/L)	1800	2000	5900	910	11000	3400	1900	15000	2300	2200	42000
TS (mg/L)	3350	3830	8560	2760	10500	3490	2210	14000	3330	3730	39871
Cadmium, diss.(ug/L)				<20				<20			<20
Chromium (ug/L)		10	15	<100		8	11	<100	4	19	<100
Lead (ug/L)		25	69	<100		30	43	<100	11	80	<100
Iron (mg/L)	5	9.7	7.5	6.3		17	8.7	64	4.3	5.8	81
Zinc (ug/L)	57	160	1100	49	480	180	230	910	77	310	790
Calcium (mg/L)	240	220	46	150	700	160	59	790	230	120	1400
Magnesium (mg/L)	150	130	21	99	450	88	41	570	180	62	1300
Hardness (mg/L)	1200	1100	200	800	360	750	320	4300	1300	560	8600
Alkalinity (mg/L)	1310	1340	1800	1035	2410	969	546	2331	1120	1070	6563
Cond., lab(umhos/cm)	3440	3620	6620	2470	6680	3180	1920	7425	2880	3320	18200
pH, lab (SU)	7.74	7.99	7.93	7.57	5.87	6.86	6.82	5.28	7.59	7.47	5.36

empty cell indicates data not available

Table 3
Site A Leachate Data

PARAMETER	Site B	Site C						Site D		
	4/26/94	06/22/93		09/20/93		04/26/94		6/29/93	04/28/94	
	LEA-1	Sample 1	Sample 2	Sample A	Sample B	Sample A	Sample B	Sample A	Sample A	Sample B
Nitrate+Nitrite-N(mg/L)	0.062	0.205	1.23	0.289	3.05	0.047	1.81	<1	0.023	<1
Ammonia-N(mg/L)	18.5	0.037	119	50.9	0.289	0.174	15.4	141	0.233	1.38
Tot. Phosphorus(mg/L)	4.12	0.61	11.9	18.5	6.1	17.2	6.72	218	7.16	13
BOD 5 day (mg/L)		16	180	230	<60			>9700		
Sulfate (mg/L)	65	8	120	140	85	110	81	760	82	160
Chloride (mg/L)	95	6	1500	215	361	94	71.9	590	388	861
COD (mg/L)	1000	97	3600	2000	870	1000	740	44000	1600	2300
TS (mg/L)	1300	360	9390	3410	2840	1440	1410	12300	3980	5850
Cadmium (ug/L)	<20					<20	<20		<20	<20
Chromium (ug/L)	<100			23	<10	<100	<100		<100	<100
Lead (ug/L)	<100			150	<40	<100	110		<100	<100
Copper (ug/L)	70					21	74		<20	<20
Iron (mg/L)	27	5.6	2.4	12	4	1.8	14	94	2.4	3.1
Zinc (ug/L)	270	27	260	470	150	160	400	1700	24	29
Calcium (mg/L)	75	18	440	44	75	39	40	1800	230	350
Magnesium (mg/L)	29	4	240	18	40	26	11	1300	260	390
Hardness (mg/L)	310	62	2100	180	350	210	140	10000	1700	2500
Alkalinity (mg/L)	254	58	2660	256	321	158	139	5570	1668	2355
Cond. lab (umhos/cm)	808	145	9340	1460	2050	782	605	12300	3897	6210
pH, lab (SU)	7.17	6.99	7.87	6.97	8.18	6.32	7.09	5.1	7.93	7.76

empty cell indicates data not available

Table 4
Site B, C, and, D Leachate Data

PARAMETER	WDNR-Study					Helfrich-Study (1) leaf/grass-mix	
	n	MIN	MAX	MEAN	STD	MIN	MAX
Nitrate+Nitrite-N(mg/L)	21	0.023	37.2	2.23	8.05	ND	7.26
Ammonia-N(mg/L)	21	0.037	424	74.19	111.04	1490	2060
Tot. Phosphorus(mg/L)	21	0.61	452	57.98	111.26	71	134
BOD 5 day (mg/L)	11	16	9700	1317	2832	840	4300
Sulfate (mg/L)	21	8	880	194	232	447	726
Chloride (mg/L)	21	6	1540	405	427	1410	2340
COD (mg/L)	21	97	44000	6934	12515	15800	24300
TS (mg/L)	21	360	39871	6567	8527	1200	24500
Cadmium (ug/L)	8	<10	<10			ND	ND
Chromium (ug/L)	16	4	<100			ND	ND
Lead (ug/L)	16	11	150	52	31	ND	70
Copper (ug/L)	5	10	74	37	32	ND	161
Iron (mg/L)	20	1.8	94	18.8	27.3	10.6	23.3
Zinc (ug/L)	21	24	1700	373	427	0.31	0.49
Calcium (mg/L)	21	18	1800	344	471	429	758
Magnesium (mg/L)	21	4	1300	258	380	224	342
Hardness (mg/L)	21	62	10000	1764	2712		
Alkalinity (mg/L)	21	58	6563	1616	1698		
Cond. at 25C(umhos/cm)	21	145	18200	4636	4404		
pH, lab (SU)	21	5.1	8.18	7.04	0.95	6.9	7.18

(1) See references list

Table 5
Summary of Leachate Results

89072244023



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051105 Investigation of Groundwater
c.1 Impacts at Yard Waste
Compost Sites

DEMCO

89072244023



B89072244023A