BioPlastics for our Cleaner Earth

“Global Forum on Human Settlements”
17th Annual Conference 2022/12/15-16

Environmental Crises: Global Warming & Plastic Pollution
Banning vs. Replacement by Bio-Plastics/Materials
Regulation & Government Policy for SUP
Research, Applications, and Market Growth for BDP
Current Policy & Planned BDP Projects in China
End-of-Life Treatment for Sustainable Development

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Environmental Crisis 1: Plastics Pollution

~ 6 Billion Tons of plastic waste remains on the Earth, slowly breaking down in ~100-500 yrs

> 100-200 million tons of Plastics in the Sea.  > 8-12 million tons/year added.

Solution: Using Bio-Degradable Plastics/Materials, e.g. PBAT/PLA/PHA/PBS/PGA/Starch...
Micro-Plastics Pollution

Micro-plastics/polymer particles in air/land/water eventually enter food chain & human body

22 human blood samples contained ave. 1.6µg/ml micro-plastics
90% PET micro-plastics as 10% of the spider web weight

Detection of microplastics in human lung tissue using μFTIR spectroscopy

Solution: Using Nature/Marine composting Plastics/Materials, e.g. PHA/PGA/Starch/Paper...

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Environmental Crisis 2: Global Warming

Green House Gases from Fossil-origin

$\text{CO}_2 > 420 \text{ ppm, up from 280 ppm before Industry Revolution.}$

$\text{Global Ave. Temp up} > 1.2 ^\circ C$

$\text{CO}_2 > 450 \text{ ppm & Temp up} > 1.5 ^\circ C \text{ by } \sim 2050.$

$\text{Sea Level may go up} > 60 \text{ m}$

Using Bio-based or Carbon-Captured Plastics/Materials: e.g. bio-PE, FDCA/PEF, PLA, PGA

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GFHS
China: Largest CO2 Emission Country
(largest only by total amount, not by per capita)
Pledged to reach Carbon Peak/Neutral by 2030/2060

Each China province/city had received CO2 emission quota to meet the goals/timelines
2018/6: UN called to “Beat Plastic Pollution”

Old ways and the 3 R’s do not work effectively
How to resolve the problem?

Old ways: Burn/Incinerate, Dump/Landfill, Export

Burning: ~300-500 ° C. Imcomplete breakdown, Serious air pollution.
Incineration: >1000 ° C. High energy consumption. CO2 emission.
Dumping: Long term pollution on air/land/water etc, Self-combustion.
Exporting to Developing countries: Stoped foreign solid waste in 2018

Reduce, Reuse, Recycle

8-9 billion tons plastics produced
only 10-30 % eliminated
> 6 billion tons waste remains
Impact environment for >100 yrs

UN & EU: Ban all Single Use Plastics
EU Regulation: Ban all Single-Use Plastics

Council adopts ban on single-use plastics

Single-use plastics: New measures to reduce marine litter

Banning SUP including all Bio-Degradable Plastics: PBAT/PLA etc. even PHA

European Council
Council of the European Union

European Commission - Press release

https://ec.europa.eu/environment/waste/pdf/single-use_plastics

Europe is tackling the 10 most found plastic waste items

UK allows PE/PP + starch etc., which cause micro-plastics

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Old 3 R’s + 3 New R’s (Jem 2018/10 UN Asia HQ)

4th R: Replacement by BioPlastics/Materials whenever possible, especially for SUP

**Bio-Materials**: Starch, pulp, paper, cellulose, waste, etc for packaging...

**Bio-based plastics**: Reduce CO2 emission (vs fossil-based):
- Non-degradable: Bio-PE, Bio-nylon, PEF (from FDCA)....
- Degradable: PHA, PLA

**Bio-degradable plastics**: Degrade to water/CO2 in <3-6 mth / 2 yrs
- Fossil-based: PBAT, PBST, PCL, some PBS. Same/high CO2 emission
- Carbon-captured or semi-bio-based: PPC, PGA, some PBS
- Bio-based: PHA (degradable in Nature), PLA (needs industrial composter)

**Traditional plastics**: Degrade in ~>100 yrs. Causing microplastics
- PE, PP, PC, PVC, PET, PS, ABS, ... Serious long-term pollution problem.
- PVA: Soluble & slowly degrade. Impact on aquatic lives
- Dis-integration: PE/PP + starch, minerals, “enzymes“, Oxo-catalysts, etc.

