The Wealth Contained: PET Recycling Opportunities we Miss!!

الثروة الكامنة: إعادة تدوير واستغلال الفرص من القناني البلاستيكية

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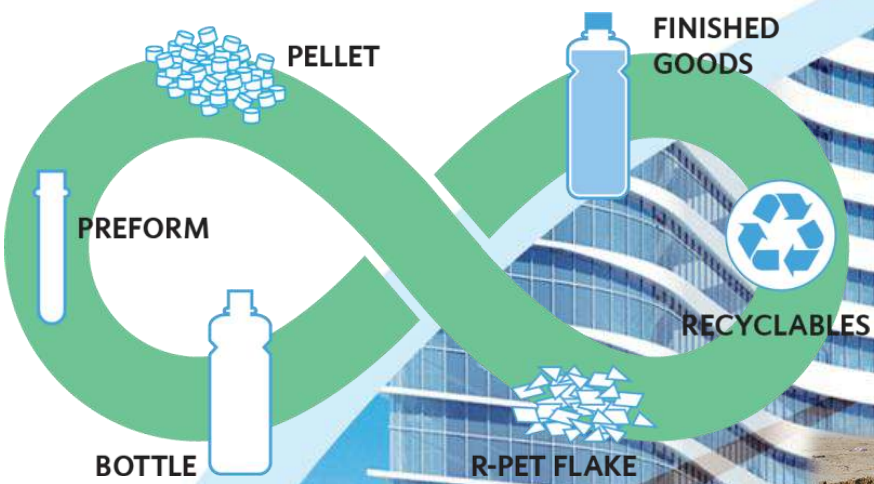
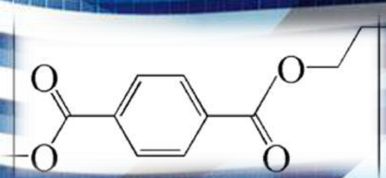
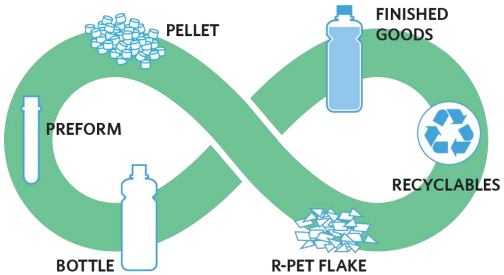
Kuwait Institute for Scientific Research





WSTA Conference 30 April – 1 May 2023 - Doha, State of Qatar

- **Introductory Remarks:** Water Bottles Design.
- **Polyethylene terephthalate (PET) manufacturing.**
- **Packaging Standards.**
- **Bottles Transportation Standards.**
- **Fate of PET and Environmental Impact.**
- **Depolymerization Technology.**
- **Plastic Solid Waste Management Hierarchy.**
- **PET Recycling Technologies.**
- **Circular Economy Opportunities in GCC.**
- **Concluding Remarks & Future Vision.**
- **Q&A - Panel Discussions.**



The design is not by coincidence!!

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- The design of the water bottle is not something that happened over time by coincidence. The design might take different shapes for plastic bottles but all of which will answer (positively) to a number of engineering/materials questions:

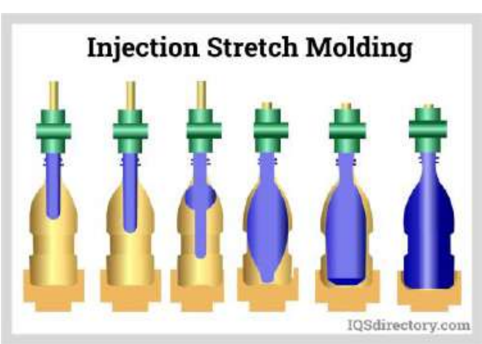
Is the shape compatible for consumers?

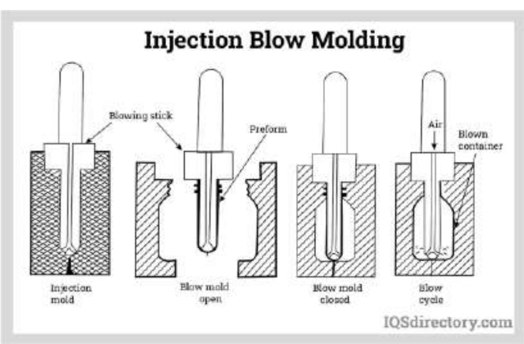
Can the bottle sustain a label?!

Is the shape able to withhold stresses?!

<u>Can the material be recycled?!</u>

- Bottles are manufactured by utilizing different mechanical processes that rely on physical moulding of resin.
- It is a question (always) of cost effectiveness against the process/product payable price.
- However, <u>main</u> shapes on the market are: **Oblong, Round, Round w/ Waist**.





Main Technologies of Conversion
Extrusion Processes for bottles

Image sources: IQS (2023), One Green Planet (2023), Tricorbruan (2023).

The anatomy of a plastic bottle

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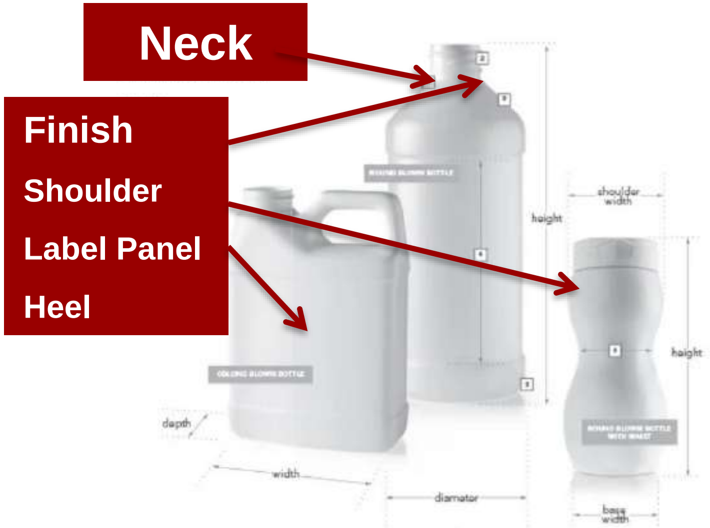
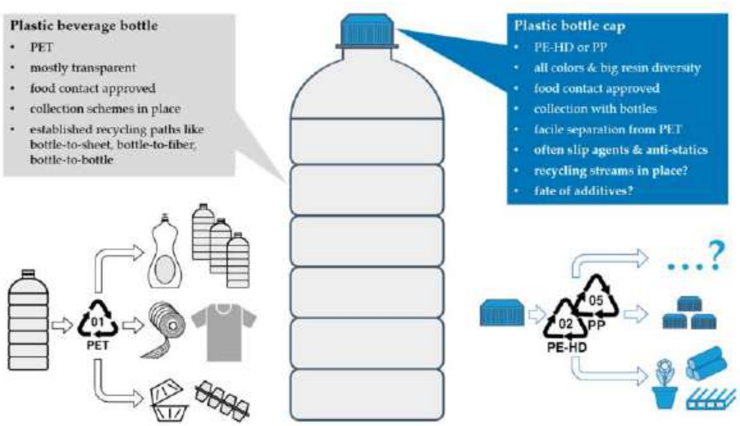
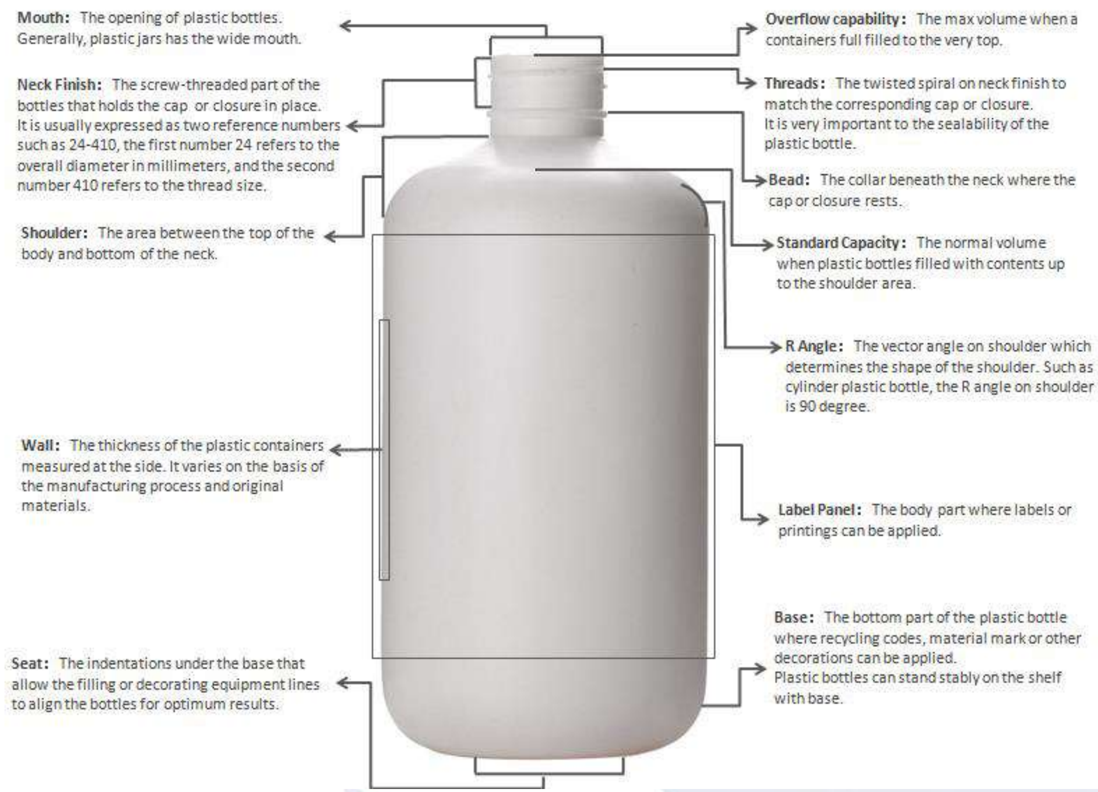




