# AN EVALUATION OF THE DETERMINATION OF PUTRESCIBLE MATTER IN THE ASH RESIDUE OF A MSW COMBUSTOR

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## ABSTRACT

Putrescible testing of residue from MSW combustors has sometimes been included in the battery of tests required for a facility to demonstrate acceptable processing performance. Putrescible matter has often been incorrectly defined and the existing testing procedures do not actually test for putrescible matter. Several different test procedures have been used to measure the putrescible content; however, each procedure will produce unique but inaccurate results. There is no need for putrescible testing or improved procedures for the modern waste-to-energy facility. Putrescible test results are not required for calculating combustion efficiency. No health risks have been associated with residue putrescible content. Odors will not be generated due to sterilization of the residue in the furnace until bacteria are naturally reintroduced to the residue. Provided the burnout of the residue is maintained at or below about 5% combustible content, the putrescible content of the residue and thus any odors will be insignificant.

## INTRODUCTION

Putrescible testing has often been required for testing on waste-to-energy facilities. Normally, this guarantee level is a fraction of 1% of the weight of the dry residue. It would appear that the reason why this testing is required is because putrescible matter testing is included in an appendix to ASME Performance Test Code 33—Large Incinerators [1]. Putrescible matter is a small portion of the unburned combustibles in the ash residue and measurement of the total combustibles, as required for thermal performance, would include any putrescible matter present. This paper is written to explore what putrescible matter is, discuss test procedures that have been used, and to determine if there is a need to measure putrescible content of the ash residue.

## DEFINITION OF PUTRESCIBLE MATTER

The word "putrescible" is defined as — liable to become putrid. Putrefaction, the process by which this decomposition occurs, is defined as — the anaerobic fermentation of proteinaceous matter [2]. Proteinaceous matter is matter which is a protein.

Much of the combustible material in residue comes from structural components of cells, namely carbohydrates, proteins, and lipids. Carbohydrates are compounds which contain atoms of carbon, hydrogen, and oxygen, such as sugars, starches, and cellulose. Proteins differ from carbohydrates because they contain these elements as well as nitrogen and possibly other elements such as sulfur, iron, or phosphorus. Proteins are the essential building blocks of plant and animal cells. Lip-

ids are a group of substances, such as fats and waxes, which are all soluble in organic solvents, such as ether.

The organic material in the waste stream will contain varying quantities of carbohydrates, proteins, and lipids. Carbohydrates make up by far the largest percentage of the refuse which is incinerated. Paper consists almost exclusively of cellulose while grass will have some protein and seeds or animal tissue which will generally have a greater quantity of protein.

The term fermentation (anaerobic decomposition) is generally limited to the decomposition of carbohydrates by an enzyme or organism in the absence of oxygen. Fermentation is the process by which wine is produced and the mild, unoffensive odor associated with granaries and feed mills.

Similarly, putrefaction occurs when proteins are digested by microorganisms in the absence of oxygen. Some of the products of putrefaction are classified as amines, or protein building blocks, some of which are putrid smelling compounds. Putrefaction is a natural process of anaerobic decomposition that may release foul smelling odors if disturbed before the decomposition cycle is completed. These putrid compounds can be made to further react when in the presence of oxygen, producing end products which are relatively odorless. The protein content of the refuse is only a small percentage and would be expected to only consist of a small percentage of the residue combustible content.

Many proteins, when partially digested, are valuable to man in everyday life. Some of the products generated by partial digestion include cheese, lactic acid, methylamine, acetic acid, butyric acid and ethyl alcohol.

The foul smell of decaying food wastes has been an impetus for incineration. Decomposition in the presence of oxygen is the process which occurs in the waste-to-energy facility when refuse is incinerated. Incineration is faster and is chemically more complete than putrefaction because it occurs in the presence of oxygen. The chemical reaction is complete and no putrid odors are produced. Burnout in modern incinerators is thorough enough to prevent odors from developing in the residue. The key point is that all three processes, fermentation, putrefaction, and incineration, are naturally occurring; however, the organisms responsible for fermentation or putrefaction would be killed during the incineration process.

Putrescible matter in MSW residue can be defined as the protein portion of the combustible matter which will become putrid if subjected to anaerobic digestion. While carbohydrates may decompose anaerobically, putrefaction only occurs in protein. These two items are often used interchangeably when discussing this issue, particularly in documents which have been translated from German references. Anaerobic decomposition of carbohydrates will produce an odor; however, the odor and chemical processes are not the same as for the decomposition of protein, and therefore the decomposition of carbohydrates and fats should not be considered as if they were putrescible.

