

Allen County Landfill (ACL) Final Report Regarding the Determination of Post Closure Care (PCC) Termination (October 2, 2013)

By Carl E. Burkhead

Introduction

The need for a study¹ to support a proposed methodology for PCC termination determination was first proposed at a Bureau of Waste Management (BWM) meeting on July 19, 2011 and then to the PCC Work Group on February 2, 2012 (This is a stakeholders group consisting of landfill owners/operators, consultants, BWM staff and a member of the Kansas Landfill Association). A meeting was held in Iola, KS on June 19, 2012 to discuss the plan and related PCC documents were sent to representatives of the ACL on June 14, 2012. A request for information relating to the proposed study was sent to Bill King, County Engineer and thoughts about the proposed study were sent to ACL representatives on June 19, 2012. The other ACL representatives included Eula Hutton (ACL Manager) and Brian Weis of Burns & McDonnell (B&M) Consulting Engineers. Dennis Degner, Charley Bowers and Carl Burkhead were the BWM representatives and the latter two were the main participants in the resultant study which began initial sampling efforts on September 27, 2012 and ended on July 3, 2013.

Objective

It should be noted that the proposed methodology is based on the analysis of emission data, i.e., leachate and landfill gas. Data collection is the heart of any PCC Termination Determination plan as explained in a paper presented on this topic by this author entitled **Post Closure Care (PCC) Termination Plans: Principles and Needs** (1). The paper outlines the variety of data and the frequency of data collection necessary to provide the information for a successful plan. Also, it identifies the data available from the ACL and other sources. The only available emission data were leachate data since there are no gas wells in the Subtitle D portion of the ACL. The objective of this report is to demonstrate the proposed methodology even though there are desirable data sources which are not available.

Available ACL Data and Sources

Available data, sources (in some cases) and pertinent notes for this report include the following (although not always with a proper bibliographic citation):

1. June 2008 Permit Modification and August 2011 Revised Facility Operating Plan.
2. Plats – August 2008 Horizontal & Vertical Expansion Permit Drawings and July 2009 Landfill Gas Improvements/Expansion.
3. Permit renewal dated July 9, 2013

¹Originally the study was referred to as a pilot study. However, given the fact that pilot operations were not conducted, the adjective was dropped. The main effort involved the collection and analysis of leachate and leachate related data,

4. Tonnage reports – BWM, Candy Williams, Crystal Reports; monthly values are available since 1993 and classified according to MSW, C&D, special and tires since 1997.
5. Historical annual leachate quality data – Compilation since July 2001 by Carl based on Dennis Degner’s request of September 1, 2011 to all Subtitle D landfill owners/operators.
6. BWM leachate quality data for sampling efforts on 9-27-12, 10-9-12, 1-3-13, 4-10-13 and 7-3-13; similar sampling data by B&M for 10-9-12 and 4-10-13.
7. Leachate haul data – A record compiled by the ACL since October 2002 of the amount of leachate hauled in gallons, on what day and the disposal location.
8. ACL compiled monthly record since 2000 of RWD No. 8 application and leachate recirculation days.
9. Basis for Estimating Moisture Addition from ACL MSW and RWD No. 8 Water (8-7-13).
10. Self compiled chronology of mostly key leachate related activities dated July 30, 2013.
11. Leachate level monitoring data from October 2004 to December 2009.
12. Leachate level monitoring data for Storage and Evaporation Basin No. 1 – A record since January 2010 of leachate levels in the SEB No. 1 basin along with the time of recording, Phases I&II and Cell 1A (also called Phase 1A) leachate head on liner; corresponding flow and rate totalizers; and various depths of phases to liner and secondary liner (Phases I&I) and wet well. The flow records are unusable for this purpose due to periods of equipment failure and repair in which no data was recorded.
13. Leachate sample collection, storage and disposal data – Compilation by Carl based on his request of January 13, 2013 to all Subtitle D landfills owners/operators.
14. Daily, monthly and yearly precipitation and temperature data for Chanute obtained from the following website: <http://www.crh.noaa.gov/ict/climate/f6form.php>

Presentation and Discussion of Results

The results presented in this section are intended to demonstrate key principles useful for the determination of PCC termination. They will include the following items: water balance, water quality balances, trends in concentration changes of key water quality parameters and considerations for a proposed PCC termination determination methodology including mass flow rate based on ACL data. Each of these discussions should be considered in light of the chronology of events which have taken place at the ACL as shown in Table 1.

Water Balance

A continuous concern of Subtitle D landfills is the need to dispose of accumulated leachate. Any disposal option requires the need to know the amount of leachate being generated and disposed along with its quality (**a similar situation exists for landfill gas except the ACL does not have a gas collection system**). This section deals with the amount of leachate, which is typically measured according to the particular landfill’s disposal method, e.g., the ACL recirculates their leachate to the active face or sends it to any one of several regional POTWs. In both cases, they use a tanker truck with a hose and pump to remove the leachate

from a storage basin (known as Storage and Evaporation Basin No. 1 or SEB No.1). The volume of the truck is known and the number of loads is recorded so that the amount can be

Table 1 - Chronology of ACL Leachate Generation & Storage Facilities*
(July 30, 2011)