Main Materials Used in Manufacturing Water Bottles. Source: Gall et al. (2020).



Description of the various (main) parts of the plastic bottle. Source: SnalePlastics (2023).

A Direct quote from the ICI design handbook.

The design combines the required curved shape with stability and removes the need to manufacture and fabricate a separate base piece whilst continuing to incorporate pressure vessel design characteristics.

The *petaloid* design of most pop bottle bases

Earlier designs were produced with domed bottoms which required the addition of a separate base piece (usually made from high density polyethylene - HDPE). Some bottle designs still retain this feature.

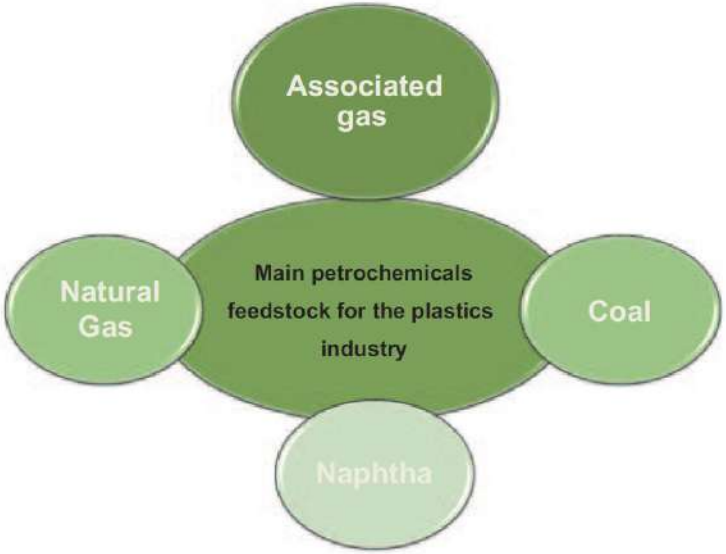
The anatomy of a plastic bottle

- Pour out Lip: The part of a container where the bottle cross section decreases to form the finish.
- Finish: The forming of the opening to accommodate a specific design for the closure.
- Shoulder: The part of a container between the main body and the neck usually sloped.

- PET might not be the most common polymer used for bottle extrusion but it is the most common for our area.
- PET provides a number of advantages; namely being not permeable to carbon dioxide.
- PET, including other bottle material types, are easily recycled after their initial usage.
- Plastic bottles are lighter than glass bottles, which saves energy and money when shipping products.
- <u>Plastic bottles require less energy to produce than glass bottles because plastics are soft and have relatively low melting temperatures.</u>

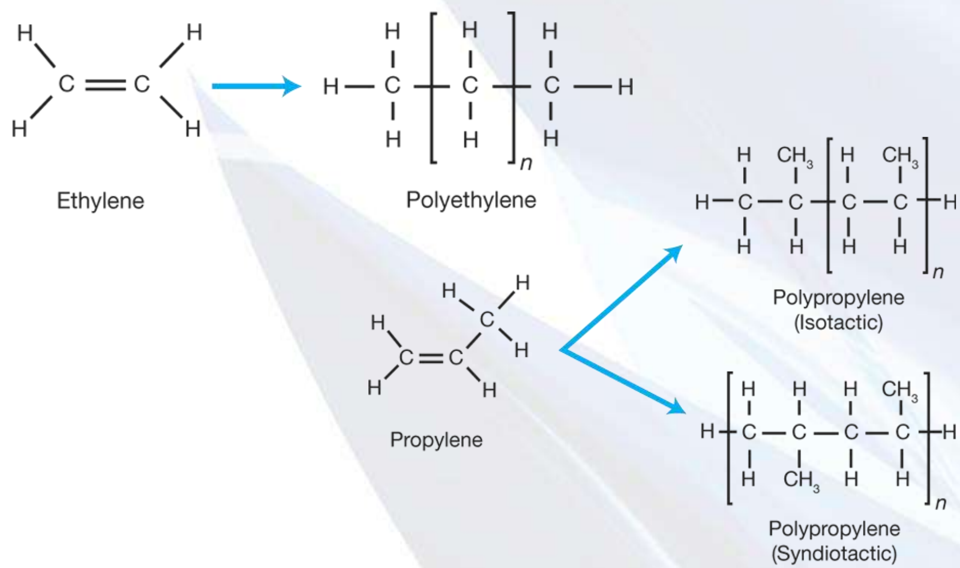
Polymerisation Technology and Petrochemicals

- When describing production of polymeric articles (i.e., plastic materials), the term olefin comes across very often. Olefins are unsaturated hydrocarbons containing at least one C=C double bond. Olefins are typically referred to as alkenes.
- Major alkenes that contribute to our daily lives in terms of various plastic materials and chemical products are ethylene (C_2H_4), propylene (C_3H_6), and butadiene (C_4H_6).
- **One of the main olefin based products is PE, which is a form of ethylene that is polymerized.**
- PE is the main plastic material that we use on a daily basis. There are various PE grades produced to cover the plastics market demand, and PE is typically classed according to its density.



Main feedstock material used to derive basic petrochemicals used in polymerization industry. Source: Al-Salem (2019)

- PE has an average chain length between 500 and 1000 repeated monomer units. PE is polymerized by contact to catalyst (e.g., Ziegler-Natta) in an exothermic reaction. Conversion of PE occurs in temperature ranges between 100°C and 200°C.
- On the other hand, PP is commonly produced using Ziegler-Natta catalyst in a bulk process. Propene as liquid in 30 atm (350 K) could be polymerised into three main types.



Polymerisation Technology and Petrochemicals

- When ethylene is oxidized, ethylene oxide (EO) results. This is the main chemical used for the production of EG after hydration.
- When ethylene is reacted to produce a chemical with ester linkage in the chemical backbone chain, it is commonly known as polyester. Polyester can be used in plastic film production, fibers, and bottles (polyethylene terephthalate, PET) resulting from terephtalic acid (TA) combination with EG.