**Bio-Plastics**: small scale, expensive, weak
- Healthy, Good for environment, Lower total costs, Need government protection/regulations

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5th R: Regulation for BDP in China

Use only BDP for SUP by 2025 nation-wide. Forbit non-BDP
Major BioPlastics Projects in China

- **PLA/PGA:** 1-5-70KT
- **PBS/PBAT:** 20-100KT
- **PHA:** 1-10KT
- **PPC:** 1-10KT
- **Starch-blending:** 2-20KT
- **PCL:** 2+50KT

Companies and Projects:

- Juren
  - PCL
- LongJun
  - Lactide
- HanFeng
  - Starch
- HuaLi
  - Starch
- GraBio
  - Starch
- BoDa
  - PPC
- TianGuan
  - PPC
- JinLong
  - PBC
- BangFeng
  - PPC
- DaZhe
  - PPC
- TunHe
  - PBS/AT
- DHTY
  - PBAT
- KingFa
  - PBAT
- MoGao
  - PBAT
- JinHui
  - PBAT
- Bluepha
  - PHBH
- PhaBld
  - P3/4HB
- Ecoman
  - P3/4HB
- MedPHA
  - P3/4HB
- TianAn
  - PHB/H
- HengLi
  - PBAT
- Xuelang
  - PBS
- ChangH
  - PBAT
- XinFu
  - PBAT
Key Bio-Plastics Projects
(& new PLA/PBAT plants)

2022/6: Current producers
PLA: NW 150 KT, TCP 75 KT
    China: Hisun 45 KT, B&G 100 KT
PBAT: BASF & Novomont ~200 KT
    China: > 300 KT, 6 major ones
        DongHuaTY, Tunhe, Hengli
        Jinhui, Kingfa, Changhong
YE2025: Expecting > Mil T
PLA: NW+75, TCP+100, BBCA+300 KT
PBAT: China + >500 KT

Announced China project: 10-20 Mil T
    (Many may not build/work)

China Planned:
3-5 million tons
PLA projects

China Planned:
10-20 million tons
PBAT projects

2017 market data from Total Corbion PLA JV
PB-AT/ST/SA: flexible/soft fossile-based BDP Mulch film, film bags (shopping, trash, shipping...) 3-5 MT market in China but planned 10-20 MT PBAT

Film bags: >2 MT Market (PBAT + 20-40% starch/minerals/PLA), Cost 2-3 X PE. Mulch film: ~ 1 MT Market (PBAT with higher vaper permiability then PE)
   Fit for wet area, root plants (peanuts, potate) & small vegetable, short term. OK. Not for cold/dry area, big plants (corn, tobacco, cotton...), 3-6 months needed
Other film: wrapping, shipping, bubble bags....

BASF: ~70 KT + new JV plant in China
NOVOMONT: ~100 KT captive for film

China: 300-500 KT PBAT, Short of BDO
   Tunhe, Jinhui, Kinfa, Hengli, Wanhua, ChHn. + ~50 new plants, ~20 MT announced
   BDO projects catching up by 2025
   Unrealistic over-planned.

Source: GuangHe, etc.
PBS (Poly Butylene Succinate)
Property between PBAT & PLA
Small scale, niche market, expensive

Regular application similar to PBAT/PLA:
film, coating, fiber..., 2x price, no clear benefits
Special/niche applications:
- Tableware, straw, etc. with higher HDT & fast processing
- Needs low residue level to meet food contact specs.