Date	Activity	Area** (acres)
November 1974	Use of the site for a landfill approved by BWM with conditions limiting the types wastes disposed & requiring that the landfill will file to obtain a permit in 1975 when permits become required.	
March 1976	Pre-Subtitle D landfill permit issued	12.5
?	Waste tire monofill** opened (no leachate collected from here)	5.92
1994 - 1997	16 Groundwater monitoring wells installed	
Fall 1995	Toe drain installed. This toe drain runs N-S across the quarry floor at the base of the pre-Subtitle D areas west slope & is now below Phases I & II . The drain also had a branch draining a pond in the quarry area that is now also below Phases I & II . This drain ran through the tire monofill area, but was solid pipe in that area.	
February 2001	Phase I** disposal initiated & leachate tank in service. Phase I was constructed in the spring & summer of 1996, but not initially used. Intermittent disposal into the pre-Subtitle D cell continued to help blend the cells' contours until October 9, 2001 when the pre-Subtitle D cell's vertical expansion exemption expired.	4.48
Summer 2002	16 Gas extraction wells were installed in the Pre-Subtitle D area concurrent that area receiving final cover and Phase II's construction	
October 24, 2002	Leachate haul record begins (confirmed by Rod Geisler's letter dated March 14, 2005)	
November 2002	Phase I disposal ends & Phase II** starts with leachates from both phases commingled. The C&D landfill which had its plans approved with those for Phase II is not constructed at this time. (Eula started working at ACL)	8.45
December 2002	RWD No. 8 water application to active site except when recirculating leachate (see next listing) or on significant rainfall events	
May 7, 2004	Leachate recirculation initiated (see Haul record)	
2005	ACL permitted to recirculate leachate to active face up to 10,000 gpd	
December 2007	Waste placement begins in C&D landfill** . The C&D landfill is not tied into the leachate collection system at this time although Charley believes C&D leachate does go to the toe drain wet well. (June flood debris added)	5.72
February 2010	Phase II MSW disposal ceases & leachate tank is taken out of service; Cell 1A** MSW disposal initiated & SEB No. 1 in service	6.00
July 2013	Cell 1B** opened & Cells 1A & 1B leachates commingled. (When Cell 1B's waste elevation is the same as Cell 1A's current elevation, disposal North to South into both cells will continue. This disposal will extend east up the slopes of Phases I & II bringing combined Cells 1A's & 1B's' elevations to match Phases I & II . To obtain the designed final cover slopes additional disposal into Phases I & II will occur	4.54

estimated.

Unfortunately, in the rainy part of the year, leachate production can be relatively high, resulting in the need to dispose of it off-site; a typically expensive alternative. Also, this increased activity can discourage reliable record keeping; especially, reading of leachate levels or flow indicators, or even truck loads.

A water balance was made using some of the previously mentioned data. The results are shown in the referenced spreadsheet (2) **Water Balance** tab. In general, the water balance takes into account the water **inputs** and the **outputs** which theoretically should allow water **accumulation** to be estimated, i.e., $I = O + A$. Input sources include:

1. **Moisture content of the incoming MSW** – This is a difficult to determine but can be estimated based on published values which range from 20 to 40 percent (3). In the referenced spreadsheet (2), the amount was estimated by relating the moisture content to the magnitude of the local precipitation with the incoming MSW tonnage.
2. **Infiltration of precipitation into stored MSW** – Active or closed landfills with pervious daily, intermediate or final covers allow precipitation to enter the landfill mass and to increase the moisture content of the stored MSW. In the referenced spreadsheet (2), the amount of infiltration was assumed to be 100 percent, i.e., there was no runoff from the surface of the landfill areas.
3. **Leachate recirculation** – This practice is common to many Subtitle D landfills because it provides an alternative method of disposal and promotes MSW stabilization because it increases the moisture content of the MSW; but, typically not to the moisture holding capacity of the MSW. The volume (or weight, if necessary) is easily determined as mentioned previously.
4. **RWD No. 8 addition** – The ACL is unusual in that it uses a potable water to wet the active face and to control dust; again, the volume (or weight, if necessary) is easily determined since they use a hydrospreader to apply a known volume of water.

Output sources include leachate collected in a sump and transferred to a storage unit, or that which flows by gravity to a storage unit (The storage unit is typically an enclosed tank or an open basin or lagoon) and any seepage from an active or close landfill. The measurement of leachate flow can be determined from pump curves with pump on/off records, flow measurement recorders or level changes in a tank or lagoon (the latter is affected by evaporation and precipitation). Unfortunately, the effort to determine the flow from these approaches failed at the ACL due to periodic failure and repair of the recording devices. Also, since Phases I&II, 1A and 1B flow into the same basin, one cannot distinguish between the three. Seepage is undesirable and is difficult to quantify. It was not a problem at the ACL.

A water balance was made as shown in the referenced spreadsheet (2) using the preceding input values (Items 1 to 4 above) and the assumed leachate production data (leachate haul data). Unfortunately, there are huge errors associated with the amount of precipitation which infiltrates into the MSW mass and the error in assuming that the leachate

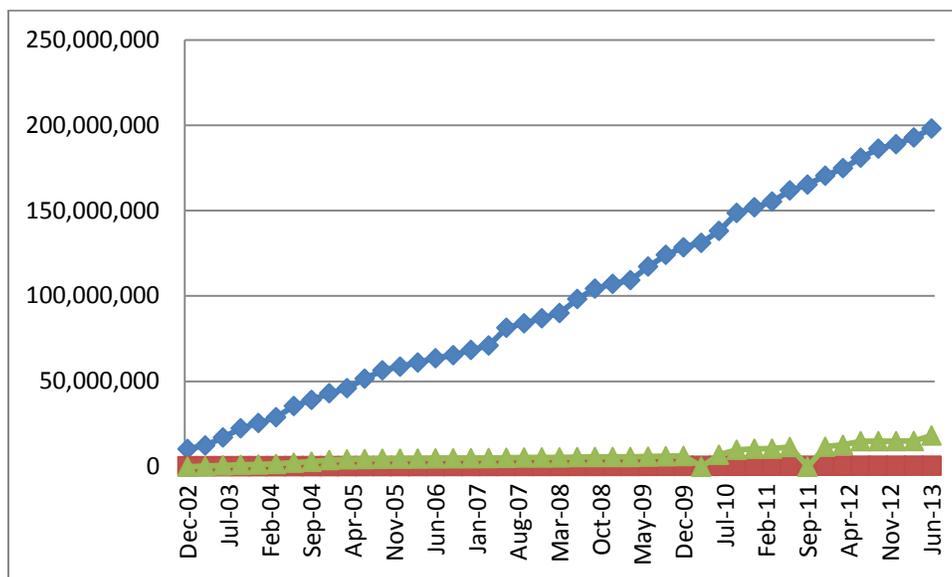
hailed is the actual leachate entering the SEB No. 1. It is not because of evaporation from and precipitation into the basin. The most accurate input measure is the leachate recirculation haul data followed by the RWD No. 8 water addition. The water balance evaluation does suggest that the precipitation is the major input source followed by the moisture in the incoming MSW. The contribution of leachate recirculation and RWD No. 8 inputs is small compared to the other sources.