Researchers at the <u>Brunel University in London</u> found 150 chemicals in drinks from plastic bottles, and 18 of them were found in dangerous levels, exceeding regulations. They also discovered that bottles made from recycled <u>Polyethylene Terephthalate</u> (PET) contained much higher concentrations of the chemicals than other plastics. PET is the third most common type of plastic in <u>food packaging</u> and one of the most popular amongst water bottles. Recently, the EU called for PET bottles to have at least <u>30 percent</u> of recycled content by 2030, but this needs to be reconsidered after this study.

$$C_2H_4 + O_2 \rightarrow C_2H_2O \text{ (EO)}$$

$$C_2H_4O + H_2O \rightarrow C_2H_6O_2 \text{ (EG)}$$

$$C_2H_6O_2 \text{ (EG)} + C_6H_4(COOH)_2 \text{ (TA)} \rightarrow C_{10}H_8O_4 \text{ (PET)}$$

Additives Used in Plastics Industry. Source: Al-Salem (2019)

Additive (Modifier)	Objective	Application	Common Examples
Plasticizers	Adding flexibility to materials, hard to soft	Upholstery, films, bottles, etc.	Di-octyl-phthalate, Di-isononyl-phthalate
Colorants	Coloring using dyes (soluble in water for transparency) or pigments (nonsoluble in water for opaque)	Films, pellets, carrier bags, etc.	Organic and inorganic substances; carbon black, malachite
Blowing agents	Produce cellular structure polymers via foaming process	Applied when material is in liquid state. PS cups are a common example.	Liquid CO_2, cyclopentane, etc.
Fillers	Improve/enhance properties	Films, rigid articles, etc.	Wood flour
Protective agents	Improve stability, preserve properties, protection against degradation and bleaching	Outdoor applied materials	UV-stabilizers, LTs, etc.
Impact modifiers	Improve bumping and impact strength by addition of another polymer	Automobiles	Acrylics
Plastics lubricants (flowing agents)	To make the plastics flow easier in molds	Tupperware	Waxes

Transportation Standards/Guidelines – European (East Europe as best example)

- Before use, the plastic containers be should cleaned thoroughly and if necessary, washed and disinfected (procedure available).
- Dynamic and static load – when using the containers, **do not exceed the specified stacking height**, static and dynamic load capacity for each container type.
- Temperature amplitudes – all plastic containers can be used at temperatures from -10°C to +40°C. If necessary, the containers can be produced to withstand continuous use at temperatures from -40°C to +100°C.
- Do not overfill the plastic containers.
- Plastic transport containers can be stored for more than 12 months without significant changes in their properties if the conditions are good. Storage under unsuitable conditions leads to reduced storage time.
- Plastic transport containers should be stored indoors or in shelters, protected from direct sunlight, rain and temperatures below -10°C or above 40°C.

Declaration of conformity:

Declaration of conformity according to: 1/Regulation 10/2011/EC; 2/Regulation (EC) 1935/2004 on materials and articles intended to come into contact with food; 3/<u>**Bulgarian**</u> Regulation for Packaging and Packaging Waste (2008) with regard to the contents of **Pb, Cd, Hg and Cr (6+) in line with** Directive 2004/12/EC; is issued only for specific shipment based on invoices issued to the client.

Design Specification – European PET Bottles

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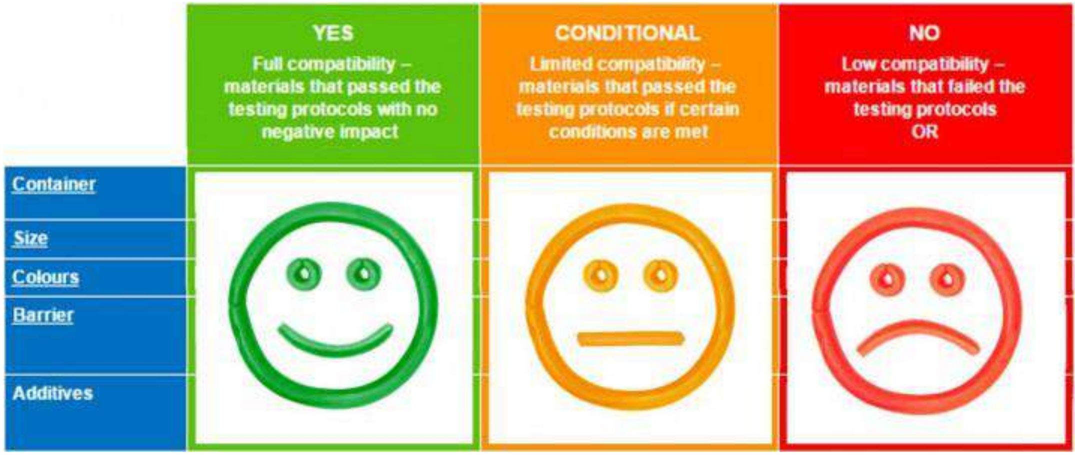
The key principles of the Design for Recycling Guidelines are appropriate for all PET bottles include:

Avoid the use of materials and/or components that are known to impede the PET recycling process or reduce the quality of the recycled PET.

Reduce the amount of non-PET components to allow for ease of separation and efficiency of recycling.

Design components, such as closures and labels, so that they can easily, safely, cost-effectively and rapidly be separated and eliminated from the recycled PET.

The goal of improving the recyclability of PET bottles cannot compromise product safety.



Materials and/or components used in PET bottles are classified under one of the following categories:

- **Full compatibility** – Materials that according to the EPBP testing protocol demonstrate no negative impact on the current European PET recycling process (also known as category "YES"). The use of these materials and/or components are encouraged to ensure that PET bottles are highly recyclable. This category also contains some materials and/or components in PET bottles which have not been tested (yet), but are known to be acceptable in PET recycling.
- **Limited compatibility** – Materials that according to the EPBP testing protocol demonstrate limited impact on the current European PET recycling process (also known as category "CONDITIONAL"). When a use is conditional, it has the ability to negatively impact the PET recycling stream, but these effects are not detrimental if certain conditions are met. For instance, the use of a material and/or component can be limited to a certain weight percent of a particular bottle design in relation to the total PET market. The specific conditions of these materials can be found on our website. This category also contains some materials and/or components in PET bottles which have not been tested (yet), but which our experts believe pose a low risk of interfering with the PET recycling processes or contaminating the recycled PET.
- **Low compatibility** – Materials that according to the EPBP testing protocol demonstrate a negative impact on the current European PET recycling process (also known as category "NO"). The use of these materials and/or components needs to be restricted because of their detrimental effect on the quality of recycled PET or interference with current PET recycling processes. This category also contains some materials and/or components in PET bottles which have not been tested (yet), but which our experts believe pose a high risk of interfering with the PET recycling processes or contaminating the recycled PET.

GENERAL STANDARD FOR BOTTLED/ PACKAGED DRINKING WATERS (Other than Natural Mineral Waters)

Codex Standard 227-2001

- **SCOPE**: This Standard applies to waters for drinking purposes.
- **DESCRIPTION:** Waters defined by origin.
- **COMPOSITION AND QUALITY FACTORS:**

Permitted physicochemical modifications and antimicrobial treatments for the waters defined by origin.

Carbonation "In the case of ground waters defined by origin, "*naturally carbonated*" *or* "*naturally sparkling*" *if, after packaging, carbon dioxide spontaneously and visibly is given off under normal conditions of temperature and pressure and the carbon dioxide originates from the source at emergence and is present at the same level as was present originally at emergence, with a possible re-incorporation of gas from the same source, taking into consideration a technical tolerance of ± 20%*"

Chemical composition

Food Safety and Standards (Packaging) Regulations, 2018

- Products made of recycled plastics including carry bags shall not be used for packaging, storing, carrying or dispensing articles of food.
- Requirement for specific migration limits of substances from plastic materials intended to be in contact with articles of food (Br, Cr, Co, Cu, Fe, Li etc ..).

SI. No.	List of Standards
1.	Specification for Polyethylene for its safe use in contact with foodstuffs, pharmaceuticals and drinking water – IS 10146
2.	Specification for Polystyrene for its safe use in contact with foodstuffs, pharmaceuticals and drinking water – IS 10142
3.	Specification for Polyvinyl Chloride (PVC) and its copolymers for its safe use in contact with foodstuffs, pharmaceuticals and drinking water – IS 10151
4.	Specification for Polypropylene and its copolymers for its safe use in contact with foodstuffs, pharmaceuticals and drinking water – IS 10910
5.	Specification for Ionomer Resins for its safe use in contact with foodstuffs, pharmaceuticals and drinking water – IS 11434
6.	Specification for Ethylene Acrylic Acid (EAA) copolymers for their safe use in contact with foodstuffs, pharmaceuticals and drinking water – IS 11704
7.	Specification for Polyalkylene Terephathalates (PET & PBT) for their safe use in contact with foodstuffs, pharmaceuticals and drinking water - IS 12252

These are not Indian but international standards

These standards are interconnected with aspects of waste!!

