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Acetolysis of waste PET for upcycling and life-cycle assessment study

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Abstract

To reduce environmental pollution and reliance on fossil resources, polyethylene terephthalate (PET) as the most consumed synthetic polyester needs to be recycled effectively. However, the existing recycling methods cannot process colored or blended PET materials for upcycling. Here we report a new efficient method for acetolysis of waste PET into terephthalic acid (TPA) and ethylene glycol diacetate (EGDA) in acetic acid. Since acetic acid can dissolve or decompose other components such as dyes, additives, blends, etc., TPA can be crystallized out in a high-purity form. On the other hand, EGDA can be hydrolyzed to ethylene glycol or directly polymerized with TPA to form PET, completing the closed-loop recycling. The life-cycle assessment shows that, compared with the petroleum route, 67% of global warming potential and 77% of non-renewable energy use can be reduced via acetolysis under optimum conditions. This is the lowest environmental impact of all chemical recycling options available today.

Introduction

Plastics have become an important material in the modern global consumer economy, and the production is estimated to increase to around 12 billion tons by 2050¹⁻⁴. As a large class of plastics, polyethylene terephthalate (PET) is widely used in various containers, packaging materials, and textiles⁵⁻⁷, with a production scale of more than 70 million tons per year⁸. Due to the material characteristics of PET, it is difficult to degrade in nature and has a low recycling rate, resulting in a large amount of plastic waste⁹⁻¹¹. Therefore, effective recycling or upcycling methods for waste plastic are being intensively developed¹²⁻¹⁴.

At present, post-consumer PET is mainly recycled by mechanical methods, but this will lead to deterioration of material structure and performance, and can only produce low-value products for downcycling^{6, 15}. Compared with mechanical recycling, PET can be converted into monomers for polymerization or other more valuable products¹⁶ through chemical methods. Common chemical methods for recycling waste PET include methanolysis¹⁷⁻²⁰, glycolysis²¹⁻²⁵, neutral hydrolysis²⁶⁻²⁹, alkaline hydrolysis³⁰⁻³², acidic hydrolysis³³⁻³⁷, etc (Table 1). However, the monomers or oligomers obtained by methanolysis or glycolysis are difficult to separate and purify, which makes the above methods highly sensitive to the source of waste PET. Besides, both acid and alkaline hydrolysis use strong acids or strong bases as solvents, which will cause serious corrosion to the equipment and produce a large amount of waste in the post-processing stage. Accordingly, due to the inadequacy of existing chemical recycling methods, colored or blended PET is regarded as “unrecyclable” back into high-quality, food-grade PET for upcycling^{38, 39}. Hence, it is of great practical significance to develop a cost-effective and green method to realize the upcycling of waste PET.

Herein, we developed a new strategy to decompose waste PET into terephthalic acid (TPA) and ethylene glycol diacetate (EGDA) through acetolysis for upcycling. In this strategy, acetic acid has three main advantages: 1) Since the solubility of TPA in acetic acid is very low (1.08×10^{-2} g/100g@32°C, 3.86g/100g@240°C), which not only ensures the complete decomposition of PET but also allows TPA to be crystallized out in a high-purity form. 2) Acetic acid can dissolve

or decompose other common components in PET materials (such as dyes, additives, blending ingredients, etc.) to ensure the separation of TPA from these impurities. 3) As the solvent for industrial oxidation of *p*-xylene to produce TPA⁴⁰, acetic acid can be directly applied to existing production devices. Additionally, to compare acetolysis with other existing chemical recycling, we designed a path to complete the closed-loop recycling PET. Through the life-cycle assessment (LCA), the results show that acetolysis can become the lowest environmental impact of all chemical recycling options available today.

Table 1 Summary of key information on different chemical methods for recycling waste PET^{39, 41}

Content	Methanolysis ^a	Glycolysis	Hydrolysis			Acetolysis (this work)
			Neutral	alkaline	Acid	
Pressure	10-20 MPa	0.1 MPa	2-40 MPa	1-2 MPa	0.1-2.8 MPa	1.2-3.2 MPa
Temperature	200-350°C	150-200°C	250-400°C	80-250°C	80-230°C	220-280°C
Products	DMT EG	BHET Oligomers	TPA EG	TPA salt EG	TPA EG	TPA EGDA
Degradation	Completely	Incomplete	Incomplete	Complete	Incomplete	Complete
Purification	Needed	Difficult	Complex	Complex	Complex	Easy
Sensitivity ^b	High	High	Medium	Medium	Low	Low
Concentration ^c	1-5 % w/v	2-25 % w/v	1-5 % w/v	1-5 % w/v	0.8-2 % w/v	20 % w/v

^a Methanolysis is normally carried out under nitrogen protection; ^b Sensitivity to the waste type; ^c Concentration of waste PET. DMT = Dimethyl terephthalate, EG = Ethylene glycol, BHET = Bis (2-hydroxyethyl) terephthalate.