One important way to improve the value of the water balance is to have an onsite weather station so that actual precipitation amounts are known. The assumed climatic data for Chanute was the best available but obviously not very good. Also, runoff values at the ACL could have been estimated by measuring depth changes in the pond and quarry storage areas after a storm event so that changes in volume could be determined. Currently, there is no way to measure the flow to these basins. (Note that the stormwater could be recirculated to improve MSW stabilization similar to leachate and RWD No. 8 water addition at ACL.)

There should be a correlation between the stored MSW and the input moisture data versus the leachate production data, i.e., the stored MSW moisture content should theoretically increase with moisture addition up to its moisture holding or field capacity at which time there is leachate production. Of course, the reality is that ideal absorption of the incoming moisture does not occur; the infiltrating water can accumulate in the MSW mass in various ways (in pockets or layers) and/or it can channel directly to the leachate sump.

Figure 1 is a plot of MSW tonnage, haul volumes and liquid inputs versus time. The assumption that all the precipitation infiltrates (which comprises over 87.3% of the total water input) into the landfill surfaces masks the other values.

Figure 1 – Liquid Inputs (blue) & Haul Volume in gallons (green) and Tonnage (red) vs. Time



Some useful distinctions can be identified by plotting these values against each other; thus, eliminating time as a direct consideration. These plots are shown in Figures 2 and 3.

Figure 2 is a plot of leachate production versus MSW tonnage and Figure 3 is a plot of leachate production versus input moisture as given in the referenced spreadsheet (2) **Water Input vs. Tonnage** tab. An underlying assumption to this comparison is that all Subtitle D phases are contributing to the leachate production.

Figure 2 indicates that there was a steady increase in tonnage from 2002 to 2013 (dates are inherent in plot's quarterly values) with two significant changes in haul data (leachate taken from SEB No. 1). The first change is when leachate recirculation began and the second when Phase 1A was started.

Figure 3 shows a linear increase in liquid inputs from 2002 to 2013. These numbers are completely dominated by the assumed infiltration of precipitation as discussed previously. The haul volumes in Figure 3 are compressed as compared to Figure 2 but the same conclusions are applicable as mentioned in the preceding paragraph.

Figure 2 – Haul Volume in gallons (red) vs. Tonnage X10⁻³ (blue)

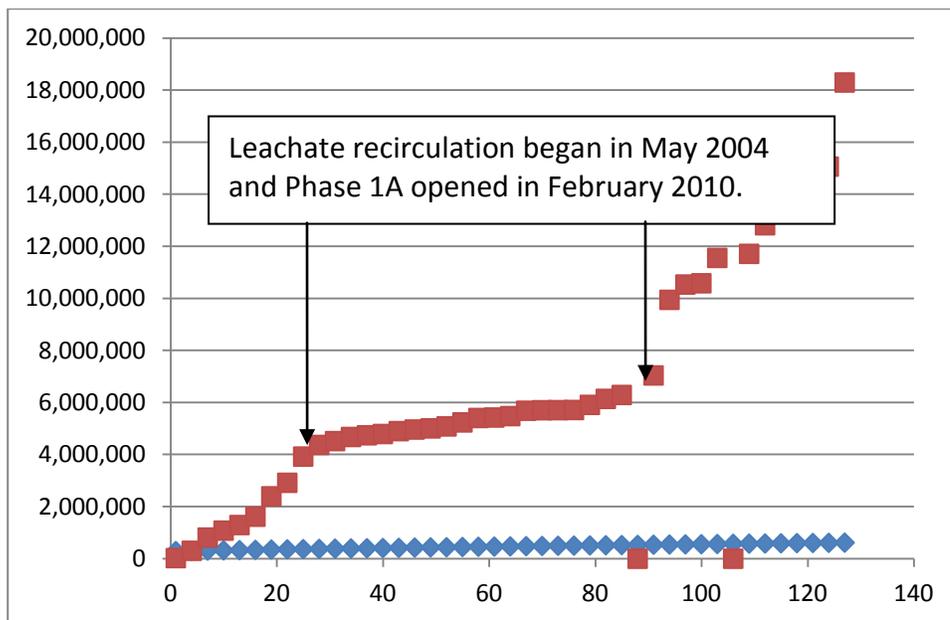
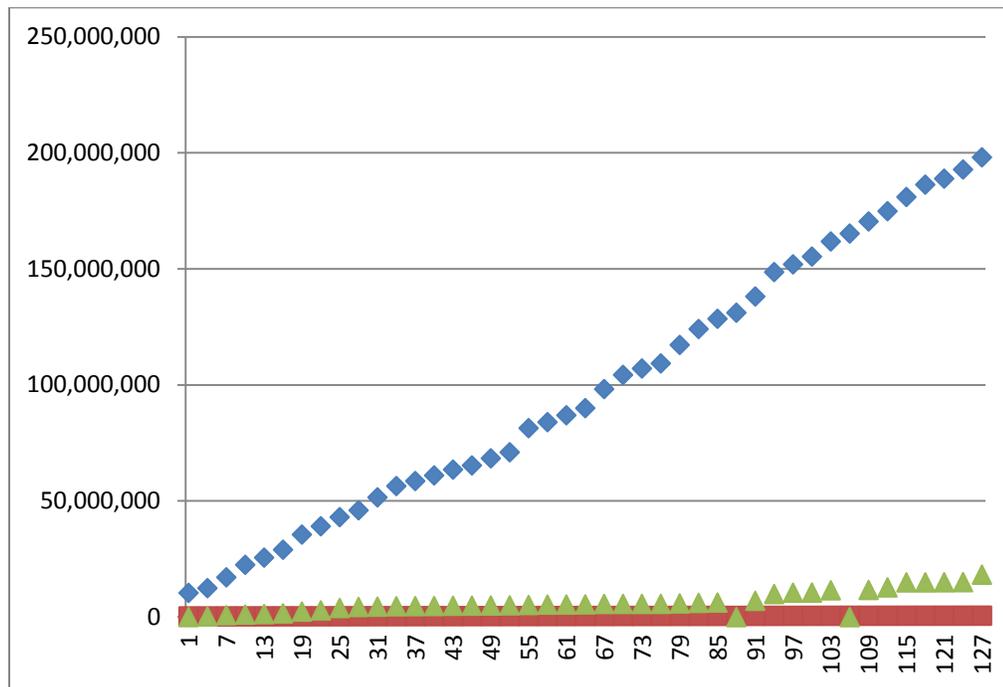