التعريفات العامة: ماهية النفايات ومالها على مستوى العالم ؟

النفاية (جمع) هي المواد بأي من الحالات الفيزيائية و التي تنجم من التدخل والعامل الادمي، تؤول الى (حالة) عدم الرغبة.

قد يستخدم المصطلح على المواد الغير مرغوب بها بعد الاستخدام من المنتوجات.

لا توجد نفايات في البيئة (او الطبيعة)، ويجب التخلص الامن منها باستخدام السبل الهندسية السليمة.

تمنهج النفايات وتصنف بأكثر من طريقة، والأكثر شيوعا (ليس دليل على الصحة في التعريف) هو التصنيف من المصدر.

6Rs (reuse, recycle, redesign, remanufacture, reduce, recover)


REDUCE
REUSE
RECYCLE
R
RETHINK
REPAIR
REFUSE
ECOART
SOLUTIONS
6 R'S TO SUSTAINABLE LIVING

النفايات بمنظور عالمي

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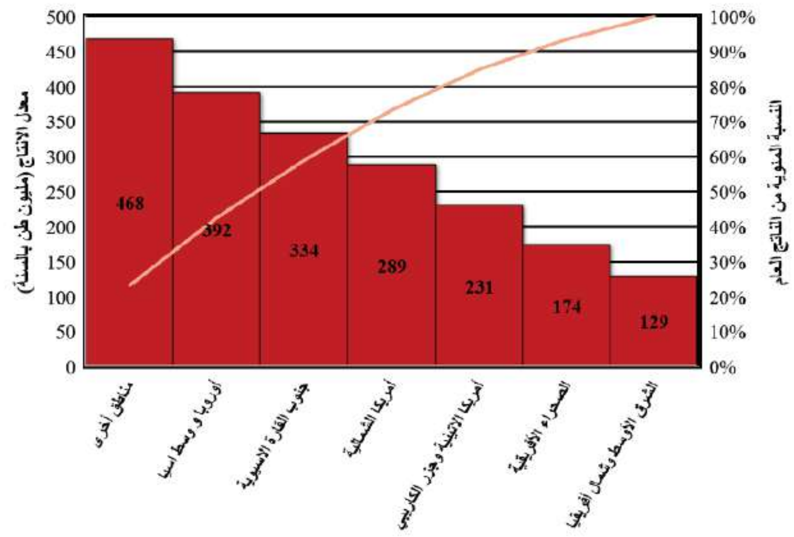
من المتوقع بحسب المصادر الرسمية بأن معدل انتاج النفايات للفرد بشكل يومي، سيتزايد في الدول المتقدمة - الصناعية بنسبة 19% الى سنة 2050 و بمعدل 40% في الدول ذات الدخل المتوسط والمحدود.

تعتبر منطقة المحيط الهادئ-شرق أسيا، اكثر دول العالم في نسبة انتاج النفايات، و في الواقع تعتبر منطقة الشرق الأوسط و شمال أفريقيا، أقل الدول انتاج للنفايات بمعدل 23% و 6% على التوالي (نسبة مئوية مطلقة).

كما تعتبر منطقة الصحراء الأفريقية أقل الدول في جمع النفايات بنسبة 44%، حين أن دول أسيا الوسطى و أوروبا وأمريكا الشمالية الأعلى بنسبة 90%.



Waste Generation by region '16. Source 'Data & Plates' Kaza et al. 2018. World Bank Report

Plastic Waste at the Thilafushi Waste Disposal Site, Maldives

A Recycler Transports Waste Using a Modified Motorcycle, Bangkok, Thailand

Where is Kuwait - Qatar !!

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Kuwait has one of the highest living standards the world over.

GDP = 120 B US$ (2017).

Population = 4.13 M Residents

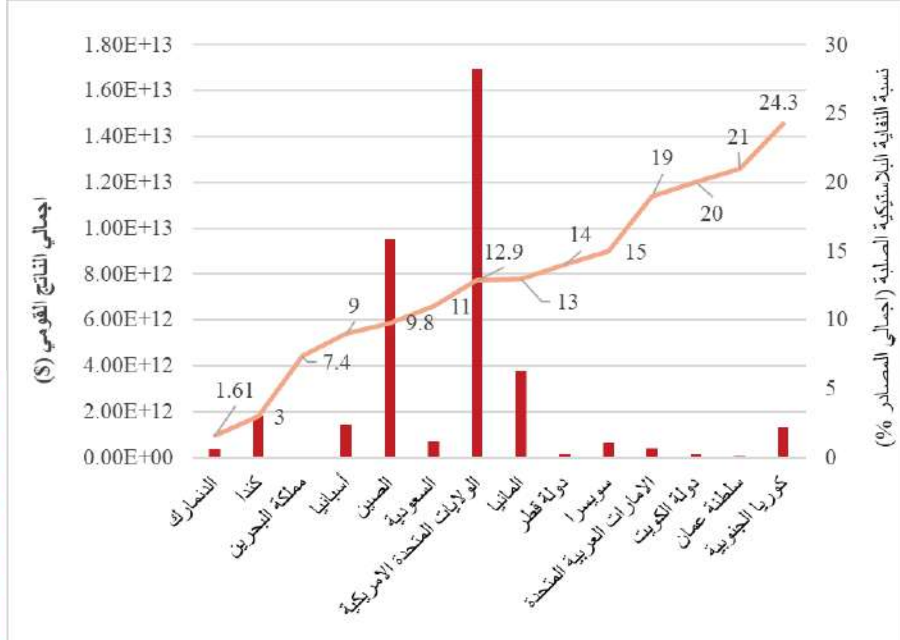
Waste generation is typically tied to economy and GDP.

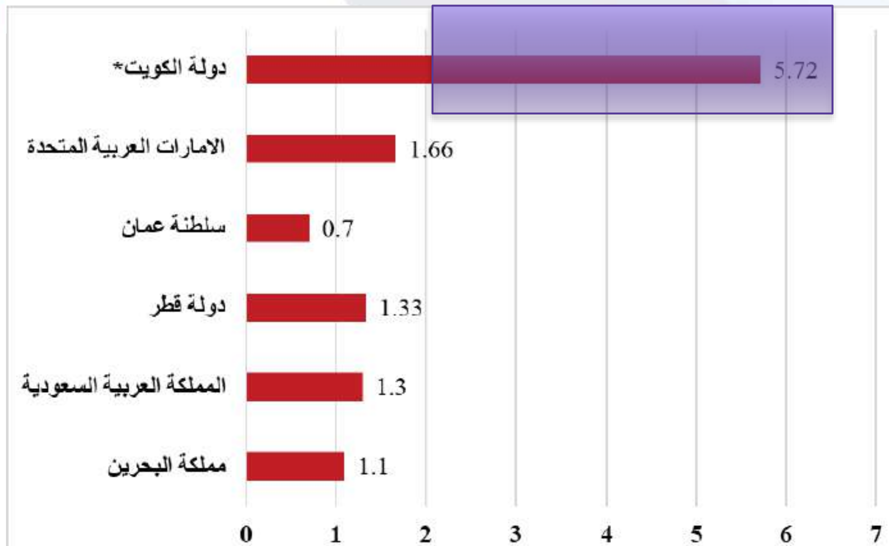
Currently, Kuwait categories solid waste into four types.

Organics are generated at a rapid rate constituting 46% (MSW), and PSW is about 18%.