Bio-Succinic acid: multiple int’l companies
China LangDian 20 KT

PBS: Thailand PTT-MCC 20 KT, bio-S
China SeaLong 20 KT, fossil-S
Tunhe uses PBAT lines for its PBS

Source: HSM Tech, PTT-MCC, etc.
PHA group (e.g. PHB, PHBV...): all nature fermentation process, bio-based, marine degradation hard to reach high Mw/purity, low sugar yield, expensive... (Some use solvent extraction process)

WW >50 projects: Daminer, Kaneka, CJ ... ~5 KT (Shut-down: Metabolix/ADM.... up to 20 KT) China: TianAn, MedPha, BluePha, PhaBuilder ... (Idled: GreenBio, Ecomann, ... up to 10 KT)

Source: PHA Builder, BluePHA, etc.
PPC (Poly Propylene Carbonate): Carbon Capture
half bio-based, fast degradation, gas barrier...
(soft/weak, low HDT, special applications)

Fixing bio-CO2 from the off-gas of ethanol fermentation plants

\[
\begin{align*}
n \text{CO}_2 + n &\rightarrow \text{(Polymer)} \\
\end{align*}
\]

PPC: 10-20 KT in China
5 plants (天冠博大中科金龙达志邦丰)

PPC-P: new version to improve strength
3 projects announced (联欣天源旭阳)

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PCL (Poly Carprolactone)
fossil-based, expensive, soft, low Tm & HDT
special application, additive, polyol

UK: 40? KT Ingevity (Perstorp tech)
Japan: DAICEL 20 KT
China: BrightChina 2 KT, etc.
Juren 5 KT, + 50 KT due 2023/7

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Jem's Law (2012): PLA Demand Forecast

TCP +100 KT
NW +75 KT
BBCA +300 KT
B&G +70 KT
Kingfa +30 KT
many others

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China LA/PLA/PLA fiber

- **D:** 金玉米 GoldenC
- **L:** 百盛 BaiSheng
- **L:** 华康 HuaKang
- **L:** 星汉 XinHang
- **L:** 金丹 JinDan
- **L/D:** 武藏野 MSN
- **L:** JXSI
- **L/D:** 郎浵 新宁
- **L:** 京粮龙江 Longjiang
- **L:** 启玉 Qiyu
- **L:**允友成 SUPLA
- **L:** 维友 Wfy
- **L:** 天仁 龙都 LongDu
- **L:** 恒天 长江 Hengtian
- **L:** COFCO
- **L:** 永光 Hisun
- **L:** Foxconn
- **L:** BWC
- **L:** JQ
- **L:** KingCh
- **L:** FIT/Cha
- **L:** ChLn
- **L:** nature
- **L:** AP
- **L:** RZY
- **L:** FENC
- **L:** BBCA
- **L:** BBCA&G
- **L:** BBCA
- **L:** MPK
- **L:** 润之缘
- **L:** 远东化纤

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PLA food/drink applications in China
cutteries, straws, bowls, cups, boxes, coffee capsule...
hot, cold/r.t., disposable or semi-durable
(PLA products need industrial composters!)

Source: HSM, Huizefeng, XinYiFeng, Hisun, GuangHe, P&P, etc.
PLA high-end/value applications in China
bottle, sand pipe, tea bag, 3 C, glasses, filter, card...
(need at least 3 years shelf-life or durability)

Source: Naton, Hengtian, Shikaer, Jierong, etc.

Need 3-5 yrs durability

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PLA fiber applications in China

shirt, tie, underwear, mask, wet-wipe, filler, pillow, blanket...
staple, filament, nonwoven (melt-blow, thermo-bond, skin-core...)

PLA 3-layer Non-woven static ele. charged. No PP
Meet N90 or N95 standards
Bio-degradable/FDA certified

Source: BBCA, NatureArts, Hengtian, RenYi, Yongguang
LightBatt/Gaoxin,

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6th R: Research & Innovation to improve the property/cost ratio
Compounding to increase melt-strength 70 folds (needed for PLA foaming ratio 10-20X)

Source: CAS Ninbo Institute of Tech

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PLA/PBAT Foaming Products

sport goods, holding box, heat resistant lunch box...