Figure 3 – Liquid Inputs in gallons (blue) vs. Haul Volume X10⁻³ in gallons (Green) and Tonnage X10⁻³ (Red)



Water Quality Balances

The major PCC concern related to the leachate water quality is that key analytical parameters reach an equilibrium which does not change significantly after PCC is terminated. This topic will be discussed in the following **Leachate Trend Analysis** section. In this section, there are two aspects of water quality discussed. These became apparent prior to and during the study. The first aspect was the importance of checking the leachate results to insure that the results were reliable. The second had to do with the proper selection of a leachate sample that would best represent the true stability of the stored MSW.

1. **Validating Analytical Results** - The checking of the leachate analytical results is demonstrated in the referenced spreadsheet (2), the **Leachate WQ** tab. The basic premise to leachate analysis reliability is the fact that there should be an ion balance between anions and cations; and that there should be a mass balance between the total dissolved solids (TDS) and the soluble species (ionic and molecular), i.e., the ratios should equal one. [Note that the reference spreadsheet (2) should have all the columns revealed, i.e., the hidden ones should be unhidden.] The average of the anion/cation balance is 0.8 for the ACL data set but it should be recognized that a true balance cannot be obtained unless **all** the ions are **accurately** measured. The 0.8 values would suggest there were anions that were not measured, e.g., nitrates and/or phosphates. The average ion and molecular species values compared to the total dissolved solids value is 2.2. This number is in error because the TDS value is usually a calculated value

rather than one determined analytically. Only certain species are used to calculate the TDS versus the several chosen to represent the dissolved species, inorganic and organic.

The preceding discussion does not mean that the ACL water quality data are in error but that not all the significant analytical tests were conducted which would have allowed the validation of the available data.

2. **Proper Leachate Sampling Location** – It was discovered early in the study that the previously reported leachate values were based on samples taken in the leachate storage facilities that existed at the time. It is believed that the leachate tank was sampled by lowering a bailer through a manhole on the top of the tank. The leachate collected from the SEB No. 1 was obtained by throwing a bailer into the basin near its edge. Neither of these locations is ideal to judge the MSW stability since they represent leachate samples that are affected by storage. The best location for this determination is the point of leachate collection as it emanates from the landfill mass itself. However, it is understood that leachate is sampled for reasons other than determining MSW stability, including characterization for the wastewater treatment facilities that accept the leachate. For this purpose, the sample location is ideal and representative of the liquid which is hauled to the facility. Reference 4 is a report of a study to validate the best leachate collection point and Reference 5 is a proposed leachate sampling protocol based on the report. Reference 6 is a summary of a survey of all Kansas MSWLF's sampling locations and storage facilities.

Leachate Trend Analysis

The key aspect of leachate values is their use to define a trend which would indicate that the phase(s) producing the leachate(s) have reached equilibrium and PCC termination has been reached. However, several key points need to be made concerning leachate quality variations. First, leachate quality changes concerning MSW stabilization is best measured by sampling the leachate as it leaves the individual phases (see Reference 4). The second key point is that there is a difference in leachate quality from older phases than newer one, i.e., the combined leachate from two or more phases masks the more stable leachate from the oldest phase (also, see Reference 4). Thirdly, there is a natural scatter of the leachate quality data as a result of the precision of the analytical test procedures. For example when considering two key MSW stability factors, the one sigma standard deviation for the BOD₅ and TSS tests is ± 30.5 mg/L for an average BOD₅ of 198 mg/L and ± 5.2 mg/L for an average TSS of 15 mg/L, respectively (see Reference 7). This scatter must be accounted for if a more reliable trend analysis is to be made as shown in the section entitled **PCC Termination Determination Methodology**. Lastly, there are EPA's effluent guidelines for MSWLF leachate as shown in Table 2.