الدولة	النفاية الخضراء (من الحدائق)	النفاية الخشبية	البلاستيك	النفاية الورقية	النفاية المعدنية	الزجاج	النفاية العضوية (من الطعام)	أخرى
مملكة البحرين			7.4	12.8	2.1	3.4	59.1	15.2
دولة الكويت	1	1	20	20	2	4	45	8
السعودية		5	11	27	5	4	45.5	2.5
سلطنة عمان	5	2	21	15		6	27	24
الامارات			19	25	3	4	39	10
دولة قطر			14	11	9	4	57	5

الدولة	اعادة تدوير	ردم غير صحي	اخرى	الحرق	الردم (الصحي)	التسميد
مملكة البحرين	8		92			
دولة الكويت		100				
المملكة العربية السعودية	15				85	
سلطنة عمان		99.99			0.01	
الامارات العربية المتحدة	20	62	9			9
دولة قطر	3		93	4		



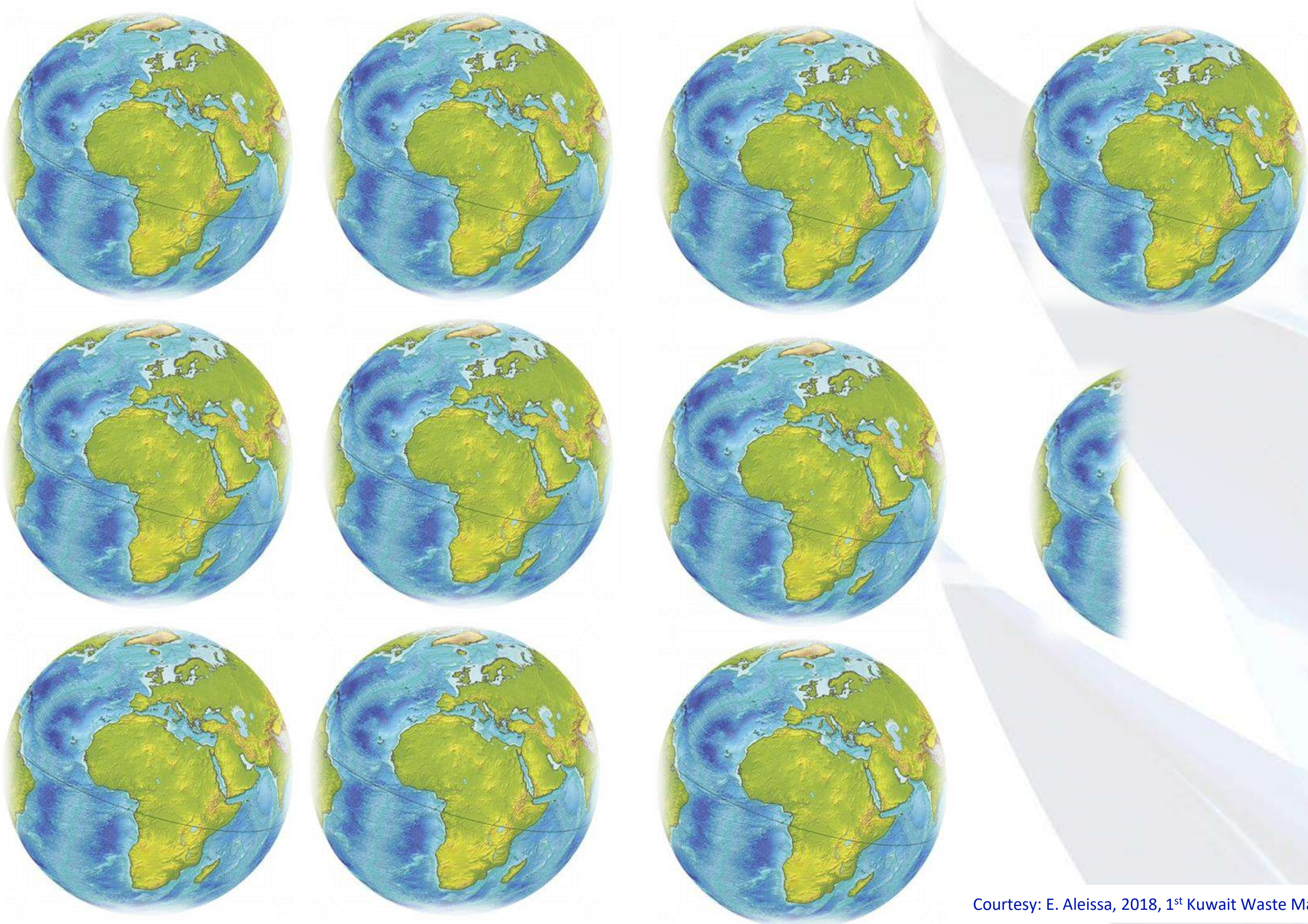


By default, crates and bottles typically constitute about 50% of the PSW from municipal sources.

This means in Kuwait it might reach about 100 ktpa, in Qatar 90 ktpa and in UAE 1 MILLION tpa (approx.)

World Bank Dataset (2020), Al-Salem (2021)

This is the price !!!



Courtesy: E. Aleissa, 2018, 1st Kuwait Waste Management Research Forum.

Landfilling in Kuwait: Past, Present & Future !!

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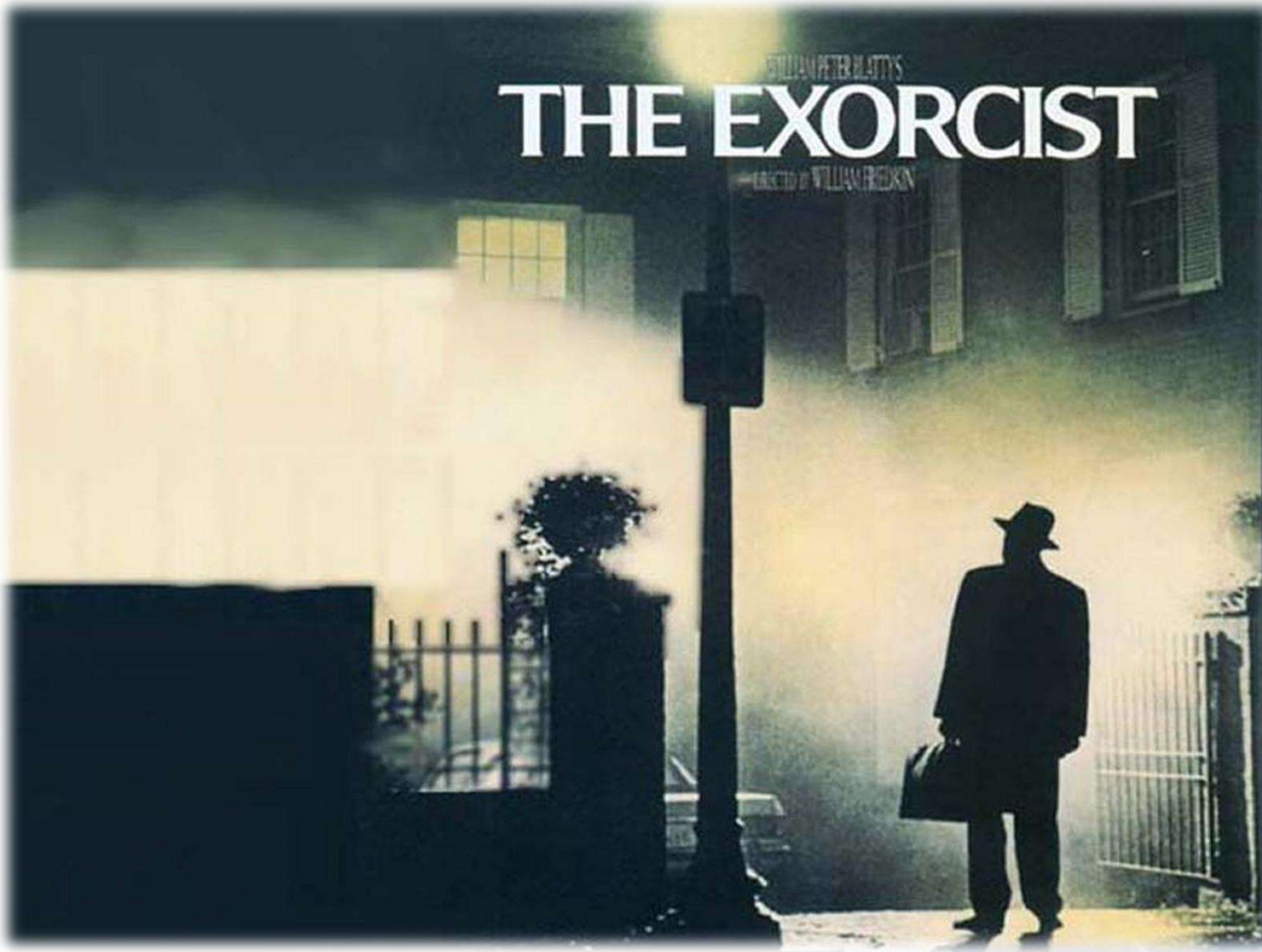

Landfilling in Kuwait: Past, Present & Future !!

