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A REVIEW OF BIODEGRADATION TECHNOLOGY IN TODAY'S BIOLOGICALLY ACTIVE LANDFILLS

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Background: The FTC on Biodegradability Claims

The FTC's *Proposed Revisions to the Green Guides*[3] states on p. 63568 as follows: "The Commission has challenged degradability claims more than any other specific claim addressed by the Green Guides. These cases were not based on products' inability to degrade under any conditions, but rather on their inability to degrade in the manner consumers expect." *(emphasis added)* Among the key pieces of evidence adduced by the FTC in gauging consumer expectations is a survey conducted by APCO Insights in 2006, commissioned by the American Plastics Council, now the Plastics Division of the American Chemistry Council (ACC)[1a].

Foremost among the findings of the survey was a perception among:

1) 80+% of the respondents that a "biodegradable" labeled article would biodegrade in a natural environment, in a landfill, or in their backyard;
2) 73.7% of the respondents that biodegradable packaging products would be less burdensome in a landfill;
3) 60.2% of the respondents that a "biodegradable" labeled package should decompose in one year or less.

The landfill aspect of the APCO respondents is critical because, as the following section shows, landfills represent by far the largest venue in which municipal solid waste (MSW) ends up. Yet, recent conversations with ACC personnel appeared to suggest by and large a significant lack of the importance in the public perception today of landfill biodegradation in the overall disposition scheme[1b]. Finally, the FTC's *Proposed Revisions to the Green Guides* landfills goes to some length to characterize landfills today as relatively inert (see below). All told, these factors lead the FTC to stipulate that a product may not be labeled as biodegradable because, among others, if it ends up in a landfill, it would not biodegrade within one year.

This document will show that the majority of landfills today indeed are not only biologically very active but in fact are very important sources of recoverable energy. A companion document will show that, in addition to the important naturally-derived bioplastics that are available today, state-of-the-art technology is also commercially in place today that renders traditional petrochemically-derived plastics biodegradable in their largest disposal venue – landfills[1c]. This in turn now makes it possible to start recovering the potential energy from the fossil raw materials from which these plastics were made in the first place.

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The Pre-eminent Position of Landfills in the MSW Stream

According to the US EPA, 32.5% of US municipal solid waste (MSW) is recovered and recycled or composted, 12.5% is burned at combustion (WTE) facilities, and the remaining 55% is disposed of in landfills[2a]. This ties reasonably well to the figures given in the FTC Green Guides proposed revision document stating that together, landfills and incinerators received 66% of municipal solid waste in 2008[2b]. Taking the 24% figure for recycling cited in the Guides revision[2b], and deducting it from the 32.5% EPA figure given above[2a] for recycling plus composting gives a net estimate of 8.5% for the commercial composting piece.

So, in addressing the Green Guide's "environment of customary disposal", in 2008 we have the vast majority, 55%, landfilled, 24% recycled (a very encouraging number; a full 43.6% of the landfilled piece!), 12.5% incinerated, and 8.5% commercially composted. This paper focuses on biodegradability considerations in regard to the MSW stream, so recycling and incineration clearly do not figure in this particular discussion – nothing biodegrades there! In the remaining venues where biodegradation can take place, landfills account for 87% of the total vs. commercial composting at only 13%. Let us therefore review the FTC's position on the fate of disposables in landfills as stated in the *Proposed Revisions to the Green Guides*. The relevant information can be found primarily on pp. 66, 67 and 70 of the Revisions and in references cited therein[3], esp. refs. 181, 185, 186, 197 and 198.