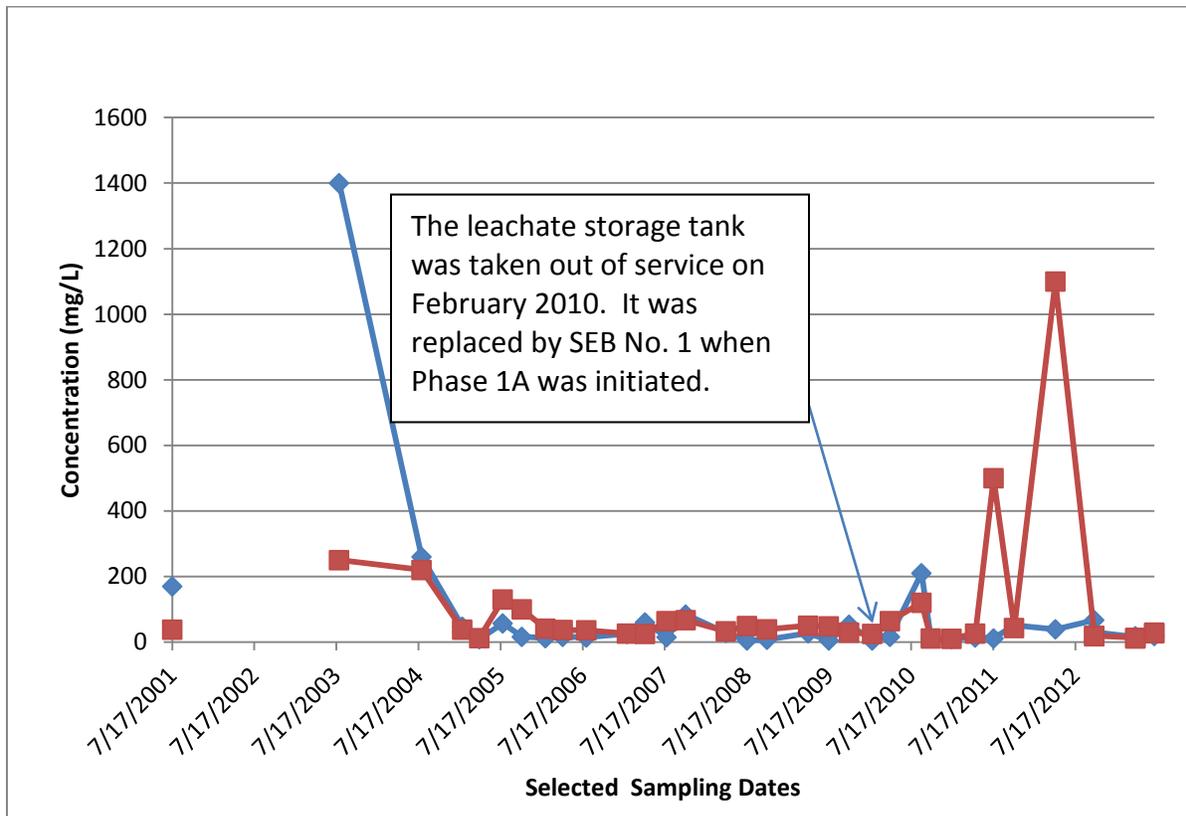
Figures 4 and 5 demonstrate four of the nine effluent limits given in Table 2. The variation of BOD₅ and TSS in Figure 4 reflects the combined effects of where the leachate was stored and the relationship between total and soluble BOD₅ since TSS represents a form of the insoluble BOD₅.

Table 2 – Leachate Effluent Limitations

Regulated parameter	Maximum daily ¹	Maximum monthly avg. ¹
BOD	140	37
TSS	88	27
Ammonia (as N)	10	4.9
α-Terpineol	0.033	0.016
Benzoic acid	0.12	0.071
<i>p</i> -Cresol	0.025	0.014
Phenol	0.026	0.015
Zinc	0.20	0.11
pH	(²)	(²)

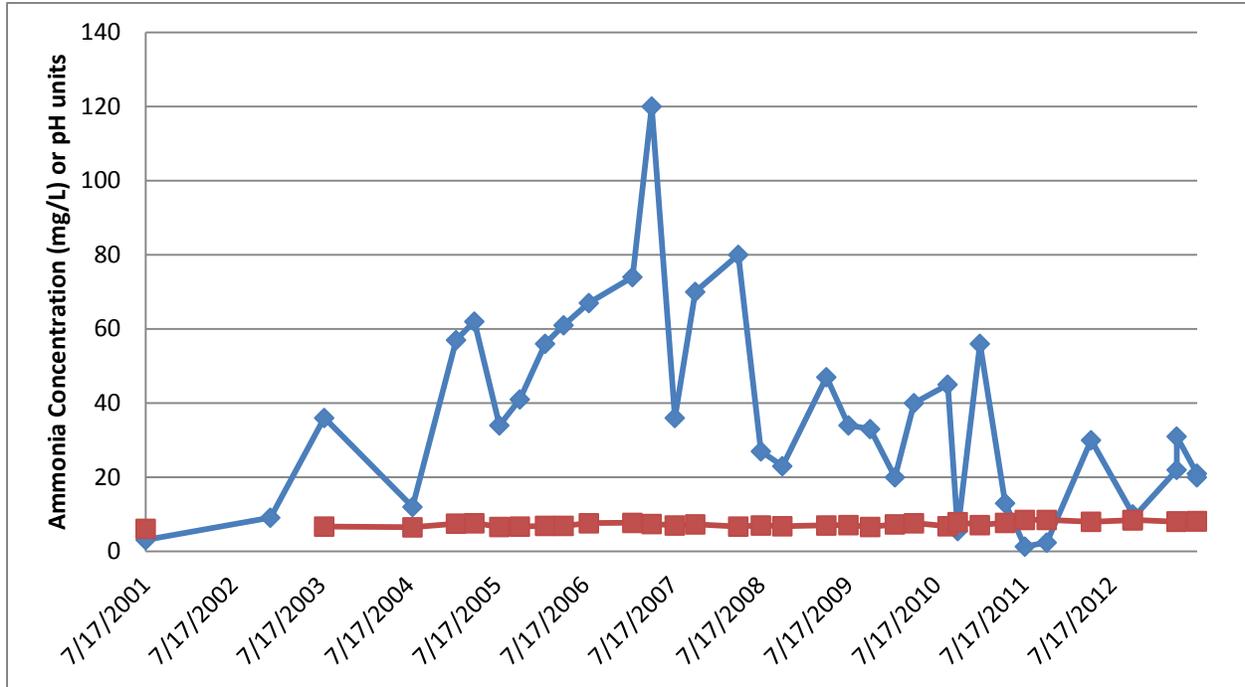
¹Milligrams per liter (mg/L, ppm), ²Within the range 6 to 9. (See **65 FR 3048**, Jan. 19, 2000; **65 FR 14344**, Mar. 16, 2000])

