BASF
We create chemistry

# Upgrading Plastics PyOils with Novel Solutions from BASF

## Introducing PuriCycle® Portfolio

## Chemical Recycling of Waste Plastics

Contributing to circular economy by returning waste plastics back into the loop

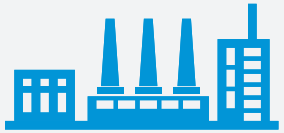
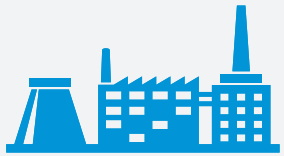
Recycle plastics for which there are no recycling solutions today

Remove undesired substances in the process

Turn waste into feedstock for the chemical industry

Produce virgin-grade recycled material

# Plastics Pyoils Upgrading Challenge

Feed Plastics →  →  → Steam Cracking

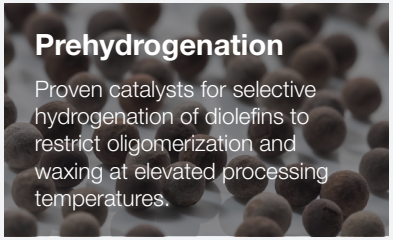
Producers Users

| Parameter | Unit | Value |
|---|---|---|
| Oxygen | wt % | 0.01-1 |
| Sulfur | ppmw | 300-4000 |
| Nitrogen | ppmw | 500-3500 |
| Halogens | ppmw | 25-400 |
| Chlorine | ppmw | 10-350 |
| Silicon | ppmw | 45-300 |
| Phosphorus | ppmw | 10-30 |
| Iron | ppmw | 5-25 |
| Paraffins | wt % | 18-45 |
| Naphthene | wt % | 10-25 |
| Aromatics | wt % | 5-20 |
| Olefins | wt % | 15-50 |
| Water | ppmw | 1000 |

| Parameter | Unit | Cracker Specs* |
|---|---|---|
| Oxygen | ppmw | 50 |
| Sulfur | ppmw | 500 max |
| Nitrogen | ppmw | 3 max |
| Halogens | ppmw | minimized |
| Chlorine | ppmw | 1 max |
| Silicon | ppmw | 1 max |
| Phosphorus | ppmw | 500 ppb max |
| Iron | ppmw | |
| Paraffins | | 50 vol % min |
| Naphthene | | |
| Aromatics | | minimized |
| Olefins | | 1 vol % max |
| Water | | no liquid |

* Exemplary specification.

# Introducing PuriCycle® Portfolio



## Prehydrogenation

Proven catalysts for selective hydrogenation of diolefins to restrict oligomerization and waxing at elevated processing temperatures.

- Removal of dienes and poly-unsaturates to avoid conden-sation and coking.
- Offered to producers looking to install selective pre-hydro downstream of pyrolysis unit.

PuriCycle® SH

## Metals Removal

Guards and catalysts to remove metals to condition pyrolysis feeds.

- Removal of Si, Na in nonregen mode by chemical sorption.
- Reduces duty load on down-stream HDM for high Si feeds.

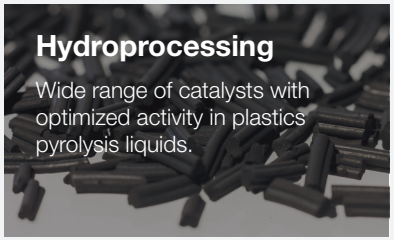
PuriCycle® M

## Dehalogenation

Guard adsorbents to remove halogens and protect down-stream equipment.

- Selective removal of halogens, designed as polishing guard in non-regen service.

PuriCycle® H



## Hydroprocessing

Wide range of catalysts with optimized activity in plastics pyrolysis liquids.

- Removal of nitrogen, oxygen and traces of halogens.
- Normally part of on purpose commercial hydro processing plants.

PuriCycle® HP

## Metals Removal PuriCycle® M

Mixed metal oxide spheres

Removal of **Si, Na and other metals**

Mixed metal oxide granules

Removal of **Si, Na and other metals**

## Dechlorination Guards PuriCycle® H

Mixed metal oxide

High efficiency dechlorination of PyOils (organic and inorganic chlorides)

Promoted alumina and molecular sieves

High performance HCl guards

## Removing Light Metals without Using Hydrogen

- Light metals i.e. Si, Na and other are often seen in commercial PyOils.
- Metals pose a challenge for downstream equipment.
- Conventional solution requires high pressure hydrogen to promote removal of these metals.
- PuriCycle M guards from BASF are excellent cost efficient adsorbents to eliminate light metals and improve PyOils purity.