Results

Acetolysis of PET plastics. As the solvent used in the industrial production of TPA, acetic acid was selected and it was more effective in depolymerizing PET than other carboxylic acids (Fig. 1a & Table S1). Through acetolysis, PET could be completely depolymerized in two hours at 280°C, and high-purity TPA (95.8% yield, over 99.7% purity) and EGDA (95.3% yield, over 98.0% purity) could be obtained. Our study found that the acetolysis of PET was very sensitive to the decrease of the reaction temperature (Fig. 1b & Table S2). When the temperature was below 220°C, satisfactory results could not be obtained even if the reaction time was extended to 18 hours. We speculated that the depolymerization reaction undergoes a melting-dissolving process, so 280°C was chosen as the optimal reaction temperature. It is worth mentioning that the acetolysis of PET is an exothermic reaction (Fig. 1d). A little energy is needed to maintain the reaction temperature, so the acetolysis of PET is not a high energy consumption process. Additionally, a certain amount of water will not have adverse

effects on PET degradation but will make part of ethylene glycol diacetate to ethylene glycol monoacetate conversion (Fig. 1c & Table S3). This showed that the process did not have strict requirements for water in the pretreatment stage.

Fig. 1 Acetolysis of PET. **a**, Effects of different carboxylic acids on the acetolysis of PET **b**, Effects of different temperatures on the acetolysis of PET. **c**, Effects of different moisture contents on the acetolysis of PET. **d**, Reaction enthalpy of the acetolysis of PET.

To better understand the depolymerization behavior of PET in carboxylic acid, a surveillance video was recorded (see Supplementary Video for details). The video showed that the depolymerization of PET in carboxylic acids underwent a melting-dissolving-precipitating process (Fig. 2a). At first, the PET melted rapidly in carboxylic acid, gradually forming an evenly dispersed emulsion. Then the melted PET depolymerized into small molecular weight oligomers that could be dissolved in carboxylic acids. Finally, the oligomers further depolymerized to form TPA and crystallized out in the system. Whereas, TPA was continuously precipitated from the acetic acid system as a p-type flake crystal according to SEM and XRD (Fig. 2b-2c and Extended Data Fig. 1). This process, unlike hydrolysis, was particularly efficient as the depolymerization of oligomers dissolved in carboxylic acid was a homogeneous reaction. The precipitation of TPA not only effectively drives the chemical equilibrium of depolymerization, but also makes the separation of products simpler. Additives such as pigments and dyes were dissolved in organic acids without precipitating along with terephthalic acid. In addition, impurities such as *p*-toluic acid (*p*-TOL) and 4-carboxybenzaldehyde (4-CBA) produced by the incomplete oxidation of *p*-xylene were in trace amounts in the PET depolymerization product (Fig. 2d), which fully complies with the

76 GB⁴² and the ASTM⁴³ standard for polymerization grade TPA. These guaranteed the purity of TPA obtained by acetolysis
77 of PET and it also could be proved by titration analysis, HPLC, FTIR, UV-Vis, etc. (Extended Data Fig. 1).

78 Fig. 2e illustrated that acetolysis had a strong tolerance to the source of waste PET plastics (please see Table S5 for
79 more examples). PET plastics like powder, particles or bottle flakes (colorless, colored or even black) could be quantitatively
80 deagglomerated into high purity TPA and EGDA. For PET flakes mixed with polyethylene (PE) labels and PET-
81 polypropylene (PP) composite films, PET decomposed into TPA sinking, whereas PE and PP melted, agglomerated, and
82 floated on the solution after acetolysis (Extended Data Fig. 2). However, with a similar density to PET, polyvinyl chloride
83 (PVC) will be partially decomposed but not affect the depolymerization of PET⁴⁴. In addition, other polyester plastics such
84 as Poly (ethylene terephthalate-co-1,4-cyclohexylenedimethylene terephthalate) (PETG), polybutylene terephthalate (PBT),
85 Polyethylene naphthalenediate (PEN), and Polyethylene 2,5-furandicarboxylate (PEF) could be degraded by this process
86 with corresponding monomers obtained in high yield (Table S7).