Figure 4 – Leachate Stability [BOD₅ (blue) and TSS (red)] Factors vs. Time



The increased variation in TSS following the start of Phase 1A and the storage of leachate in SEB No. 1 is a result of combined effects, i.e., the sampling of a more transitional regime where wind action, precipitation, evaporation and in-situ reactions take place. It is believed that the same effect is not seen in BOD₅ because of the non-biodegradable nature of the increased TSS although the two significant TSS outliers after the switch to SEB No. 1 may be due to sample collection errors. The latter explanation seems more probable than the former.

Figure 5 – Ammonia (blue) and pH (red) Variations vs. Time



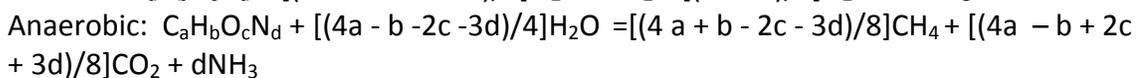
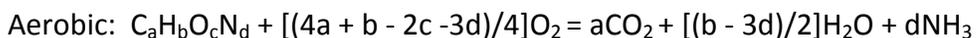
The change in ammonia is much more pronounced than in the pH because pH is a log function. There is a gradual increase in the pH, but the general increase and decrease in ammonia is likely related to the release of ammonia in the anaerobic stabilization of the MSW. The eventual decrease may be due to the reduced production in ammonia from Phases I and II and later the removal of ammonia by algae to create algal protoplasm. Also, it is possible that ammonia was also removed by nitrification in the aerobic environment of SEB No. 1.

Consideration of ACL Data for PCC Termination Determination

Data given in the referenced spreadsheet (2) (see **Leachate WQ** tab) include surrogate (BOD₅, COD, TOC, alkalinity, TSS, turbidity, TDS and conductivity; marked in blue) and specific organic and inorganic measurements including pH. The leachate measurements most appropriate for the appraisal of MSW stabilization are the BOD₅, COD, alkalinity, TSS, turbidity, ammonia, Kjeldahl and nitrate nitrogen, sulfate and pH for the following reasons:

1. **BOD₅ and COD** - BOD₅ is an approximate measure of the biodegradable organic matter in the COD; hence, indicators of residual organics emanating from the stored MSW mass whether soluble or insoluble. A key assumption is that when the amount of both decreases then the MSW mass is more stabilized because microbial and other reactions [physical (solubilization) and chemical] have ceased to produce by-products.
2. **TSS and Turbidity** – These includes solids released from and/or transported through the stored MSW mass. They can include inert, microbial and other reactive solids. It is speculated that most are microbial because they can slough off the MSW media. TSS are measured indirectly when total and soluble BOD₅, COD and TOC samples are tested and the results are subtracted from each other; thus, giving the insoluble portion.
3. **Alkalinity and pH** – Microbial stabilization of MSW is pH dependent. Alkalinity is a natural buffer to maintain pH levels to keep them from going too high or low.
4. **Ammonia, Kjeldahl, Nitrate and Sulfates**– Nitrogen is a key nutrient for microbial metabolism. In an anaerobic environment (such as exists in the larger part of stored MSW undergoing stabilization) reduced forms of nitrogen and sulfur exist. The absence of oxygen results in the reduction of nitrate to ammonia and sulfate to sulfide. Kjeldahl nitrogen measures both organic and ammonia nitrogen.

Another way of looking at the rationale for the above mentioned analytical measurements is that they are an integral part of the following theoretical reactions for the stabilization of MSW where anaerobic metabolism is the dominate reaction (see Reference 3, pages 288 and 293):



Note that a microbial end product is not included in the two reactions, i.e., the resultant mass produced by the bioconversion of the MSW to new microbes. Also, note that the two step anaerobic reactions of acid production and methane formation, nor sulfate reduction, are not shown in the anaerobic reaction; but, for sake of simplicity was not chosen for inclusion.

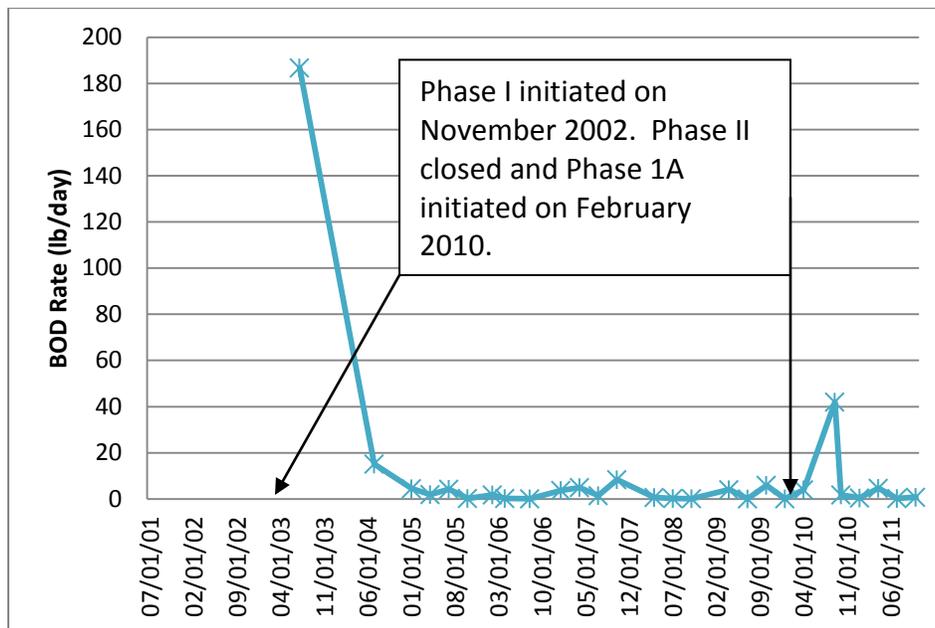
Besides the microbial end product as estimated by TSS, the other end products are organic acids, ammonia and methane. BOD₅ and COD measure organic acids and TSS; TSS measures microbial mass; ammonia and Kjeldahl measure ammonia and pH measures changes in alkalinity, organic acids and ammonia.