## PUTRESCIBLE TEST PROCEDURES

There are at least four basic methods which have been used for putrescible testing. Each method approaches putrescible testing in a different manner. These methods are Method A (PTC 33) [1], Method B (PTC 33) [1], the Düsseldorf Method, and Method 503D (Standard Methods) [3].

### Method A

Method A calculates the putrescible content by totaling measured quantities of lipids, carbohydrates, and proteins. This procedure is complicated and time consuming. However, many compounds which are detected by these measurements are not in fact putrescible.

The test procedure states that the method is apt to be biased, reporting more decomposable fats than there really are. However, many lipids, such as paraffin waxes or saturated oils, are not to be considered putrescible when applying the procedure. The carbohydrate analysis procedure is subject to incomplete identification of all carbohydrates; however, the author of the procedure states that even though the complex carbohydrates (such as cellulose) are potentially missed, they should not be considered to be putrescible anyhow. Proteins are identified by the presence of nitrogen. The nitrogen in the residue which was not part of a protein compound, such as products of a $NO_x$ control system or inorganic nitrogen, would again potentially bias test results.

### Method B

This test procedure is comparatively simple, employing a magnifying glass, tweezers, and the not-so-discriminating eye of the laboratory technician. In Method B of PTC-33, the technician is directed to look for fibrous materials; however, "... black particles, such as paper, char or charcoal are not putrescible. . . ." All fibrous particles are considered to be putrescible matter. However, few putrescible materials are "fibrous" in appearance. An old untitled putrescible test procedure used by the German technology manufacturer, Martin, is very similar to Method B.

Fundamental to any sampling process is the preparation of a uniform sample. To minimize the impact of the nonhomogeneous nature of residue, the sample must be dried, ground, and thoroughly mixed so that the repeatability of test results is acceptable. Standard sample preparation procedures, such as ASTM D2013, would potentially cause test results to be biased. Method B becomes infeasible because the putrescible particles become too fine and indistinguishable when ground. In order to improve repeatability for unprocessed samples, sample size becomes so large that the technician cannot properly screen for putrescible particles. If the samples are not ground, inconsistent results may occur due to a single larger particle throwing off the test. Either way, grit and other nonputrescible matter clinging to fibrous material may be counted as putrescible. The subjectiveness of the uncalibrated eye of the laboratory technician should be reason enough to discard this procedure.

### Düsseldorf Method

The Düsseldorf Method is a chemical analysis procedure available in several different unofficial translations which is significantly different from Method A in its analysis. This procedure attempts to identify all fermentable matter in the residue. The fermentable matter is dissolved in a sodium hydroxide (NaOH) solution and subsequently reacted to generate carbon dioxide ($CO_2$). The quantity of $CO_2$ produced is indicative of the content of fermentable material. This procedure is similar to Method A in that it is very complicated and reports more than just the putrescible content of the residue. If reactions are not taken to completion, the fermentable content may be underestimated.

### Method 503D

This procedure has been adapted from wastewater analysis. It is a test for lipids and is similar to the lipid determination portion of Method A and should therefore, in theory, provide the same conclusion as the test for lipids from Method A. This procedure does not measure or include the protein or carbohydrate content and implies that putrescible matter should be defined as the lipids content of the residue. The procedure text offers a caution that if any sulfur compounds and certain other compounds are present, they may be extracted and be reported as lipids.

## COMPARING THE TEST PROCEDURES

The purpose of a putrescible test procedure is to accurately report the putrescible content of MSW residue. None of the putrescible test procedures adequately accomplish the intended result.

PTC-33 [1] includes Methods A and B for putrescible matter, but does not provide a definition of putrescible matter, nor does it provide guidance for use. It is clear from the two test procedure descriptions that not all organic matter is considered to be putrescible, nor will the two procedures produce the same result, except by pure chance. Method A of PTC-33 tests for most lipids, carbohydrates, and proteins, but Method B only looks for fibrous material. It appears that fibrous cellulose, as long as it was not charred, would be considered putrescible under Method B, but not under Method A. Most fatty substances, if any were to survive the incinerator, would not be considered putrescible under Method B, because they are not fibrous in appearance, but would be reported as putrescible under Method A. Obviously, the two procedures can not produce comparable results.