Fig. 2 Results of chemical degradation of PET through acetolysis. **a**, the reaction process of acetolysis of PET bottles. **b**, SEM pattern of TPA obtained from waste PET bottles through acetolysis. **c**, XRD pattern of TPA obtained from waste PET bottles and textiles, **d**, HPLC spectra of TPA obtained from waste PET bottles and textiles. **e**, Universality of PET degraded by acetolysis, 1-8 are photos of PET powder, particles, transparent bottle, blue bottle, green bottle, black tray, physical mixing of PET and PP, PET/PP composite films, 1a-8a are the photos of terephthalic acid obtained by acetolysis of the above materials.

Acetolysis of PET textiles. PET fiber, namely terylene, is the highest market shared chemical fiber with the most important application of PET products (ca. 80%). Compared with bottle grade PET, fiber grade PET generally has a lower degree of polymerization, and its textiles are generally more complex. For PET textiles, the current physical recycling method can

96 only be downcycling since the gradually decreasing degree of polymerization, while the chemical recycling method is
97 unable to achieve upcycling due to the difficulty of separating and purifying the depolymerized products.

98 We applied the acetolysis method to successfully achieve the depolymerization of PET textiles (Table 2, please see
99 Extended Data Fig. 3 and 4 for more examples). Since some dyes or other organic impurities are partially decomposed and
100 carbonized during the acetolysis process, the depolymerized product TPA resulted in a darker color. These dark TPAs could
101 be decolorized by activated carbon after being dissolved in alkaline or amide (e.g.: N, N-dimethylacetamide, N-methyl
102 pyrrolidone). Processing the above decolorization, white PET with qualified chromaticity (Hazen < 10) could be obtained⁴².
103 Even altering the high-temperature (280°C) pure water recrystallization with activated carbon to decolor, the appearance
104 of the product can also be significantly improved (Extended Data Fig. 5).

105 In addition, for PET blended textiles, the method of acetolysis is also applicable. Since acetic acid can decompose and
106 transform other common chemical fibers at high temperatures to form acetic acid-soluble depolymerization products (e.g.:
107 nylon 6 is decomposed into acetaminocaproic acid; nylon 66 is decomposed into adipic acid and diacetyl hexamethylene
108 diamine; acrylic fiber is converted into polyacrylic acid; spandex is decomposed into acetanilide), so it will not affect the
109 separation of TPA. Meanwhile, because these chemical fiber decomposition products have high boiling points, this will not
110 cause the separation and purification of EGDA via distillation to be more troublesome. It is worth mentioning that EGDA
111 is non-toxic and has a strong dissolving ability that can be used as a green solvent for ink coatings, making this acetolysis
112 process more economical.

Table 2. Degradation of real textiles by acetolysis ^a

	Polyester fabric	Variegated clothes	Blue towel
Photographs of real textiles
Contents	100% polyester	100% polyester	80% polyester, 20% nylon 6
Solution after reaction
TPA
Decolored
Yield ^b (purity)	92.02% (99.83%)	90.20% (99.74%)	94.10% (99.78%)
Chromaticity	5 Hazen	5 Hazen	5 Hazen
EGDA
Yield (purity)	90.96% (98.6%)	87.68% (98.4%)	92.06 (98.2%)

^a Reaction conditions: PET Textile fragments (60 g), acetic acid (300 mL), reaction temperature (280 °C), reaction time (2 h).

^b Yields are calculated for decolored TPA based on PET textile raw materials

Life-cycle assessment for closed-loop upcycling PET via acetolysis process. We implemented a life-cycle assessment (LCA) study to compare and evaluate the environmental impact degree of the acetolysis method with other existing methods for recycling PET. Since the subsequent use and disposal of various PET products vary greatly, the system boundary of this LCA is set as “cradle-to-gate”. To make a fair comparison with previous work and to simplify the analysis⁴⁶⁻⁴⁹, the LCA of PET recycling is based on the "cut-off" approach (Fig. 3a). According to the above rules, we assumed that the difference of environmental impact to the collection and transportation of various waste PET materials could be negligible, then the scope of this LCA was "gate-to-gate". Within the “gate-to-gate” boundary, the mechanical recycling includes two units, “waste PET shredding” and “PET flakes thermoforming”, while the chemical recycling adds a “depolymerization & re-polymerization” unit. Therefore, as a chemical recovery method, we focused on the environmental impact of the acetolysis process in "gate-to-gate".