## Chlorides Challenge in Waste Plastics PyOils

- Chlorides contamination is a major challenge for waste plastics PyOils, mostly due to residual PVC in feedstock.
- Structure and levels of chlorides in waste plastics PyOils are highly dependent on pyrolysis conditions and type of in-process purification.
- Most commonly PyOil chlorides in naphtha range streams are hard to remove complex low reactivity species.
- No standardized universal commercial adsorbent solution to remove these chlorides.
- High level of chlorides significantly influence the performance of the hydroprocessing catalyst.
- Corrosion and plugging issues due to HCl and $NH_4Cl$ formation.

## Speciation of Chlorides in Waste Plastics PyOils

Wide range of complex chlorides including long chain low reactivity species.

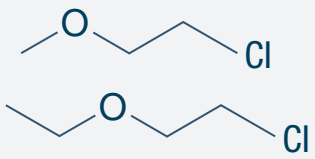
**Increased difficulty to remove Cl**

Chloroalkanes

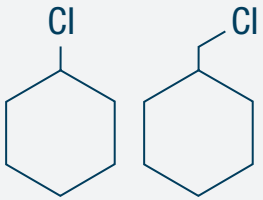

n = 3-12

Chloroalkenes

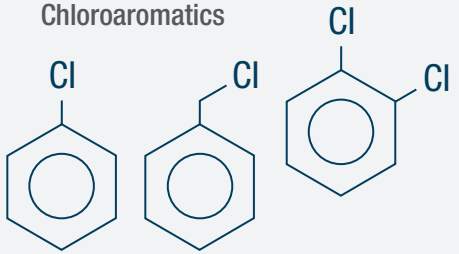

Chlorooxygenates




Chloronaphthenes

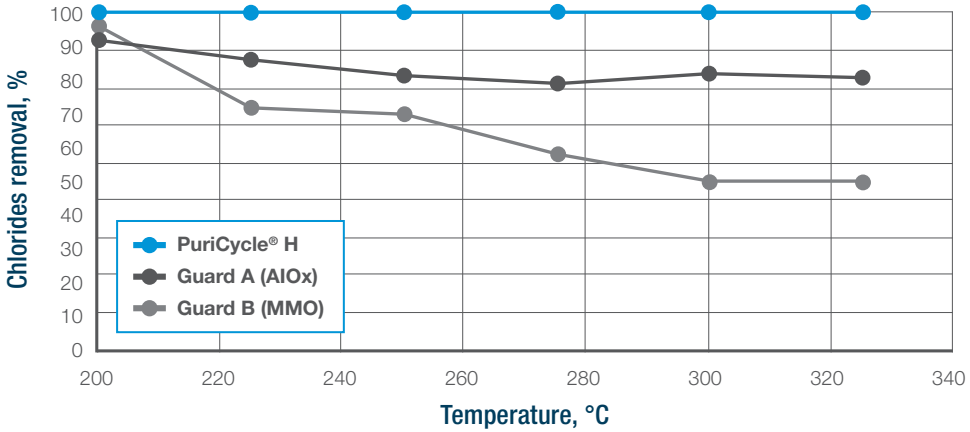



Chloroaromatics




* Exemplary speciation that might differ depending on a process and conditions.