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العدد 1077 - 2010/10/21

تاريخ الطباعة: 2018/28/11

اطبع

مردم القرين... حرق غازات ومعالجة مياه

عبدالله جاسم

بدأت مشكلة موقع ردم النفايات في منطقة القرين السكنية منذ عام 1975 عندما سمح لشركات النظافة حينذاك باستغلال حفر الدراكيل المخصصة لاستخراج مواد البناء لردم مختلف انواع النفايات خصوصا المنزلية حتى امتلأت الحفر بالنفايات عام 1985، واثناء تنفيذ مشروع القرين الاسكاني عام 1989تبين ان بعض النفايات تمتد داخل حدود المشروع، ما تسبب في انبعاث روائح كريهة وحرائق وغازات ناتجة عن عملية التحلل البكتيري والتي تعرف في مجموعها بغازات مواقع ردم النفايات المنزلية.

ويعتبر غاز الميثان الذي يمثل حوالي (45 -60) في المئة وغاز ثاني أكسيد الكربون بنسبة (35 -50) في المئة من مجموع الغازات المتولدة من الغازات الاساسية الناتجة عن عملية التحلل البكتيري للمواد العضوية الى جانب نسب مختلفة من الغازات المصاحبة العضوية وغير العضوية الاخرى، والتي من أهمها غاز كبريتيد الهيدروجين ذو الرائحة الكريهة.

وغازات مواقع ردم النفايات يجب التخلص منها بعد تجميعها خصوصا غاز الميثان القابل للاشتعال والانفجار مع اختلاطه بالهواء عند تركيز يتراوح من (5 -15) في المئة وبوجه عام تتوقف الفترة الزمنية التي تستمر فيها عملية تولد الغازات بمواقع الردم على مساحة وعمق الموقع ونوعية وكمية النفايات المردومة، ونسبة المواد العضوية بها ودرجة الحرارة داخل الموقع ورطوبة النفايات في الموقع وطريقة وأسلوب الردم وقد تستمر الفترة الزمنية لتولد الغازات داخل الموقع لعشرات السنين.

تلك المقدمة التعريفية هي موجز لمشكلة مردم القرين للنفايات أفادنا بها القائمون على المحطة من مهندسي ومشرفي الهيئة العامة للبيئة لكن «النهار» لم تكتف بذلك فجالت في الموقع لتتعرف على المشكلة عن كثب وتقف على آخر المستجدات فيها وتطلع من هم خارج أسوارها على ما يدور فيها، وكانت أول من التقت المستشار البيئي للمشروع م. فرحات محروس ليتحدث عن المحطة منذ بداية المشكلة قائلا :

«بدأ التعامل مع مشكلة موقع الردم بمنطقة القرين السكنية منذ اوائل عام 1989 حيث تبين من المسح الميداني الشامل الذي تم اجراؤه في ذلك الوقت ان مساحة الموقع تبلغ كيلو متر مربع تقريبا، وحجم كمية النفايات الصلبة المردومة بالموقع تقدر بحوالي 5 ملايين متر مكعب ما بين نفايات منزلية ونفايات انقاض البناء او النفايات الانشائية، وتبين ايضا ان اعماق طبقات الدفن داخل الموقع تتراوح ما

مشروع القرين... تحويل غاز الميثان إلى كهرباء

+ تكبير الخط - تصغير الخط

01 أبريل 2015 12:00 ص | الكاتب: بقلم محمد عبد الرحمن الصرعاوي* | 21

يعتبر مشروع القرين من المشاريع الحيوية التي قامت بها الهيئة العامة للبيئة خلال الأعوام (1997-2001)، وهو من المشاريع الرائدة على مستوى الوطن العربي والخليجي، حيث يتم فيه تحويل غاز الميثان إلى كهرباء من خلال شبكة هندسية تم تصميمها للحد من تصاعد الغازات والاستفادة منه بصورة مباشرة.

ويحتوي المردم المغلق في منطقة القرين على ما يقارب 5 ملايين متر مكعب من النفايات العضوية الغنية بتصاعد غاز الميثان، والذي عادة يتولد من تخمير القمامة العضوية في أكياس القمامة البلاستيكية، كما تقدر مساحة الموقع بحدود 1 كيلومتر مربع، وأعماق النفايات في المردم تتراوح بين 15-30 مترا، وهذه المساحة الشاسعة تنتج عنها كميات هائلة من غاز الميثان، والذي يتصاعد من الفجوات والشقوق على سطح الأرض حيث يسبب روائح كريهة وخطورة على الموقع

2098

16 قنبلة موقوتة ... تحت تراب الكويت

مرادم النفايات «أزمة بيئية» ثمارها «سرطان» ... والمعالجة تصطدم بـ «البيروقراطية»

+ تكبير الخط - تصغير الخط

30 مارس 2013 12:00 ص | 9

مرادم النفايات الكويتية مستباحة ... أميركياً

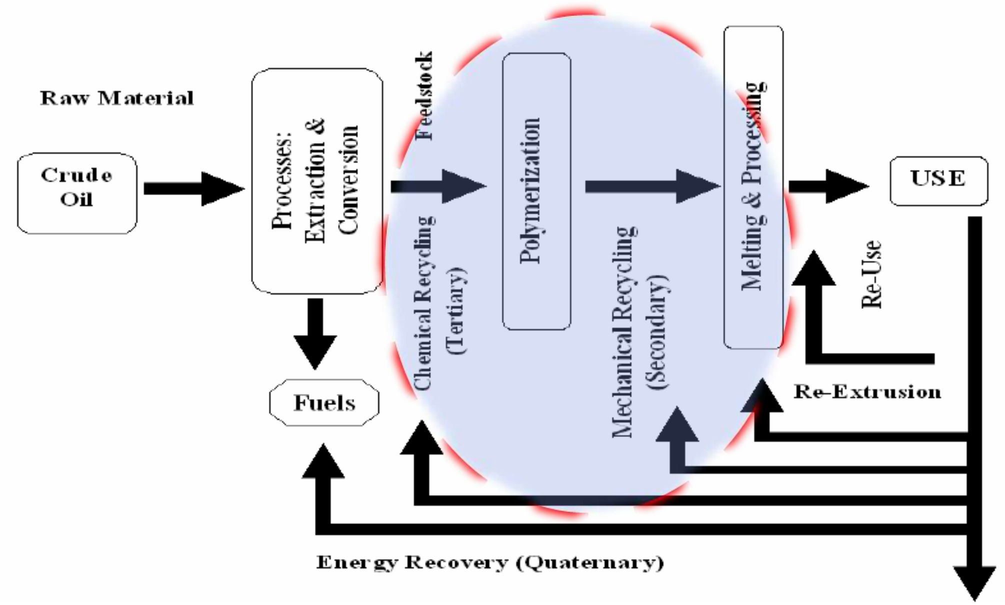
جولة «الراي» على المرادم برفقة 4 من أعضاء «البلدي» كشفت المستور واستشعرت الأخطار المحدقة

+ تكبير الخط - تصغير الخط

10 أبريل 2013 12:00 ص | 22

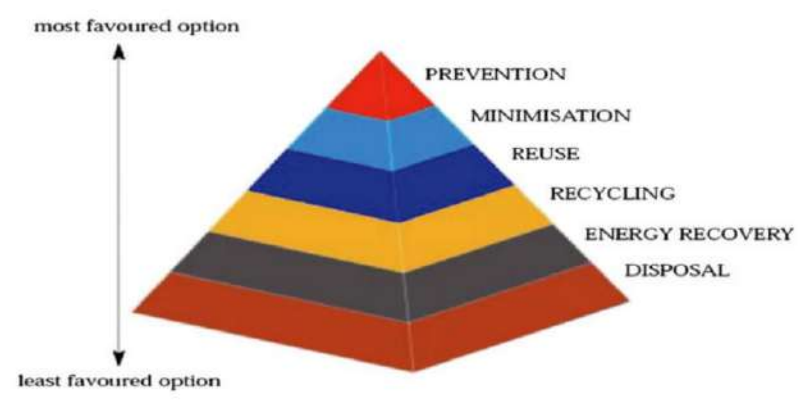
| كتب محمد أنور |

في جولتها السابقة على المدن العمالية برفقة اثنين من أعضاء المجلس البلدي، لاحظت «الراي» تلالا كبيرة خلف مدينة الشدادية، فظنناها جبالا، واستغربنا **وجودها ونحن الذين نعرف أن جغرافية الكويت صحراوية ليس فيها جبال، وكانت المفاجأة أن تلك التلال الشاهقة ما هي إلا أكوام نفايات في مردم جنوب الدائري السادس.