The process for upcycling PET from waste PET via acetolysis was shown in Fig. 3b, which includes five units: 1) mechanical shredding and other simple pretreatments of waste PET; 2) acetolysis of PET flakes to produce TPA and EGDA (Section1); 3) hydrolysis of EGDA into ethylene glycol (EG)(Section2); 4) re-polymerizing of EG and TPA into PET resins (Section3); and 5) thermoforming of PET resins into products. The first and last two units could be attributed to mechanical recycling. The process composed of the remaining three units (Section 1-3) was simulated on an industrial scale (100,000 tons per year) in ASPEN Plus V11 in terms of mass balance and energy consumption. The global warming potential (GWP) and non-renewable energy use (NREU) of the process were calculated by OpenLCA.

Fig. 3 the process for closed-loop upcycling PET via acetolysis. a, Cradle-to-factory gate system boundary of closed-loop upcycling PET via an acetolysis process based on the "cut-off" approach. **b,** Schematic diagram of closed-loop upcycling PET via the acetolysis.

LCA study data illustrated that, compared to the process for preparing virgin-PET by the fossil resource⁴⁶, the GWP and NREU of the acetolysis process (Case 1 of Figure 3a) could be reduced by 26% and 47% respectively, which was very close to the methanolysis process (Fig. 4a). Further sensitivity analysis showed that section 2 (the EGDA hydrolysis section) contributed the most GWP and NREU (Fig. 4b). This was mainly because a large amount of water was needed to ensure complete hydrolysis of EGDA, while the separation of EG, acetic acid, and water required a lot of energy. Therefore, a low

energy consumptive process for separating and purifying the hydrolysate EG was desired. In addition, we proposed and assessed another process that omits Section 2 (Case 2 of Figure 3a). In this process, EGDA would be directly condensed with TPA and polymerized into PET by removing acetic acid. Due to the omission of the hydrolysis section, LCA results showed that PET produced in a closed-loop cycle via case 2 could reduce GWP (1.35 kg CO₂-equivalent/kg PRO-PET) and NREU (22 MJ/kg PRO-PET). This is the lowest environmental impact degree in chemical degradation at present. The specific process, energy consumption, and material balance of case 1 and case 2 were described in supplementary Fig. S2-S3, supplementary table S12-S19, and supplementary Note 2-3 respectively. Besides, this process has the potential advantage of not forming diethylene glycol fragments, which usually affect the strength of PET, on the polyester chain. However, since the nucleophilicity of the acetoxy group is weaker than that of the hydroxyl group, it is necessary to seek a more effective catalyst to promote the polymerization of EGDA and TPA. Despite this, the acetolysis of PET we proposed is currently the only method that can obtain high-purity TPA directly from waste PET. This method provides a feasible and low environmental impact solution for upcycling waste PET.

Fig. 4 LCA results for closed-loop upcycling PET via acetolysis. **a**, LCA results for 1 kg of recycled PET, based on the “cut off” approach, cradle-to-factory gate. * The data is from Ref. 46. **b**, Sensitivity analysis of NREU and GWP via acetolysis.

Discussion

In this work, we developed a simple and cost-effective method for the upcycling of waste PET bottles and textiles by acetolysis. Our approach is to degrade waste PET in acetic acid to obtain high-purity TPA and EGDA in yields over 95%.

And the acetolysis is compatible with impurities, dyes, and other components (polyethylene or polypropylene or nylon, etc.) present in waste PET. We have also proposed two schemes for closed-loop recycling of PET via acetolysis and assessed their environmental impact through LCA. LCA results showed that the production of PET by acetolysis could significantly reduce the environmental impact in terms of GWP and NREU compared to conventional petroleum routes. Under the optimal conditions, acetolysis has the lowest environmental impact of the currently available chemical recycling methods for waste PET. Besides, as a new generation of green solvents, the by-product EGDA brings greater economic attractiveness to acetolysis. Briefly, this work provides a promising and sustainable way for the upcycling of waste PET materials.