## De-chlorination with PuriCycle® H

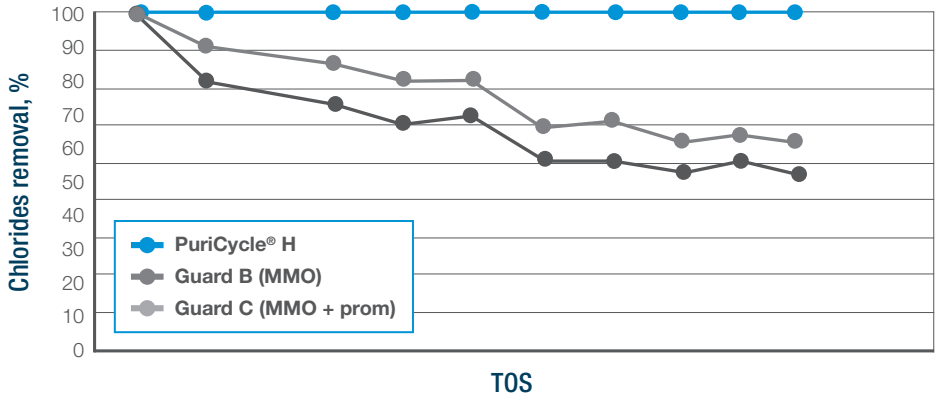



### Conditions

Commercial waste plastics PyOil chlorides inlet ~ 80 ppmw

T = 200-330 °C  P = 50 barg Argon

**PuriCycle® H enables complete removal of chlorides from commercial waste plastics PyOils starting 200 °C.**




### Conditions

Commercial waste plastics PyOil chlorides inlet ~ 150 ppmw

T = 250 °C  P = 50 barg Argon

**Conventional mixed metal oxide guards used for chlorides removal do not perform in complex waste plastics PyOils.**

# Prehydrogenation Catalysts PuriCycle® SH

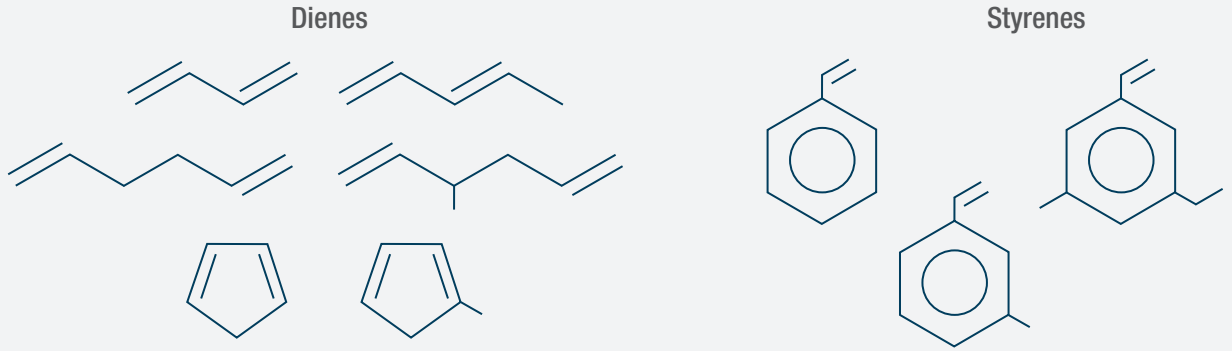
Pd based catalysts

Selective hydrogenation of dienes and styrenes

NiMo and CoMo based catalysts

Full hydrogenation of unsaturates

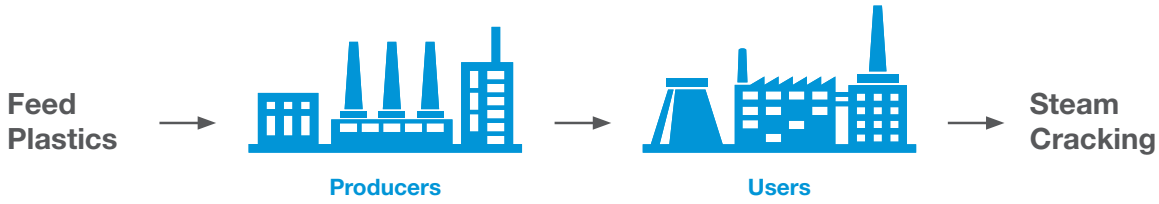
## Speciation of Reactive Compounds in Waste Plastics PyOils




* Exemplary speciation that might differ depending on a pyrolysis process and conditions.

Wide range of high reactivity species. Unstable at elevated temperatures contributing to PyOil processing equipment fouling.

## Selective Hydrogenation is Important for Low Grade PyOils




| | | |
|---|---|---|
| **Low Grade PyOils** | Diene Value (DV) UOP326 | 10-25 gI2/100 g |
| | Bromine Number ASTM1159 | 40-100 gBr2/100 g |

| | | |
|---|---|---|
| **High Grade PyOils** | Diene Value (DV) UOP326 | 1-10 gI2/100 g |
| | Bromine Number ASTM1159 | 10-40 gBr2/100 g |

| | | |
|---|---|---|
| **Low Grade PyOils** | Diene Value (DV) UOP326 | None gI2/100 g |
| | Bromine Number ASTM1159 | Below 0.5 gBr2/100 g |

| | | |
|---|---|---|
| **High Grade PyOils** | Diene Value (DV) UOP326 | None gI2/100 g |
| | Bromine Number ASTM1159 | Below 0.5 gBr2/100 g |

* Exemplary specification.

# Hydroprocessing Catalysts PuriCycle® HP

## CoMo based catalysts

Nitrogen, oxygen removal and olefins hydrogenation

## NiMo based catalysts

Nitrogen, oxygen removal and olefins hydrogenation

## Integration into Commercial Plants

Plastics Pyrolysis

Prehydrogenation

Hydroprocessing

Steamcracker

- Prehydrogenation **PuriCycle® SH**
- Metals Removal **PuriCycle® M**
- Dechlorination **PuriCycle® H**
- Nitrogen compounds **PuriCycle® HP**

Feed

Product

Upgrading Waste Plastics PyOils with Novel Solutions from BASF PuriCycle® Portfolio

We create chemistry

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## About Us

BASF's Catalysts division is the world's leading supplier of environmental and process catalysts. The group offers exceptional expertise in the development of technologies that protect the air we breathe, produce the fuels that power our world and ensure efficient production of a wide variety of chemicals, plastics and other products, including advanced battery materials. By leveraging our industry-leading R&D platforms, passion for innovation and deep knowledge of precious and base metals, BASF's Catalysts division develops unique, proprietary solutions that drive customer success.

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