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MANY REPORTS, WEAK EVIDENCE? EVIDENCE LEVELS FOR MICROBIAL PLASTIC DEGRADATION IN THE 2,535 RECORDS OF PLASTICDB

Abstract: Plastics are often compared by how many microorganisms have been reported to degrade them. This study asks whether that count reflects the strength of the evidence. All 2,535 records of PlasticDB, a public database of microorganisms reported to degrade plastics, were downloaded. Each record was placed in one of four levels by the strongest method it lists: a screening test only, a change in the material, breakdown products, or CO_2 production or respiration. Ranked by the number of records, the leading plastics were polyethylene (PE, 513), polyurethane (PU, 395), polycaprolactone (PCL, 291) and polyethylene terephthalate (PET, 247). Ranked by records with breakdown products or CO_2, PE stayed first, polylactic acid (PLA) rose from sixth place to second, and PU fell from second to fourth. Under five other ways of weighing the evidence, PE stayed first, PLA ranked second or third and PU fourth or fifth. Of the PU records, 299 rest on a clear zone test only, 220 of them from one study. Record by record, PLA records listed breakdown products or CO_2 more often than PE records (59.6% against 32.2%), but at the level of studies the difference was smaller and not statistically clear (51.5% against 41.2%). Most PLA records do not come from thermophilic conditions. The author had predicted that PET would have the most degrading microorganisms and that most PLA records would come from high temperatures; neither was correct. The number of reports is an unreliable guide on its own.

Keywords: plastic biodegradation; microorganisms; PlasticDB; polyethylene; polylactic acid; polyurethane; evidence

1. Introduction

Many studies report microorganisms that can break down plastics, and PlasticDB collects these reports in one public database [1, 2]. Each record links one microorganism to one plastic and one publication, and lists the laboratory methods used to show degradation. The authors of the database compared plastics by the number of species reported to degrade them. They noted that polyethylene is the only plastic with a carbon-carbon backbone whose number of reported species is comparable to that of plastics with other atoms in the backbone, such as polyesters, "but most studies lack strong evidence of polymer biodegradation" [2].

The methods behind the records are not equally strong. A clear zone is a transparent halo that forms around a microorganism growing on agar mixed with fine plastic particles; it shows that the organism breaks down these particles, usually with enzymes it releases. A loss of weight shows that the material changed, but the database's authors did not accept weight loss alone as evidence, "because this technique does not differentiate between the

biodegradation of additives or polymers" [2]. The strongest evidence traces the carbon of the plastic into CO_2 and into the microorganism's biomass [3]. The database's home page also states the authors' belief that no enzymes have been "categorically shown" to degrade polymeric and crystalline polyethylene, ether-based polyurethane, polystyrene, polyvinyl chloride or polypropylene [4].

The question matters for plastics sold as biodegradable. Polylactic acid (PLA) is widely seen as a replacement for ordinary plastics, but it is "basically non-degradable in seawater", and laboratory tests often do not match real conditions [5].

This study asks two questions. Does the ranking of plastics change when records are weighed by the strength of their evidence instead of being counted, and does the answer depend on how the counting is done? And does PLA have stronger evidence of microbial degradation than polyethylene, and is that evidence limited to high temperatures?

2. Data and methods

2.1. Data

The microorganisms table of PlasticDB (degraders_list.tsv) was downloaded on 17 October 2026 and again on 18 October 2026; the two files were identical [4]. It contains 2,535 records and 22 columns, with 608 different references, 933 microorganism names and 70 plastic labels, published from 1974 to 2025. The columns used were the plastic, the methods listed as evidence, the plastic product used, the thermophilic conditions field, the field "degradation extrapolated from enzyme" and the reference. In an earlier paper by the database's authors, thermophilic conditions mean temperatures above 50 °C [1].

2.2. Plastic groups

The labels PE, LDPE, HDPE and LLDPE were combined as polyethylene (PE), and the label Impranil was added to polyurethane (PU). Blends were not combined with pure plastics. The analysis covers the 14 plastics with at least 40 records each, 2,277 records in total (89.8% of the database). Six are conventional plastics: PE, PU, PET, polystyrene (PS), polypropylene (PP) and polyvinyl chloride (PVC). Eight are usually called biodegradable: PCL, polyhydroxybutyrate (PHB), PLA, polyhydroxyalkanoates (PHA), polybutylene succinate adipate (PBSA), polybutylene adipate terephthalate (PBAT), polybutylene succinate (PBS) and polyethylene succinate (PES).