(PLA rigid, PBAT soft)

Source: Bio-Plus, Tongjia
PGA (Poly Glycolic Acid) : Carbon Capture

Fixing CO (or CO2), off-gas from coal related plants (China: very rich on coal but not oil/gas)

Process: from CO to DMO (Dimethyl Oxalate), GA and/or Glycolide then PGA

Kureha: 4 KT in USA
China Pilot: 0.5, 1.5, 3 KT
ChnEnergy: 50 KT 8/2022
SinoPec: 200 KT by 2024 Phase 2 +300 KT

Source: Pujing (PGA tech provider)
PGA vs. PLA: Similar/Complementary

Strong/rigid, high HDT, fast degradation, gas barrier, soon cheaper
(Shortage: high density, darker & not durable but resolvable)

PGA will replace some PLA applications

Source: Pujing Chem

“Marine bio-degradable”

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PGA Applications in China

Tableware, straw, bags, hotel SUP, oil-gas drilling...

(future cost only half of PLA, no sugar needed)

Fit China’s needs of using coal & reduce CO2 & plastic pollution

Oil-gas drilling: High HTD
High strength, Fast degradation

Source: Pujing, Xinyifeng, Sunflux...

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Paper/Pulp Applications in China

tableware, cuttery, cup, bowl, egg box, lunch box, ...
(paper bottles need interanl plastic layer)

Steam/energy intensive. Need water-prof coating/layer

Paper board w/ BDP coating layer

PBS frame, w/ cover: 46.4g

PLA film on top: 28.4g

Source: Hengxin, Zidan, HuiZeFeng...

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Starch Applications in China
foaming, compounding, adding to BDP or PE/PP
bag, film, tray, filler, buffer, ....

BDP: Starch+PBAT etc

Starch, modified/foamed

Fake BDP: Starch+PE etc

20-30% Starch + PLA or PBAT for rigid/soft BDP
fast/control degradation

Source: GraBio, Green Fill, ...

Fakely claimed:
“All-nature, Degradable”
PE portion breakdown to micro-plastic particles
causing serious pollution
Future Work for BDP in China: #1

Build Composting/Biogas Facility (esp. for PLA ...) for Circular Economy & Sustainable Development

**Incineration**: Force BDP and garbage separation, then dump all waste to incineration, add fuel to raise temp, cause CO2 emission, defeat the whole environment protection program. Wrong direction.

**Composting/Biogas Plants**: Use localize or subcontract small fast-track industrial composters to reduce volume of wet garbage, then ship to central final naturalizing facility. Carbon neutral.
Future Work for BDP in China: #2

Law Enforcement to stop Fake BDP
e.g. oxo-degradation & starch/additives to PE/PP...
banned in EU, illegal in US

Central government banned traditional non-degradable plastics (PE, PP etc) for SUP, and only allow “Degradable” SUP for personal needs.

Soon expand to hotel & agri SUP, etc.

Problem: Some local companies claimed thier PE+starch/additives products (e.g. “OBE”) as “Degradable”, and called PLA/PBAT etc as “Bio-Degradable” to confuse local governments. Even called me a spy.
Future Work for BioPIs in China: #3

Solid RD to improve tech & reduce costs
(especially for lactide and compounding)

- Most BDP: technology and cost competitive (barely)
  Will compete by big volume/scale. Need effort/control.
- Bio-based, non-degradable plastics: bio-PE, PEF, nylon...
  Start to compete with other countries. Not there yet.
- Bio-waste (cellulose) conversion to sugar for fermentation:
  Cost > corn sugar, similar to other countries. Far to go.
- LA/lactide/PLA: Lower on conversion yield & purity.
  PLA cost > 50% higher. High-end PLA worse.
  Many fake projects will fail/delay. Need solid effort.
- Coumpounding for the needs, e.g. cost, mulch film, bottle...
BioPlastics for our Cleaner Earth
Summary + Q&A

- **Current China**: Largest CO2 and plastics producing country, but not per capita (US #1 polluter?). Very serious to reduce pollution, protect environment, promote BioPlastics/Materials. **Falling Behind!** (vs. EU/Canada bans BDP for SUP, UK allows PE/PP+starch, US?)

- **Future China**: Soon to be the largest BDP producer (especially PBAT/PLA) and market (>5 mil T) in the world. **Set the example!**

  **Work to do**: Add composting facility. Stop fake BDP, Improve tech & reduce costs, Enlarge the BDP/SUP market, control over-expansion.

- **One Earth**: Global collaboration & Harmonization of BDP/SUP policy.

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