Methods

Polyester materials, chemicals, and reagents. In all experiments, PET fragments were obtained from various PET products, including transparent and colored, mono- and multi-layer post-consumer PET lunch boxes and trays, and PET water bottles without caps and labels. These materials were simply washed with tap water, dried, and cut into approximately 3×3 mm fragments for experiments. PET textiles fragments were donated by the author and his collaborators. PEF particles (yellow solid particles, average molecular weight > 30000) and PEN polyester (pressure-sensitive silicone tape) were generously gifted by Hefei Leaf Biotechnology Co., Ltd. PETG polyester (3D printing consumables) was purchased in the Lambo flagship store. These materials were cut into fragments (or particles). PBT powder (300 mesh) was purchased from the Hongyuan polymer supply chain. PVC powder was purchased from Suyuan plastic raw material mall. TPA (99%), *p*-TOL (98%), 4-CBA (98%) were purchased from Adamas Reagent Co., Ltd. Other chemicals are commercially available and utilized without further treatment.

Acetolysis of PET plastics. A typical acetolysis process was shown as follows. 60.0 g PET flakes and 300 mL glacial acetic acid were mixed in a 500 mL titanium hydrothermal reactor. Then the hydrothermal reactor was placed in a homogeneous reactor for depolymerization at a constant temperature of 280°C for 2 hours. After the reaction, the hydrothermal reactor was cooled down to room temperature. The solid products obtained by filtration and were washed

three times with pure water and dried in an oven. The TPA yield was calculated by equation (1). The purity of TPA was tested by acid-base titrations according to the National Standard of the People's Republic of China GB/T 30921.5-2016.

$$\begin{aligned} \text{TPA Yield (\%)} &= \frac{\text{Produced TPA amount (g)}}{\text{Theoretically Produced TPA amount (g)}} \times 100(\%) \\ &= \frac{\text{TPA quantity by obtained (g)}}{\frac{\text{PET amount (g)}}{192.13(\frac{\text{g}}{\text{mol}})} \times 166.13(\frac{\text{g}}{\text{mol}})} \times 100(\%) \end{aligned} \quad (1)$$

The products in the liquid phase were analyzed by GC equipped with a flame ionization detector (FID) for quantitative analysis. The yield of EGDA was calculated by equation (2):

$$\begin{aligned} \text{EGDA Yield (\%)} &= \frac{\text{Produced EGDA amount (g)}}{\text{Theoretically Produced EGDA amount (g)}} \times 100(\%) \\ &= \frac{\text{EGDA amount quantified by GC (g)}}{\frac{\text{PET amount (g)}}{192.13(\frac{\text{g}}{\text{mol}})} \times 146.14(\frac{\text{g}}{\text{mol}})} \times 100(\%) \end{aligned} \quad (2)$$

Acetolysis of PET textiles. A typical acetolysis for textiles process was shown as follows. 60.0 g PET textile fragments and 300 mL glacial acetic acid were mixed in a 500 mL titanium hydrothermal reactor. Then the hydrothermal reactor was placed in a homogeneous reactor for depolymerization at a constant temperature of 280°C for 2 hours. After the reaction, the hydrothermal reactor was cooled down to room temperature. The products were separated and analyzed as previously shown.

Decolorization of dark TPA. Decolorization of black TPA was carried out by activated carbon. **a)** 40 g of dark TPA and 0.4 g of activated carbon were added to a 200 mL aqueous solution containing 20 g of sodium hydroxide and the mixture was refluxed for 15 minutes. The impurities were removed by hot filtration and white TPA was obtained by adding an equal amount of dilute sulphuric acid. **b)** 40 g of dark TPA and 0.4 g of activated carbon were added to 200 mL of N, N-dimethylacetamide (DMAC) and the mixture was stirred at 80 °C for 15 minutes. The insoluble impurities were removed by hot filtration. The adductive crystals of TPA and DMAC selectively precipitated out of the filtrate. White TPA could be obtained by heating the crystals or adding water after filtration. **c)** 40 g of dark TPA and activated carbon fiber felt (10 cm × 15 cm) were added to 200 mL of water and stirred for 15 minutes at 280 °C. Then cooled the reactor to room temperature slowly to obtain clean TPA crystals. All dark products obtained by acetolysis of waste PET materials were easily decolorized in the above described ways.