2.3. Levels of evidence

The methods are written in the database in 101 spellings (97 when capital letters are ignored). Every method was placed in one of four levels, and each record was given the highest level among its methods:

- screening test only: a clear zone, turbidity, spectrophotometry and similar tests;
- change in the material: weight loss, electron microscopy (SEM), infrared spectroscopy (FTIR), tensile strength, water contact angle and similar measurements;
- breakdown products: products or shorter polymer chains detected by chromatography (HPLC, GC, GPC, SEC), mass spectrometry or NMR, or a rise in total organic carbon (TOC);
- CO_2 or respiration: CO_2 produced, oxygen consumed, or labelled carbon traced from the plastic.

The database marks 399 records as "degradation extrapolated from enzyme"; in this paper they are called inferred from an enzyme and are counted separately, whatever methods they list. A record has strong evidence if it is not inferred and its highest level is breakdown products or CO_2 or respiration. "Strong" is used here for short: it means that a higher-level method was listed, not that degradation was proven.

The main ranking counts records with strong evidence. Because the result could depend on these choices, the ranking was repeated in five other ways:

- counting studies with at least one strong record instead of records;
- counting spectrophotometry as a breakdown-product method;
- a strict definition in which GPC, SEC, NMR and TOC count only as a change in the material;
- counting the inferred records by the methods they list;
- merging the 18 labels of the PHA family (PHB, PHA, PHBV and others) into one group.

PLA and PE were compared with Fisher's exact test, both by records and by studies. This classification shows which methods a study reported, not whether each method confirmed degradation. Every number in the paper was calculated by a Python script from the downloaded file.

2.4. Prediction

The author was asked to write a prediction before counting, and he sent it together with his counts of the records for each plastic and of the thermophilic records for PLA and PE, made in a spreadsheet. He predicted that PET would have the most microorganisms that degrade it and that most PLA records would come from high temperatures.

3. Results

3.1. The whole database

Of the 2,535 records, 399 (15.7%) are inferred from an enzyme. Of the others, by the strongest method listed, 703 (27.7% of all records) rest on a screening test only, 681 (26.9%) on a change in the material, 541 (21.3%) on breakdown products and 195 (7.7%) on CO_2 or respiration; 16 list no method. A single method is listed in 1,060 records (41.8%), and in 661 records (26.1%) that method is a clear zone. Labelled carbon was traced in only 8 records from 6 studies.

3.2. Counting records against weighing evidence

Ranked by the number of records, the leading plastics were PE (513), PU (395), PCL (291), PET (247), PHB (223) and PLA (171) (Table 1, Figure 1). Ranked by records with strong evidence, the order was PE (165), PLA (102), PHB (93), PU (55), PCL (47), PHA (30) and PET (29).

Table 1. Records of microbial degradation in PlasticDB by plastic and by strength of evidence

Plastic	Type	Records	Studies	Inferred, %	Screening only, %	Strong, %	CO_2 or respiration, %
PE	C	513	160	1	5	32	13
PU	C	395	62	3	75	14	3

PCL	B	291	82	11	58	16	1
PET	C	247	66	74	2	12	3
PHB	B	223	80	14	20	42	16
PLA	B	171	68	15	4	60	17
PHA	B	86	44	29	35	35	1
PBSA	B	57	31	19	44	23	4
PS	C	57	24	0	0	42	4
PBAT	B	52	24	35	17	35	0
PBS	B	50	30	18	26	48	2
PP	C	49	17	0	0	37	20
PES	B	43	26	23	26	37	9
PVC	C	43	12	0	0	21	12

Note: Plastics are ordered by the number of records. Type: C, conventional; B, usually called biodegradable. Studies: number of different references. Inferred: inferred from an enzyme. Strong: breakdown products or CO_2 or respiration, not inferred; Strong includes CO_2 or respiration. The rest of the records have a change in the material as their highest level or list no method. Source: PlasticDB, downloaded 17-18 October 2026 [4]; author's calculation.