None of the procedures have been subjected to the testing and procedure standards of the American Society for Testing and Materials (ASTM). All the putrescible test procedures are subject to much interpretation, resulting in probable errors from test-to-test and laboratory-to-laboratory. There is not a testing authority knowledgeable about residue putrescible which can be approached when questions arise concerning the ambiguous procedures.

Putrescible levels are usually quoted as tenths of a percent of the residue weight, typically 0.2% or 0.3%. No basis for this limit has been found and, as shown below, test results can vary widely. At these levels, a single seed or minute quantities of contaminants can cause a high reading for certain procedures. When dealing with very small percentages, testing errors can have a very significant impact on the test results. Because the test procedures are subject to interpretation, the likelihood of obtaining incorrect conclusions is significant. ASTM procedures indicate the precision and bias of each test procedure. Little information concerning accuracy is available for any of the putrescible methods.

All of the procedures report results which include more than or something other than the putrescible content. Because none of these procedures measure putrescible material per se and since each of the procedures measures different parameters, the results from the four tests could only agree by chance or error.

## TEST DATA AVAILABLE

Very little test data is available which can be used to verify or compare results from one method with an-

TABLE 1 COMPARISON OF METHOD A AND METHOD B USING SPLIT SAMPLES

| Sample | Method A % | Method B % |
|---|---|---|
| 1 | 0.556 | 0.908 |
| 2 | 0.541 | 1.98 |
| 3 | 0.253 | 0.683 |
| 4 | 0.17 | 0.0405 |

other. No information was found which demonstrates that any method accurately determines putrescible content. Some information is available which compares results from a split sample at two independent laboratories. For the limited data comparing tests completed on split samples using different test procedures, correlation could not be demonstrated. Using Method A, test data showed that different laboratories did not even agree on the percentages of lipids, carbohydrates, and proteins. Errors or differences, sometimes greater than a factor of ten, were common between the data from the limited comparative tests which have been documented.

Some data which compared test results from the same sample when using Method A and Method B was found. Documentation of the testing program and results was not complete; however, no other comparisons were found. A series of four samples were developed and were sent to a laboratory for split sample comparative testing. Table 1 summarizes the results of the tests. The test results are not useful for comparison of procedure accuracy because it is not possible to know which procedure more correctly determined the actual putrescible content or if both procedures were inaccurate. The range of the samples shows a wider range of putrescible content than would normally be expected from modern resource recovery facilities. This data does demonstrate that significant differences between the two procedures used can occur, even when looking at samples containing very little putrescible matter.

The best collection of test data holding the same sample constant but comparing laboratories and procedures has been compiled by Mr. Wolfram G. Schuetzenduebel, as reported in Waste Age, August 1991 [4]. For each of the tests reported, samples of residue were obtained from a facility and were tested using various methods at different laboratories. A summary of several tests are presented in Table 2. No correlation between test procedures or laboratories was evident and large discrepancies and questions remain concerning the quality of the test procedures.

Further discrepancies arise when the breakdown for the Method A results for Sample A are compared.

TABLE 2 COMPARISON OF TEST PROCEDURES AND LABORATORIES
(Courtesy of National Solid Waste Management Association)

| Sample | Lab. | Test Procedure | | |
|---|---|---|---|---|
| | | Method A % | Düsseldorf % | Method 503D % |
| A | 1 | 0.82 | 0.08 | 0.59 |
| | 2 | 0.76 | | |
| B | 1 | 0.49 | 0.30 | 0.02 |
| | 2 | 0.04 | | 0.04 |
| C | 1 | 0.25 | 0.43 | 0.02 |
| | 2 | 0.05 | | 0.05 |

Adapted from data reported in Waste Age, August 1991.

TABLE 3 COMPARISON OF METHOD A TEST RESULTS FOR SAMPLE A
(Courtesy of National Solid Waste Management Association)

| Laboratory | Lipids % | Carbohydrates % | Protein % | Total % |
|---|---|---|---|---|
| 1 | 0.60 | <0.10 | 0.22 | 0.82 |
| 2 | 0.01 | <0.02 | 0.73 | 0.76 |

Adapted from data reported in Waste Age, August 1991.

Refer to Table 3 for a listing of the lipid, carbohydrate, and protein content for each sample. On first glance Laboratory 2 appears to report consistent results when using Method A and Method 503D for Samples B and C. Recall however that Method 503D only tests for lipids. No data was reported for samples B and C presenting a breakdown between lipids, carbohydrates, and proteins for the Method A runs. In order for the data to be consistent, the laboratory should not have found any carbohydrates or proteins for Sample A. If this was the case, the laboratory should have reported the detection limit for their equipment. No detection limit was reported for proteins in the article, however, a detection limit of 0.02% was reported for carbohydrates. This implies that at least a 40% difference between the quantity of lipids was reported by the same laboratory using the same sample but different test methods. This data also show significant problems with the test procedures and again does not confirm the accuracy of any of them.