Figures 4 and 5 presented changes in leachate quality for BOD₅, TSS, ammonia and pH. BOD₅ and TSS showed a general decline, ammonia an increase and then a decrease, and pH a

gradual increase. If it were assumed that closure existed and no additional MSW was added to the existing mass and liquid addition was to cease, then it would be expected that these parameters would reach equilibrium (8). (It is realized that there is an estimated life to the ACL of over 100 years). Given the assumption of closure, it is reasonable that the resultant equilibrium values could be determined for each of these parameters. The question is when do the changes in values constitute the true equilibrium values? Two aspects of this question require consideration. The first has to do with mass flow and the second is the proposed criteria for making such a determination based on assumed equilibrium constraints as defined in Reference 9.

1. **Mass Flow** – The product of leachate contaminant concentration times the flow of leachate is the mass flow of the contaminant. This is illustrated in Figure 6 for BOD₅ based on calculations given in the referenced spreadsheet (2), **BOD Mass Flow** tab. The calculations are crude and complicated because of limited data, but they do illustrate that the real environmental concern is how much of the contaminant mass is emanating from the landfill.

Figure 6 – Estimated BOD₅ Mass Flow



2. **Proposed PCC Termination Determination Methodology** – Reference 9 is a proposed alternate termination policy for PCC. The guidelines presented in the policy are potentially applicable to closed Phases I&II once they receive their final cover and because the leachate from these sources are measureable in terms of quantity and quality, and can be isolated from SEB No. 1 for final disposal prior to the future disposal of leachates from subsequent phases (e.g., Phases 1A to 4A).

Actually, isolation is not necessary until the flow and quality show that they meet the guidelines.)

Unfortunately, there are no historical flow data for Phases I&II despite the fact that the wet well servicing these phases has a flow recorder (indicator and accumulator). However, the recent quality data collection effort by Bowers and Burkhead (see Reference 4) do provide information which could be used to test the proposed effluent and PCC termination guidelines.

- a. **Comparison with Effluent Guidelines** - Table 1 of Reference 4 shows that Phases I&II samples were collected on four occasions. Table 10 of Reference 4 compares the parameters mentioned in the previous section (along with other parameters).

Table 1 of Reference 4 – Leachate Sampling Goals¹

Event No.	Sampling Date	Landfill	Regime(s) Sampled	Goal of Sampling Effort ¹
1	9-27-12	ACL	Phase 1A	To determine leachate TSS changes with time.
2	10-9-12	ACL	Phase 1A, Phases I&II & SEB No. 1	To compare BWM and B&M sampling results
3	10-24-12	JCL	Phase 3	To determine leachate quality changes with time.
4	12-12-12	JCL	Phase 5 & Toe Drain	To determine leachate quality changes with time.
5	1-3-13	ACL	Phase 1A & Phases I&II	To compare leachate quality with Events 1 & 2.
6	4-10-13	ACL	Phase 1A, Phases I&II & SEB No. 1	To compare leachate quality with Events 2 and 5; also to compare SEB No.1 samples.
7	7-3-13	ACL	Phases 1A, Phases I&II, & SEB No. 1	To compare leachate quality with Events 2, 5 and 6; also to compare SEB No. 1 samples.

Table 10 of Reference 4 – Comparison of Leachate Results for Phases I&II

Parameter	Units	10-9-12	1-3-13	4-10-13	7-3-11
Alkalinity as CaCO ₃	mg/L	984	954	865	972
Ammonia (N)	mg/L	75	NA	50	48
Biochemical Oxygen Demand	mg/L	13	16	17	16
Calcium	mg/L	210	200	210	NA
Chemical Oxygen Demand (COD)	mg/L	190	250	110	140
Chloride	mg/L	290	440	230	240
Iron	mg/L	7.6	7.8	17	NA
Kjeldahl Nitrogen	mg/L	30	160	42	45
Nitrate & Nitrite (N)	mg/L	0.262	<0.450	<0.168	<0.150

Potassium	mg/L	47	65	29	NA
Sodium	mg/L	270	410	210	NA
Specific Conductivity	µS/cm	2,900	3,700	2,300	2,400
Sulfate	mg/L	210	240	96	15
Total Dissolved Solids	mg/L	NA	2,000	1,400	NA
Total Hardness	mg/L	NA	NA	750	NA
Total Organic Carbon	mg/L	52	73	39	52
Total Phosphorus (P)	mg/L	0.21	0.059	0.16	0.12
Total Suspended Solids (TSS)	mg/L	28	24	39	32
Turbidity	NTU	NA	NA	100	120
pH	pH unit	7.3	7.7	7.5	6.8
Temperature	°C	NA	NA	NA	20.0
Color	Subjective	NA	NA	NA	Colorless