Description of Landfills as Given in the FTC Green Guide Proposed Revisions

The *Revisions*[3] refer to federal environmental regulations that require landfills to minimize inter-action with water, oxygen, and light.[3a] Referenced comments reportedly submitted as the FTC was preparing these *Revisions* include suggestions that, absent a robust supply of these elements, decomposition is severely retarded[3b]. The *Revisions* document goes on to cite commentary to the effect that very little, if any, degradation occurs when a product is disposed of in a landfill, and that modern landfills are in fact entombment facilities where air, light and water are excluded by strict design[3]. The FTC also refers to their Staff Business Brochure, which reportedly states that a "reasonably short period of time" depends on where the product is disposed. The brochure then explains that in landfills, where most trash is taken, materials degrade very slowly and certain materials take decades to decompose[3c].

Actually, several of the FTC's references are quite familiar to this author from two decades ago, when he was executing successful large-scale plastics recycling efforts at Rubbermaid Commercial Products. At that time, a growing negative public perception of plastics centered on their perceived accumulation in dwindling landfill space, while environmentalists were urging the alternative use of the presumably biodegradable paper offsets. It was Prof. William Rathje, one of the FTC's *Revisions* reference sources,[3b] who, in addition to pointing out the much larger paper contribution to landfilled MSW relative to plastics, also was seen by millions of TV viewers retrieving 40-year-old totally readable newspapers and even undegraded foodstuffs from Arizona landfills. The widely broadcast conclusion was that little if anything degrades in landfills – not even paper and often not food, either. That, however, was twenty years ago!

Using all the aforesaid as a reference basis still today, the FTC concludes that in fact landfill biodegradability time far exceeds the reasonably short period of time as espoused in the current *Green Guides*, and certainly does not fit the consumer perceptions given as the basis for their present one-year degradation time limit. Therefore, unless a marketer can show test data showing complete decomposition in the disposal venue – in this case landfills – in one year or less, a claim of biodegradability is to be defined as deceptive[4].

Biologically Active Landfills

Much has changed in twenty years! According to the US EPA, the number of open landfills in the U.S is steadily decreasing, from 8,000 in 1988 to 1,754 in 2006. The capacity, however, has remained relatively constant. New landfills are much larger than older ones.[2a] Conversations with major landfill operators suggest that the number of active landfills today is closer to 1,500[5]. All are required to collect methane by the EPA. Several hundred more are closed and/or capped.

Great advances have been made in the past twenty years in studying the variables that govern methane generation, and in managing today's landfills to maximize the biodegradation of the materials present in such a fashion as to optimize methane generation rate and use. The major landfill operators as well as several university laboratories have conducted and/or participated in many decisive studies that lead to our current understanding of these active systems and to enhanced methane capture and extensive commercial use[5,6]. Among these, one of the most comprehensive studies, albeit somewhat dated by today's standards, was performed at Virginia Polytechnic Institute[6].

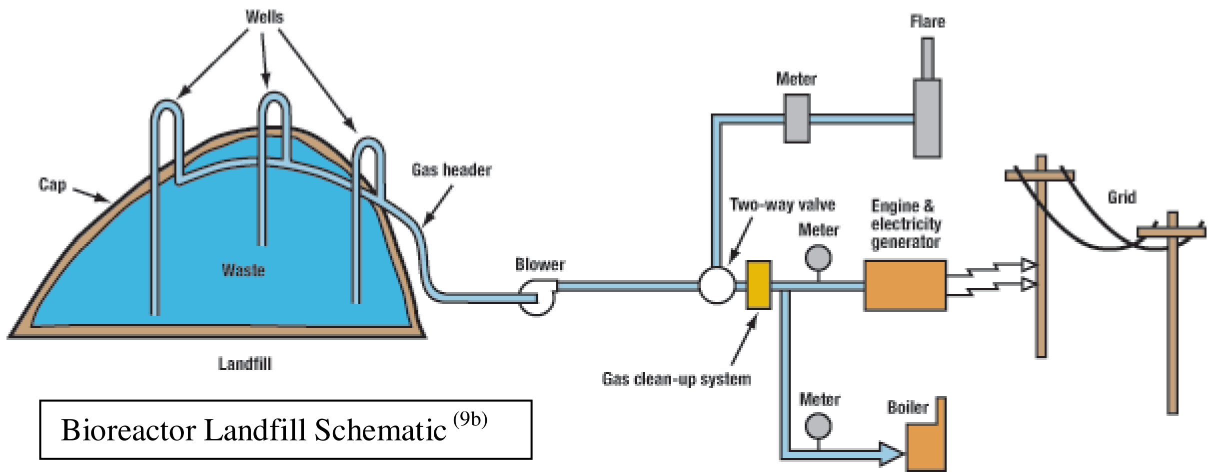
Among all the thoroughly studied landfill variables that contribute to biodegradation rate, and therefore have a pronounced effect on the performance of today's biologically active landfills as compared to the relatively inert so-called dry tombs referenced by the FTC Green Guide *Revisions*, the most significant by far is moisture level[5,6]. It is therefore no surprise that US landfills vary significantly in activity by region as a function of available moisture, with West Coast landfills being the driest at 7-15% moisture level. These are also the slowest in rate, heat up the least as a consequence, and would have been expected to yield old yet readable unearthed newspapers in Arizona[3b].