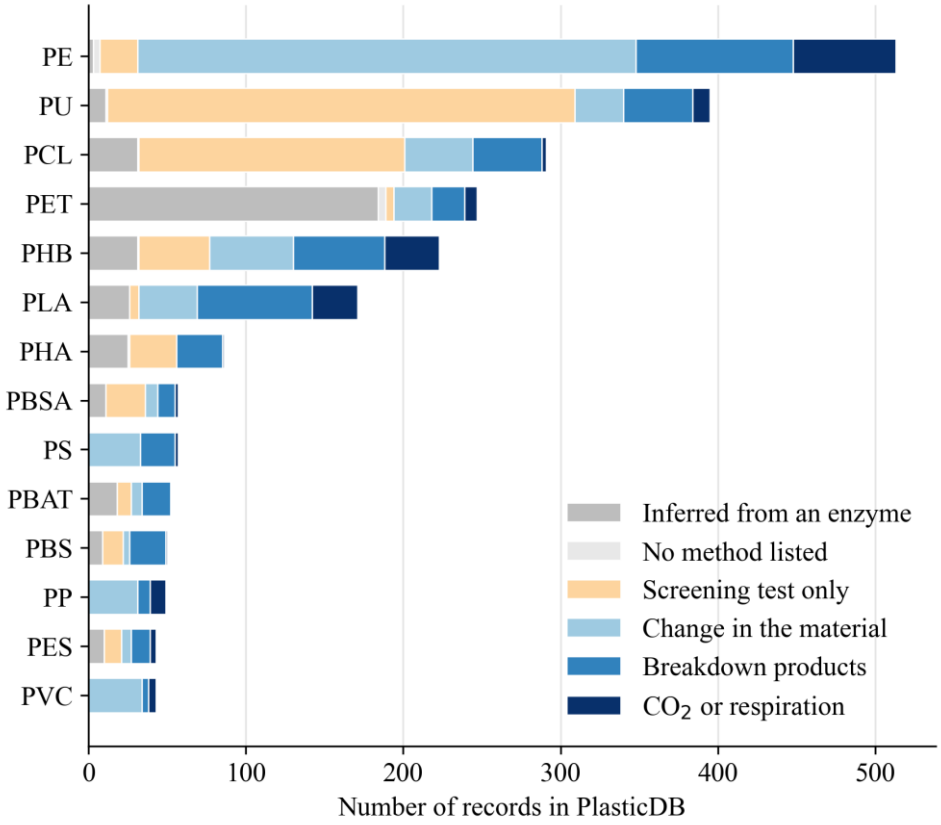


Figure 1. Records of microbial degradation for the 14 plastics, divided by the strongest method listed; records inferred from an enzyme are shown separately. Source: PlasticDB [4]; author's calculation.

Two plastics owe much of their count to one kind of evidence. Of the 395 PU records, 333 used Impranil, which the largest PU study describes as a soluble, commercial polyester polyurethane [6]. Of the PU records, 299 rest on a clear zone only, 297 of them with Impranil. That study screened more than 1,000 fungal strains and scored the clear zone around each one [6], and it contributes 220 PU records. Of the 247 PET records, 184 (74.5%) are inferred from an enzyme, and 99 of these come from one study that used

machine learning to find PET-degrading enzymes in natural diversity [7]. In the largest of these studies, the enzymes were made in the laboratory and tested on PET [7]; the database does not show that the microorganisms themselves were tested. The enzymes behind the inferred PET records are mostly PETases (128) and cutinases (23); 7 are lipases.

3.3. How much the ranking depends on the counting

Table 2 shows the rank of each plastic by records and under all six ways of weighing the evidence. Three results held under every one of the six: PE ranked first, PU ranked fourth or fifth instead of second, and PLA ranked second or third instead of sixth. The rank of PET depended on one choice. It was fifth to seventh when inferred records were set aside, but fourth when they were counted by their listed methods. When the PHA family was merged into one group, it ranked second with 144 strong records, ahead of PLA. Counting the records of the PLA/PHB blend study described in Section 3.4 as a clear zone only, PLA still ranked second, with 78 strong records.