The stability related parameters (highlighted in yellow) show different trends over the approximately eight month period (Note that Reference 4 discusses these data in greater detail). The organic parameters (BOD, COD, Kjeldahl nitrogen, TOC and TSS) when compared to Table 2 (see page 10) values (BOD, TSS, ammonia and pH) suggest an effluent which is satisfactory for disposal except for ammonia. The BOD and COD values indicate a stable effluent with ratios of 0.068, 0.064, 0.155 and 0.114, respectively. Reported stable benchmark values for MSW (as opposed to leachate) are reported to range from 0.1 to 0.25 (see Reference 10, page 3). As discussed in Reference 4, there is an error in the ammonia and/or Kjeldahl values since the latter should be greater than the former. The author believes the error is in the Kjeldahl measurements since high ammonia values are typically reported in the literature for leachates (see References 11 and 12). Sulfates are not related to MSW degradation directly but indirectly in that they serve as an alternate source of oxygen as a hydrogen acceptor. The downward trend indicate that they are being used which would show up in available landfill gas analyses as hydrogen sulfide.

- b. Comparison with Assumed PCC Termination Guidelines** –As mentioned in the **Leachate Trend Analysis** section, page 10, one approach to test leachate equilibrium is to compare the measured values with their standard deviation values. Using the BOD and TSS data given in Table 10 of Reference 4, one can demonstrate if Phases I&II are approaching an equilibrium. The previously stated precision data for BOD₅ and TSS for one sigma standard deviation are: ± 30.5 mg/L for an average BOD₅ of 198 mg/L and ± 5.2 mg/L for an average TSS of 15 mg/L, respectively (see Reference 7). (It should be recognized that precision data for each analytical parameter will depend on the magnitude of the measurements and that certified laboratories can provided this information for all of their test procedures regardless of the type of data distribution.) For sake of example, use precision data of ± 2.3 mg/L for BOD₅ and ± 6.8 mg/L for TSS over the concentration range given in Table 3. The resultant ranges of values are shown.

Table 3 – Hypothetical One Sigma Concentration Ranges

Parameter	Units	10-9-12	1-3-13	4-10-13	7-3-11
Biochemical Oxygen Demand	mg/L	13 ± 2.3 or 10.7 to 15.3	16 ± 2.3 or 13.7 to 18.3	17 ± 2.3 or 14.7 to 19.3	16 ± 2.3 or 13.7 to 18.3
Total Suspended Solids (TSS)	mg/L	28 ± 6.8 or 21.2 to 34.8	24 ± 6.8 or 17.2. to 30.8	39 ± 6.8 or 32.2 to 45.8	32 ± 6.8 or 25.2 to 38.8

The BOD₅ results demonstrate that equilibrium has been achieved over the approximate eight month period; however, the TSS results are not at equilibrium. Application of the proposed guidelines over time will allow the BWM to decide if phase or whole landfill equilibrium has been obtained. However, there are possible weaknesses in the proposed methodology. These include the following:

- 1) The more the number of stability parameters used to establish equilibrium, the more difficult will be approval process.
- 2) The use of higher allowable precision ranges (one, two or three sigma standard deviations), the easier will be the approval process.
- 3) The method of dealing with outliers must be determined in advance to avoid the rejection of valid data.
- 4) Environmental data are typically non-parametric which does not support the use of standard deviation values based on normal distribution.
- 5) Lack of data will postpone approval of PCC termination.

Final Conclusions and Recommendations

Data collection and evaluation are vital if landfill owners/operators are to be successful in getting BWM approval of their proposed PCC termination plan. The ACL study has demonstrated some of the key considerations in formulating such a plan.

Abridged Bibliography

Introduction References (Not listed in Introduction)

1. Pilot Study of a MSWLF for PCC Termination Identification (7-19-11).
2. PCC Working Group (PCCWG) Meeting Minutes (March 7, 2012).
3. Allen County Landfill (ACL) Tour and Meeting (6-19-12).
4. Pilot Study of a MSWLF for PCC Termination Identification (7-19-11).
5. Allen County Pilot Study Re Post Closure Care (PCC) Termination Validation (date unknown).
6. Thoughts about Allen County Landfill (ACL) as a PCC Termination Pilot Plant (6-20-12).

Final Report References (Note that references 9 and 13 are pending)

1. Burkhead, Carl E., "Post Closure Care (PCC) Termination Plans: Principles and Needs," last presented at the A&WM meeting in Overland Park (February 19, 2013).

2. SS#10 – ACL Water Balance (8-7-13).
3. Tchobanoglous, G., Theisen, H. and Eliassen, R., "Solid Wastes: Engineering Principles and Management Issues," McGraw-Hill, Inc., Table 4-3, page 57 (1977).
4. Burkhead, Carl E., "A Basis for a Leachate Sampling Protocol: Comparison of Allen and Johnson County Landfill Leachate Sampling Results" (8-5-13)
5. Burkhead, Carl E., "Leachate Sampling Protocol," (2-13-13).
6. Burkhead, Carl E., "Summary of Leachate Sample Collection Locations and Storage Facilities," (4-17-13).
7. APHA, AWWA and WEF, "Standard Methods for the Examination of Water and Wastewater," 22nd Edition (2012).
8. BWM Burkhead, Carl E., "PCC Termination Determination and the Concept of Equilibrium," (9-26-12).
9. Proposed Policy 13-XX, "Alternative Post Closure Care (PCC) Termination."
10. Burkhead, Carl E., "Benchmarks for Assessing Municipal Solid Waste Landfill (MSWLF) and Hazardous Waste Facility (HWF) Stabilization for Post Closure Care (PCC) Termination," (9-16-11).
11. Hjelmar, O., et al, "Leachate emissions from landfills," AFR-REPORT 265, Swedish Environmental Protection Agency (January 2000).
12. Kjeldsen, P., et al, "Present and Long-Term Composition of MSW Landfill Leachate: A Review," Critical Reviews in Environmental Science and Technology, 32(4):297-336 (2002).