## THE NEED FOR PUTRESCIBLE TESTING

Often, this testing requirement has been passed from project to project without any serious analysis concerning what the putrescible test is intended to accomplish

and what it actually demonstrates. The need for putrescible testing, as indicted in PTC-33, was to insure that no health risks are caused by the MSW residue.

Before modern scientific methods were applied, it was assumed that if something smelled bad, it must be bad for you. There is no need to develop a better procedure because burnout in modern incineration systems has improved significantly since the early systems, and the quantity of putrescible matter is now so minute that it will not support significant bacterial growth. If there is no bacterial growth, objectionable odors can not be generated by putrefaction.

In addition, the residue has, as a minimum, been uniformly heated, well above 180°F required to be sterilized, killing all the microorganisms in the residue. Of course bacteria and other microorganisms are ubiquitous, so they will be eventually reintroduced to the ash residue that is subject to putrefaction, but this is a slow natural process that will not take place before the residue is placed in a landfill or is further processed for beneficial use.

The primary purpose of acceptance testing is to demonstrate throughput, energy recovery, and residue quality (burnout). Completing a putrescible test is not useful for determining the higher heating value (HHV) of the MSW fired which is required to demonstrate the throughput and energy recovery or satisfactory burnout of the residue. Determination of the residue combustible content is useful for demonstration of HHV and residue quality.

Burnout of the residue can be demonstrated by performing tests for combustible content and, therefore, putrescible testing is not necessary. There are ASTM standards which are used by many laboratories for testing coal and other similar materials which are used for combustible testing. These test procedures are interpretable, repeatable, and standardized. Accuracy and bias information is provided for each procedure. Any statement concerning residue quality which is based upon a putrescible test is highly suspect and not meaningful.

The quantity of combustible matter in residue is typically less than 5%. The quantity of putrescible matter is a subset of the combustible matter and is well less than 1% of the total residue stream. The impact of this material and the natural decomposition process is intuitively negligible.

## CONCLUSION

There is no need for putrescible testing in the modern municipal solid waste-to-energy facility. Putrescible testing should not be completed for testing of MSW residue and should not be included in future test procedures.

This conclusion is supported by German testing experience. Some of the early procedures were developed in Germany and were imported to the United States. However, no German standard was ever accepted. VGB Code of Practice for Warranties for Steam Boiler Plants With Refuse Firing Systems [5] recommends that

> ". . . stating of contents of fermentable substance in the grate slag should be dispensed with since, on the one hand, the various methods of determination lead to very different results, and, on the other hand, the high combustion temperatures make it possible to expect sterile residues."

The focus in residue testing should be to demonstrate the facility's ability to thoroughly burnout the residue. Analysis of the combustible content of the MSW residue should be completed to monitor burnout and is adequate and appropriate for this task. Comparable and reliable ASTM test procedures are available which more accurately demonstrate facility performance. These procedures have been used and checked to the extent that estimates of accuracy and bias are provided. Because the total combustible content in the residue is about twenty times greater than the putrescible content, small errors will have much less impact on the final answer.

It is the position of the ASME PTC-34 Committee on Waste Combustors with Energy Recovery that the putrescible matter content of incinerator residue is not a meaningful parameter in the evaluation of incinerator performance. Therefore, the Committee does not intend to include the measurement of putrescible matter in the upcoming code.

## REFERENCES


[1] The American Society of Mechanical Engineers. ANSI/ASME PTC 33-1978, *Large Incinerators,* 1979, New York, pp. 18, 47–50.

[2] Clifton, C. E. *Introduction to the Bacteria,* New York: McGraw-Hill, 1958, pp. 36–37, 172–173, 180–181, 229–233.

[3] *Standard Methods for the Examination of Water and Wastewater,* 16th ed., Method 503D, Washington D.C., American Public Health Association, 1985, pp. 496–503.

[4] Schuetzenduebel, W. G. "Putrescibles are Hard to Find," *Waste Age,* **22**, 8, August 1991, 113–118.

[5] *VGB Code of Practice. "Warranties for Steam Boiler Plants With Refuse Firing Systems."* VGB Technische Vereinigung Der Grosskraftwerksbetreiber E. V., 1987, p. 14.