Treatment methods related to the production cycle of polymers [1].

- Focus on secondary & tertiary methods.
- **What we lack in GCC!!**



Classic waste management hierarchy

- There are no proper assessment studies in Kuwait.
- PSW is accumulating in landfills and is typically exported.
- PSW is estimated to be generated at an alarming rate of ~~150 ktpa (2001).~~

Property	Catalysts	Increasing temperature
Density	Down	Down
Viscosity	Down	Down
RON	Up	Up
MON	Up	Up
Cetane number	Up	–
Pour point	Down	–

[1] Al-Salem et al., 2009. Waste Manage. [2] Al-Meshan & Mahros, 2001. Arabian J Sci & Eng. [3] Butler et al. 2011.

Processing technologies

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Source of Tables: Jiang et al. (2022)

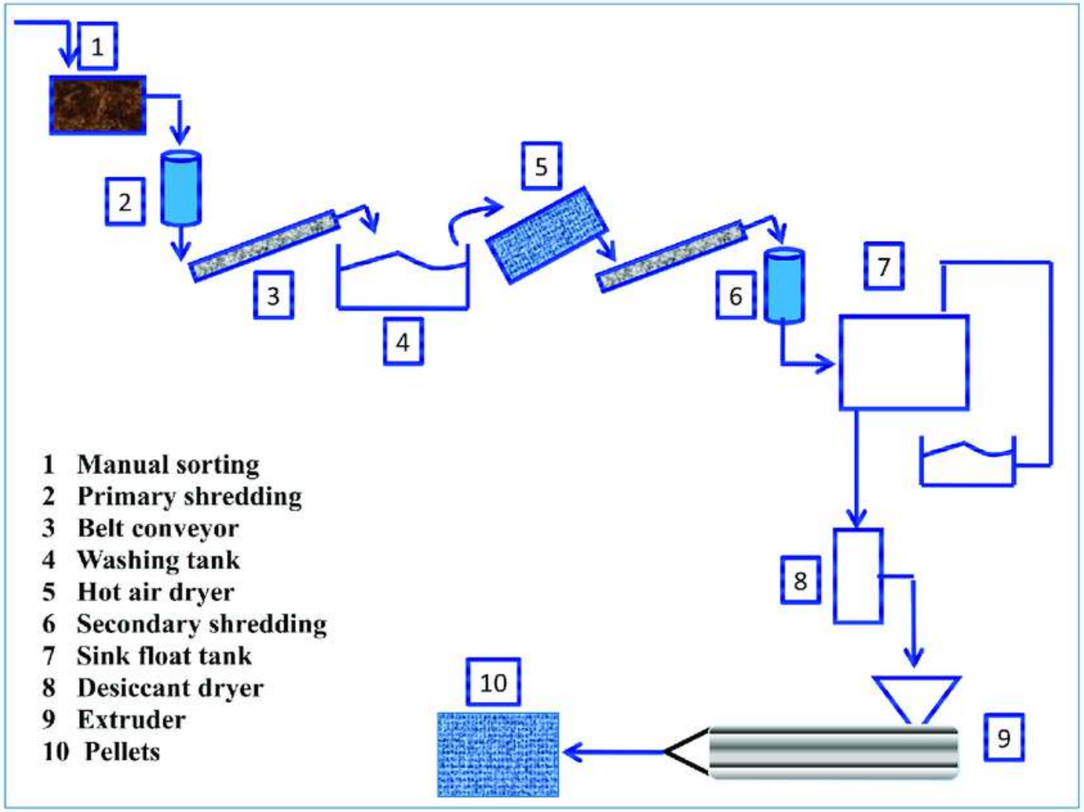
The common plastic waste recycling technologies.

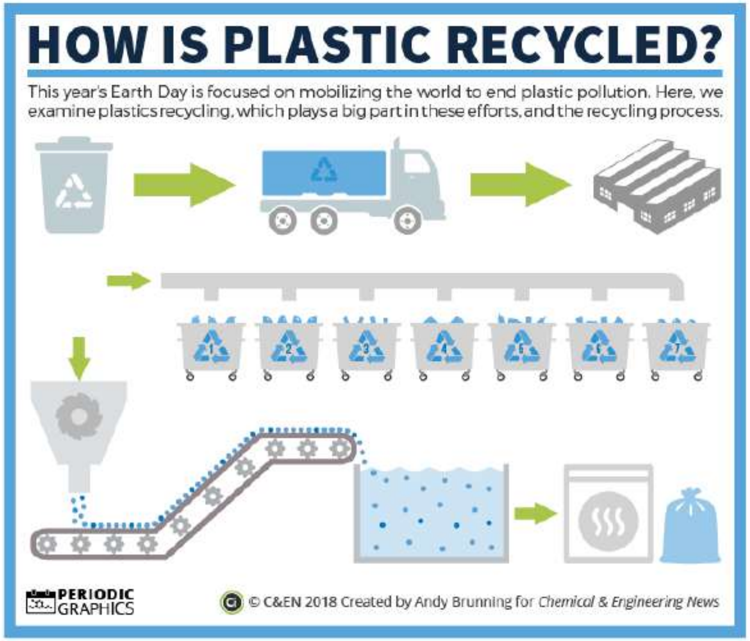
Method	Process description	Advantages	Disadvantages
Mechanical recycling	Plastic is converted into lower value plastic via re-melting or re-processing	• Large-scale disposal • Effective method • Cost-effective • Commonly used • Flexible feedstock supply	1. Environmentally unfriendly 2. Poor mechanical properties of the product 3. Limited to monolayer plastics
Biological recycling	Plastic polymer bond cleavage into monomers via enzymes produced by microorganisms	•Environmentally friendly	–Time-consuming when compared with chemical and mechanical methods
Chemical recycling	Plastic is converted into chemical feedstocks via pyrolysis, solvolysis and gasification	• Converted into chemical raw materials • Obey sustainability principles • Processability of the final product	1. Costly active catalysts 2. High temperatures 3. Energy-consuming 4. Limits industrial applications

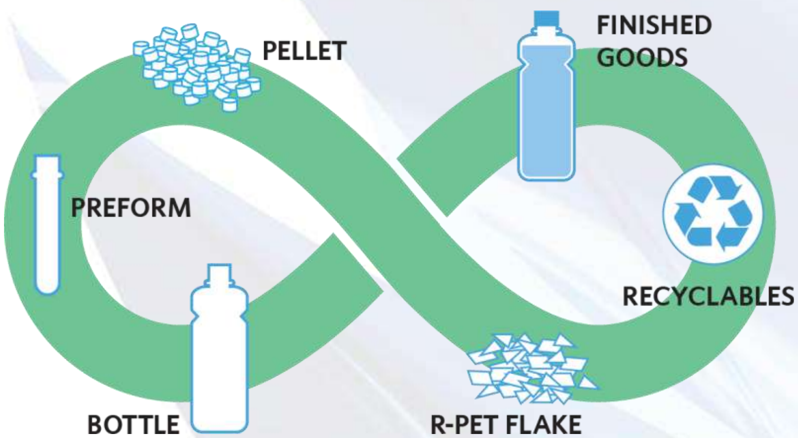
Summary of different chemical recycling approaches.