US Pacific NW and Central zone landfills are intermediate at 20-30% moisture and the wettest landfills are encountered in Florida at 35-45% moisture, with 45% being about the practical upper limit of moisture[5,6] based on mechanical stability (weight support, etc.). Landfill Methane Potential (LMP) is one of the widely used laboratory measures of potential landfill biological activity[7]; one can almost overlay rainfall and LMP maps of the US.

By far, the greatest single advance in landfill biodegradation rate acceleration through moisture level elevation has been the incorporation of the leachate recirculation process to increase moisture content and homogenize the overall cell moisture profile. Leachate recirculation is the basis of today's bioreactor landfills, and is among the most intensively studied and carefully managed operating parameters. Studies too numerous to mention here have shown major increases in most landfill operating indicators with leachate recirculation, and of these, the jump in LMP, twofold or more, has been among the more dramatic as a function of moisture level[5-7].

This process of conversion of the so-called dry-tomb landfills referenced in the FTC *Revisions*[3] to today's increasingly typical active bioreactor landfills incorporating leachate recirculation continues steadily[8,9]. As of October 1, 2010, 526 landfill methane operational projects had been established, which is one-third of the 1,500 estimated active landfill sites in operation today[5], with an additional 515 sites eyed for conversion to bioreactor landfills.[8] This contrasts with the 399 operating bioreactor sites estimated by the EPA in 2005[9a].

The EPA LMOP program has produced some very encouraging operating statistics that were reported in 2008, when in April of that year, approximately 450 bioreactor landfill LFG energy projects were operational in the U.S. At the time, these 450 projects were reported to generate approximately 12 billion kilowatt-hours of electricity per year and deliver 235 million cubic feet per day of LFG to direct-use applications[2a].



Bioreactor Landfill Schematic [9b]

The LMOP 2008 report stated that a typical 3 megawatt landfill gas (LFG) project can potentially increase the output of the U.S. economy by more than $14 million. Among the commercial successes cited were:

- BMW expects a savings at their Greer, SC manufacturing plant of more than $1MM/year;
- General Motors expects savings of more than $5MM/year from their 4 current direct use LFG projects.
- SC Johnson estimates $1 million in savings per year at its plant in Racine, WI.

The LMOP report goes on to state the potential advantages of bioreactor vs. dry tomb landfills, which include:

- *Decomposition and biological stabilization in* ***years vs. decades*** *in "dry tombs"*;
- A 15 to 30 percent gain in landfill space due to an increase in density of waste mass;
- Reduced leachate disposal costs and reduced post-closure care.