Table 2. Rank of each plastic by the number of records and under six ways of weighing the evidence

Plastic	Records	Strong	By studies	Spectr.	Strict	Enzymes	PHA family
PE	1	1	1	1	1	1	1
PU	2	4	4	5	4	5	4
PCL	3	5	5	4	6	6	5
PET	4	7	6	7	5	4	6
PHB	5	3	3	3	2	3	*
PLA	6	2	2	2	3	2	3
PHA	7	6	7	6	8	7	*
PBSA	8	13	11	12	13	13	12
PS	9	8	8	9	7	10	7
PBAT	10	10	12	10	11	8	9
PBS	11	9	9	8	10	9	8
PP	12	11	13	11	9	11	10
PES	13	12	10	13	12	12	11
PVC	14	14	14	14	14	14	13

Note: Rank 1 is the plastic with the most records or studies of the given kind. Records: all records. Strong: records with strong evidence (main ranking). By studies: studies with at least one strong record. Spectr.: spectrophotometry counted as breakdown products. Strict: GPC, SEC, NMR and TOC counted as a change in the material. Enzymes: inferred records counted by their listed methods. PHA family: the 18 PHA labels merged; * PHB and PHA are part of this family, which ranks 2nd. Tied plastics are ordered by their number of records. Source: PlasticDB [4]; author's calculation.

PE ranked first in every column, but its strong records come from 66 of its 160 studies. Its records with CO_2 or respiration come from 20 studies, one of which, from 2024, contributes 15. Of the eight records with labelled carbon, five are for PE.

3.4. PLA and polyethylene

PE has three times as many records as PLA (513 against 171). Record by record, PLA had strong evidence almost twice as often (59.6% against 32.2%), also among records marked as not thermophilic (Table 3). But a few studies weigh heavily. Four studies give 57 of the 102 strong PLA records. Without the four largest studies of each plastic, the shares

were 39.5% for PLA and 26.3% for PE. The main reason for caution is the comparison of studies: 51.5% of PLA studies and 41.2% of PE studies had at least one strong record, a difference that could be due to chance. With the strict definition of breakdown products, the shares were also close.

Table 3. Evidence of microbial degradation for PLA and polyethylene (PE) in PlasticDB, number (%)

Comparison	PLA	PE	p
Records with strong evidence	102 of 171 (59.6)	165 of 513 (32.2)	<0.001
Same, records marked as not thermophilic	94 of 143 (65.7)	146 of 485 (30.1)	<0.001
Studies with at least one strong record	35 of 68 (51.5)	66 of 160 (41.2)	0.19
Records with strong evidence, without the 4 largest PLA studies	45 of 114 (39.5)	165 of 513 (32.2)	0.15
Same, without the 4 largest studies of each plastic	45 of 114 (39.5)	124 of 472 (26.3)	0.008
Records with strong evidence, strict products	51 of 171 (29.8)	130 of 513 (25.3)	0.27
Records with CO_2 or respiration	29 of 171 (17.0)	65 of 513 (12.7)	0.16
Same, without the PLA/PHB blend study	5 of 147 (3.4)	65 of 513 (12.7)	<0.001

Note: p is from Fisher's exact test, which treats records or studies as independent. Strict products: GPC, SEC, NMR and TOC counted as a change in the material. The PLA/PHB blend study is a soil burial test of blend mulches [8]. Source: PlasticDB [4]; author's calculation.

The CO_2 result for PLA rests almost entirely on one study. It gives 24 of the 29 PLA records with CO_2, and 28 of the 35 for PHB. That study measured CO_2 in soil burial tests of PLA/PHB blend mulches [8], and every one of its 52 records lists the same two methods, CO_2 and a clear zone. The CO_2 was measured for the blend in soil, while each microorganism was tested on agar plates, so here the CO_2 method describes the study, not the organism. Without this study, PLA had CO_2 evidence in 3.4% of its records, a lower share than PE (12.7%).

Thermophilic conditions play a small part for PLA. Only 25 of the 171 PLA records are marked as thermophilic, and 94 of the 102 strong PLA records are not. At the level of studies, 8 of 15 thermophilic PLA studies (53.3%) and 27 of 51 other PLA studies (52.9%) had a strong record.