Characterization. Products in the liquid phase were detected by flame ionization detector gas chromatography (**GC-FID**, Shimadzu-Nexis GC-2030), which used HP-INNOWAX (30 m × 0.25 m × 0.25 mm) as a capillary column. High-performance liquid chromatography (**HPLC**) was performed using Agilent HC-C18, 4.6×250mm column and Waters UV detector 2489 at 254 nm. Nuclear magnetic resonance (**NMR**) spectroscopic measurements were carried out in deuterated dimethyl sulfoxide (DMSO-d₆) or deuterated chloroform (CDCl₃) on a Bruker Advance 400 (400 MHz) spectrometer for the product characterization. The morphology of the samples was observed with Zeiss Gemini 500 Schottky field emission gun scanning electron microscope (**SEM**) (2-5kV). X-ray powder diffraction (**XRD**) data were acquired on a JEOL-2010 diffractometer using Cu K α radiation at 4~30 degrees. Fourier transform infrared spectrum (**FTIR**) were recorded on an FTIR/Raman Thermo Nicolet 8700 spectrometer in the wavenumber range of 3800 to 500 cm⁻¹, with instrument resolution of 0.1 cm⁻¹. The Ultra Violet-Visible Spectroscopy (**UV-VIS**) absorption spectra were collected with a UV-1750 UV-vis spectrophotometer (Shimadzu, Japan).

Life-cycle assessment. The LCA analysis followed the ISO standard series 14040 and was conducted using OpenLCA 1.10.3. Two functional units were used, one was a constant mass (1kg) of the new PET plastic produced and the other was the standardization of the environmental impact results through the production of PET by acetolysis, which enabled us to compare different methods of PET recycling in terms of environmental impact. The system boundaries were set as “cradle-to-gate”, which included: collection and transportation of waste PET, production of PET flakes, the whole process of depolymerization and re-polymerization, and PET products thermoforming. See details in the Supplementary Information.

Data availability

Data are available on reasonable request from the authors, according to their contributions.

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332 **Author Contributions**

333 J. D. and Y. P. designed the experiments. Y. P. carried out experiments. J. Y. provided the LCAs. C. D. and Y. F. provided
334 some useful suggestions. J. D., Y. P. and J. Y. collaboratively analyzed the data and wrote the paper. All authors commented
335 on the final manuscript.

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338 **Competing interests**

339 The authors declare no competing interests.

341
342 **Extended Data Fig.1 Some spectral data of TPA obtained by acetolysis.** **a**, FTIR spectra of TPA obtained from waste PET bottles and
343 textiles. **b**, UV-Vis spectra of TPA obtained from waste PET bottles and textiles. **c**, TPA powder purchased commercially (50 - 200 μm).
344 **d**, TPA obtained by acetolysis of PET bottle fragments (500X). **e**, TPA obtained by acetolysis of PET textiles fragments (500X). **f**, TPA
345 obtained by acetolysis of PET powder (500X). It could be seen from FTIR and UV-Vis spectroscopy that the TPA obtained by acetolysis
346 had high purity, whether it came from high-quality bottles or low-quality textiles.

348
349 **Extended Data Fig.2 Acetolysis of PET mixed with other plastics.** **a**, Acetolysis of physically mixed flake PET with polyethylene
350 (PE) labels. **b**, the reaction solution after acetolysis, PET was decomposed into TPA and settled, while PE melted, clumps and floated on
351 the solution. **c**, Acetolysis of PET-polypropylene (PP) composite films. **d**, the reaction solution after acetolysis, PET was decomposed
352 into TPA and settled, while PP melted, clumped and floated on the solution. This meant that there was no need to separate the label for
353 acetolysis of the PET bottles.

354 **Extended Data**

356
357 **Extended Data Fig.3 Acetolysis of various PET fibers.** Decolorized terephthalic acid obtained from different textiles yielded greater
358 than 90% and purity over 99.7%. We tried the acetolysis of all PET fibers available and all of them could achieve good results.

360
361 **Extended Data Fig.4 Acetolysis of various textiles blended with PET.** Decolorized terephthalic acid obtained from different textiles
362 yielded greater than 90% and purity over 99.7%. Satisfactory results of acetolysis were attributed to the excellent
363 dissolution/decomposition effect of acetic acid on most impurities.

364 **Extended Data**

365
366 **Extended Data Fig.5 Decolorization of dark TPA.** **a**, Dark TPA obtained directly from acetolysis of Variegated clothes. **b**, Product
367 obtained by decolorizing dark TPA (sample **a**) in an alkaline solution with activated carbon. **c**, Product obtained by decolorizing dark
368 TPA (sample **a**) in N, N-dimethylacetamide with activated carbon. **d**, Product obtained by decolorizing dark TPA (sample **a**) in hot water
369 (280°C) with activated carbon. All dark products obtained by acetolysis of waste PET materials were easily decolorized in the described
370 ways.

371 **Supplementary information**

372 Supplementary information includes Supplementary Notes, Tables, Figures, Video and References.

Supplementary Files

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