We believe that the foregoing discussion explains what appears to be a major disconnect between the stated FTC *Revisions* perception that materials will for the most part not degrade in landfills *vs.* the fact that indeed biodegradation in the wetter landfills will occur at measurable rates, but especially *vs.* the fact of increasing conversion of the referenced dry tombs to commercially productive bioreactor landfills. It would therefore appear inappropriate to rule out the properly qualified labeling of a product as biodegradable based on a blanket assertion that the product is unlikely to degrade in a landfill.

Biodegradation of Suitably Treated Conventional Thermoplastics in Bioreactor Landfills

The biodegradation reactions occurring under the initially aerobic (air present) and ultimately anaerobic (absence of air) conditions in landfills are very well known and need not be gone into here. Suffice it to say that, among the many nutrients required, the primary "foodstuff" is a source of carbon for microorganism growth. Carbon sources, their moisture content, ease of breakdown, etc., are an entire science and also beyond the scope of this paper.

Plastic products made from traditional petrochemically-derived raw materials are potentially a major source of carbon nutrient if they can be metabolized by suitably acclimatized microorganisms. In the US, the total market for just two plastic raw materials, polypropylene (PP; No. 5) and polyethylene (PE; Nos. 2,4) is over 40 billion pounds/year, of which approximately one third goes into packaging applications, and in turn of which 55% or more is likely to end up in a landfill.

As pointed out at the beginning of this paper, our companion document[1c] shows that, in addition to the current availability of the important naturally-derived bioplastics such as PLA and others, state-of-the-art technology is also commercially in place today that renders traditional petrochemically-derived plastics biodegradable in landfills while fully maintaining their original recyclability. That paper describes in detail the laboratory-scale testing using, among others, the ASTM D5511-02 protocol that has demonstrated such anaerobic biodegradation in a correlatable landfill environment[5-7].

That said, it is important here to raise a very important flag as to the use of an elapsed-time standard - whether it be based on public "biodegradability" awareness or the lack thereof, or on a pass-fail standard such as the ASTM D6400 certification for commercial compostability (90% disappearance in 180 days or less) – as the basis on which to set expectations for practical biodegradability in a landfill environment for <u>any</u> waste, including biodegradable plastics.

The challenge here is obvious from the above discussions: the <u>variation</u> in landfills, primarily in moisture content by US region as well in terms of other variables, and even in bioreactor landfills, is <u>greater and degradation times longer than the public seems to think, and certainly longer than in commercial composters</u>. The EPA defines the <u>accelerated</u> degradation rates in bioreactor landfills in terms of <u>years</u> vs. the dry tomb decades[2a]. While we cannot point to any specific information as to actual hard start-to-finish degradation times for materials in landfills, we are told that the recirculating leachate in a bioreactor landfill shouldn't be sampled as a representative inoculum source for tests for at least three years[5]. Thus, attempts to define longer-term anaerobic landfill biodegradation limits in terms of manufacturing-style commercial composting standards such as ASTM 6400 <u>does not address these realities of landfill biodegradation</u>.

As mentioned in the companion paper[1c], work is currently underway to extend the ASTM D5511 anaerobic test studies to arrive at an assessment of a reasonable longer-term expectation for achievement of complete conversion to biogas in the rapidly proliferating bioreactor landfills. In the meantime, we have received some expressions of interest from landfill operators as to possibly accessing the biogas potential of suitably treated biodegradable conventional plastics as a means of incrementally boosting their under-capacity bioreactor landfills, as well as offers to assist in quantifying the gas available from the plastics.

<u>Conclusion</u>

Given all the foregoing, the Plastics Environmental Council (PEC) concludes and recommends the following:

<u>Whereas</u> during the past two decades, landfills have increasingly moved from operation as strictly sanitary holding units, or dry tombs, <u>managed to minimize biodegradation</u> as referenced in the *Revisions*, to commercially viable bioreactor landfills <u>managed to accelerate and maximize biodegradation</u> as a source of valuable recovered energy, and

<u>Whereas</u> in addition to the availability of environmentally attractive naturally-derived bio-plastics, technology now also exists to render conventional plastics biodegradable in their venue of primary disposal – landfills – while fully maintaining their original recyclability, and