4. Discussion

Counting records gives a misleading picture of which plastics microorganisms have been shown to degrade. PU is second by count, but three quarters of its records rest on a clear zone test, most of them with one soluble polyurethane product and 220 of them from one study. PLA, sixth by count, ranks second or third whenever the evidence is weighed, under every way of counting tried here. Most of the PET records are inferred from enzymes; at least in the largest study, the enzymes, not the microorganisms, were tested on PET.

The author's prediction was not correct on either point. PET ranks fourth both by records and by different microorganisms (152 against 248 for PU, 238 for PE and 208 for

PCL). Only 14.6% of PLA records are marked as thermophilic. After seeing the first results, the author explained in Russian why PU and PET have so many records with little direct evidence. These plastics are very common and popular as research subjects. Both contain ester bonds that many lipases can split, so many organisms and enzymes enter the list on indirect grounds. The data agree in that PU and PET records rest mostly on indirect methods. The ester-bond part fits PU in this database, because Impranil is a polyester polyurethane [6]. For PET, the enzymes behind the inferred records are mostly PETases and cutinases rather than lipases. Neither part was tested directly here.

Polyethylene ranks first under every way of counting, yet the database's own authors write that most polyethylene studies lack strong evidence [2]. This disagreement shows the limit of the method used here. The same limit shows for PS, PP and PVC: 42%, 37% and 21% of their records reach the two highest levels, more than PCL (16%), although the database's authors state that no enzyme has been shown to degrade them [4]. A method name such as GPC or CO_2 shows what a study measured, not whether the measurement proved that the polymer itself was broken down. Weight loss can come from additives rather than the polymer [2], and the same may be true of CO_2 measured from a plastic film. Tracing labelled carbon from the polymer [3] rules this out, and it appears in just 8 records.

PLA does not appear to depend on high temperature in these records, but the comparison with polyethylene is less certain than the record counts suggest. It rests on a few large studies, and the CO_2 evidence comes almost entirely from one soil study of a blend. Even strong laboratory evidence would not mean that PLA breaks down easily in nature, since it hardly degrades in seawater [5].

5. Limitations

The four levels were assigned by the method names written in the database, not by reading each study, so a listed method does not mean that the result was positive or convincing. The method fields also seem incomplete: the database's criteria required several methods for each publication [2], yet 41.8% of the records list only one, so some fields may describe the whole study rather than each organism. Some choices of level are open to debate, which is why the ranking was repeated in five other ways. The meaning of the field "degradation extrapolated from enzyme" is not defined in the database's published descriptions, and it was used as given. Records are not independent: one study can add hundreds of records, so the comparisons were also made by studies. Plastics were grouped by their labels, blends were left out, and 7 PE and 3 PLA records do not state whether thermophilic conditions were used. Finally, PlasticDB covers almost only published reports, and studies that found no degradation are rarely published.

6. Conclusion

In the 2,535 records of PlasticDB, the number of reports for a plastic is an unreliable guide on its own to how well its microbial degradation has been shown. Weighed by the strength of the evidence, polyurethane falls from second to fourth or fifth place, and PLA rises from sixth to second or third, under every way of counting tried. The ranking of PET depends on how records inferred from enzymes are treated. Record by record, PLA has strong evidence more often than polyethylene, mostly outside thermophilic conditions, but by studies the difference is small and uncertain. Polyethylene ranks first by every count,

although the database's authors consider most of its evidence weak, which shows that the methods named in a database are not enough to judge a claim of plastic degradation.

Data availability

The data are publicly available from PlasticDB [4]. The script that calculates every number in the paper is available from the author's mentor on request.

AI and tools disclosure

The author chose this topic, the one recommended by his mentor, from five topics the mentor proposed. He downloaded the PlasticDB table and counted the records for each plastic and the thermophilic records for PLA and PE in a spreadsheet; he sent his prediction together with these counts. After seeing the first results, he wrote the explanation for PU and PET discussed in Section 4, in Russian, translated by his mentor. The classification of methods, the calculations, the tables and the figure were made, and the text was drafted, by the author's mentor with the help of a generative AI assistant (Claude, Anthropic). The scripts and text were also reviewed by separate AI assistants; corrections were made by the mentor. The author read and approved the final text.

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Conflicts of interest

The author declares no conflicts of interest.

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