<u>Whereas</u> today's accelerated landfill biodegradation processes now operate in terms of <u>years,</u> not decades as with the old dry tombs, but not as fast commercial composters that are mechanically managed to operate in terms of months but are outnumbered by landfills by almost 7/1,

<u>The PEC thus submits</u> that, rather than accede to a popular misconception as to biodegradation time spans under any imaginable circumstances and so mandate a blanket biodegradation time limit, the FTC could provide a great service by educating the public as to the proven facts of <u>all</u>

the modern end-of-life scenarios. This would include the fact that suitably made and properly labeled biodegradable products indeed will biodegrade in the venue of greatest prevalence – modern, active landfills – but the timeframe will be several years, not one year or many decades, and valuable energy recovery will occur as well.

Therefore, the PEC recommends that it should remain permissible, as is the case with the current Green Guides, for a product to be conscientiously marketed in good faith as biodegradable provided that suitable, accurate and scientifically supportable qualifications are provided to support such claims.

There is plenty of information contained and referenced in this and the companion documents[1c] to arrive at such good-faith qualifications, thus making it possible for the FTC to provide detailed guidance in order to prevent misleading, unqualified biodegradability claims.

References:

1) (a) American Plastics Council, *Biodegradable and Compostable Survey*; APCO Insights (September, 2006). The results of a more recent survey are the subject of a separate report. (b) Charles J. Lancelot, Ph.D.; private communication with Keith Christman, Managing Director Plastics Markets, and Ashley Carlson, Director Packaging; ACC Plastics Division (November 29, 2010); (c) Charles J. Lancelot, Ph.D.; *Anaerobic Biodegradation of Conventional Thermoplastics as Induced by Organic Additives;* Unpublished Document (December 04, 2010); as presented to the FTC.

2) (a) US EPA Methane to Markets Partnership Landfill Subcommittee: *United States Profile of Solid Waste Disposal Practices and Strategic Plan for Landfill Gas Management*; (6 June 2008); (b) US EPA, *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2008*

3) 16 CFR Part 260, Project No. P954501, Section V, Subsection C in Vol. 75, No. 199, pages 63568 – 63570 and 63603 (October 15, 2010): (a) *Ibid.* Ref. 197. (b) *Ibid*. Refs. 185, 198. (c) *Ibid.* Ref. 181.

4) *Ibid*., p. 71, Section C.4.b

5) We have had several conversations with leading technical and operating experts in the field of modern bioreactors and bioreactor landfill technology. These values and results represent their collected inputs.

6. Brad Shearer, *Enhanced Biodegradation in Landfills*, MS thesis submitted to the faculty of Virginia Polytechnic Institute and State University; (May 14, 2001) and many references cited therein. See also Ramin Yazdani, *Full Scale Bioreactor Landfill for Carbon Sequestration and Greenhouse Emission Control,* Yolo County (CA), Planning and Public Works Dept. (March, 2006).

7. The Landfill Methane Potential (LMP) test is largely the creation of *Prof. Morton Barlaz*, Professor and Department Head, Water Resources/Environmental Engineering, North Carolina State University, Raleigh, NC. Prof. Barlaz is one of the most widely published experts on biologically active landfill technology and engineering, and has collaborated frequently with landfill operators. The reader can readily access Prof. Barlaz's background and many landfill technology references at http://www.ce.ncsu.edu/faculty/barlaz/

8. (EPA Homepage/LMOP/*Energy Projects and Candidate Landfills* (October, 2010)

9. (a) Wendy Koch, *Projects across USA turn landfill gas into energy*; USA Today (February 24, 2010); (b) Brian Guzzone and Mark Schlagenhauf, *Garbage in, energy out - landfill gas opportunities for CHP[*] projects*; Power-Gen Worldwide (September 1, 2007). (*): Combined Heat and Power.