Recycling method	Process description	Polymer type	Advantages	Challenges
Pyrolysis	Degradation of polymeric chains in presence of the inert atmosphere	All plastics	• Relatively no significant release of toxic gases • Produce electricity and heat • Broad distribution of solid, liquid, and gaseous products	1. Complex chemistry 2. Requires high volumes to be cost-effective 3. Heteroatoms reduce product quality
Solvolysis	Solvent medium is used to break the plastic waste into low molecular weight products	PET, PLA, PC	• Manageable and effective • Extensive reactions • Solvent to depolymerization	1. Long time for complete depolymerization 2. Cannot handle high content additives 3. Difficult to separate feedstock impurities
Gasification	Partial oxidation process (using air or steam) for the conversion of plastic wastes into gases	All plastics	• Polymer separation into different categories is not necessary • Produce electricity and heat • Heat to depolymerization	1. Release of toxic gases 2. Lacks technology for gasification of mixed plastic waste 3. Cannot be used in monomer production 4. Tar formation

Processing technologies

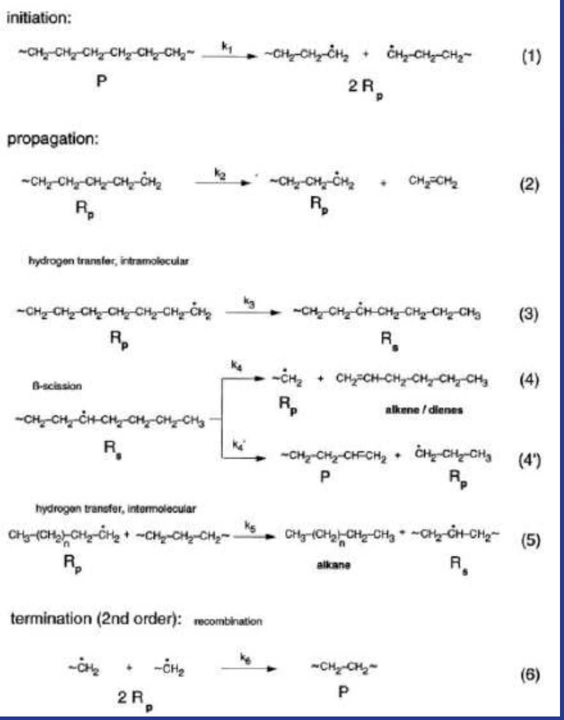




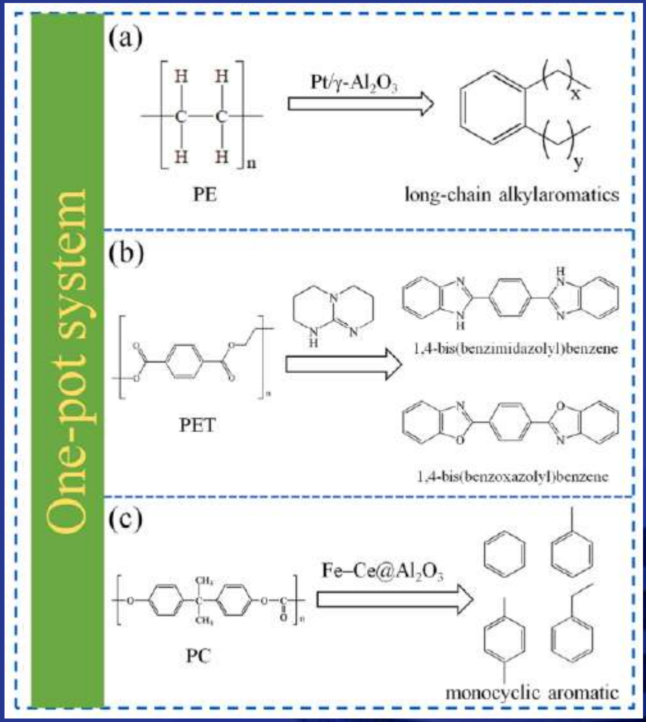


Various online sources.

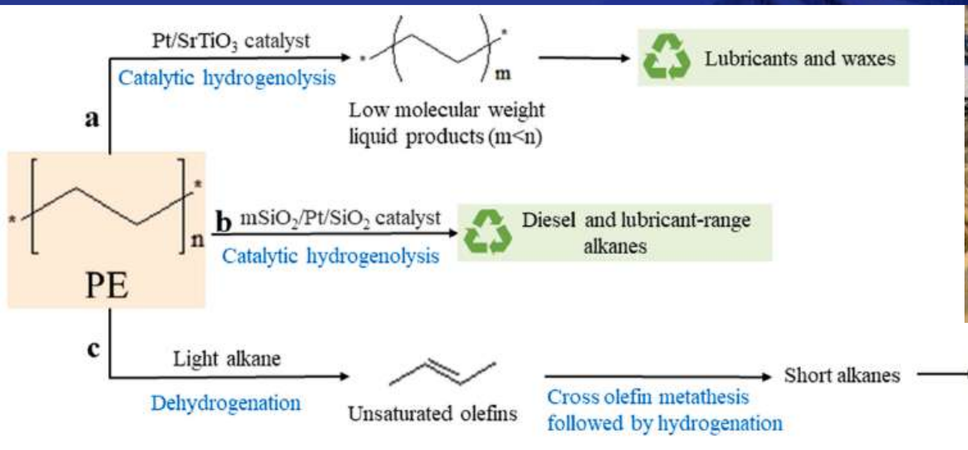
Processing technologies



Radical PE (Thermal) mechanism



PSW Cracking rxn



PE Pyrolytic rxn

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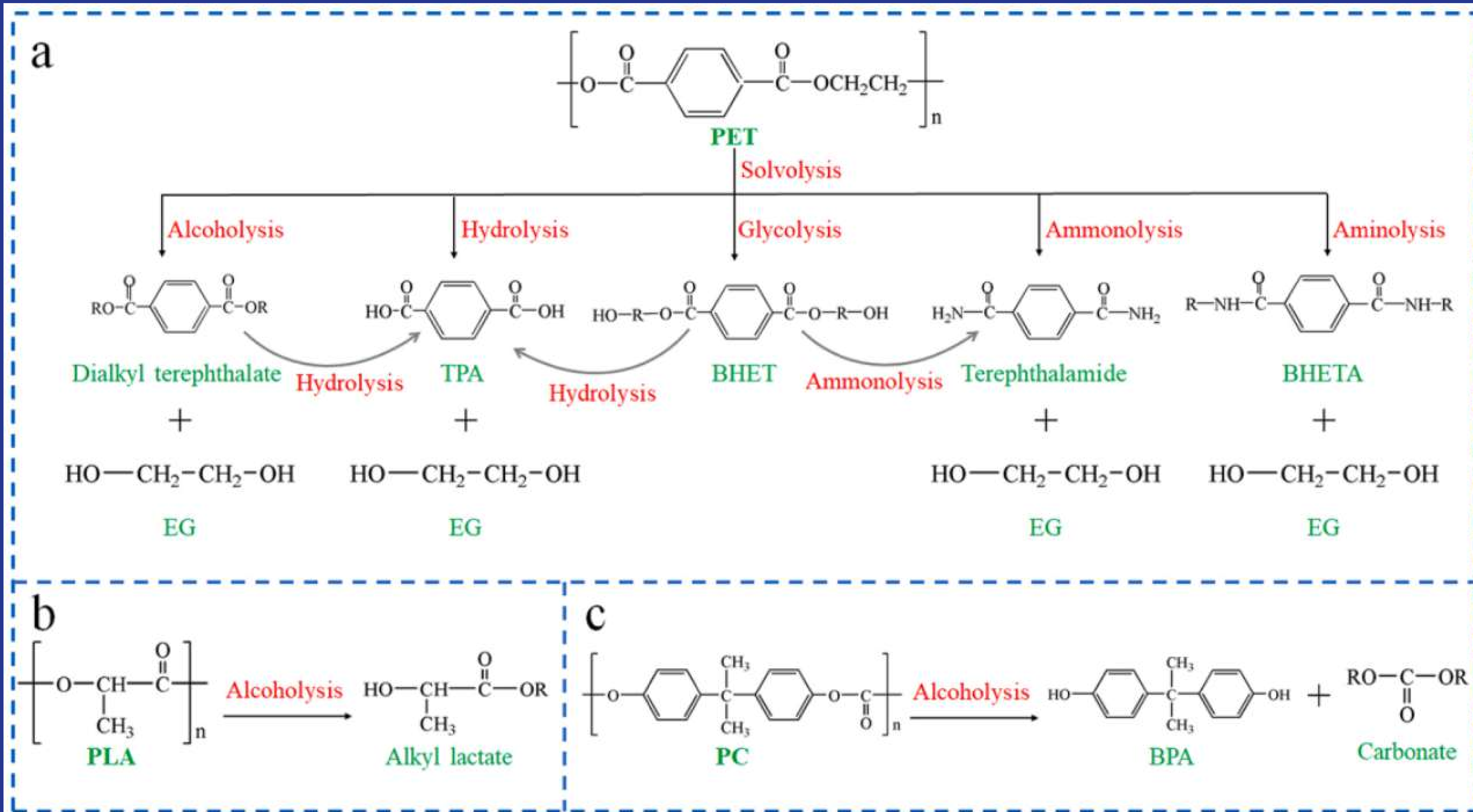

The proposed solvolysis process of PET (a) , PLA (b) , and PC. Jiang et al. (2022)

الاقتصاد الدائري

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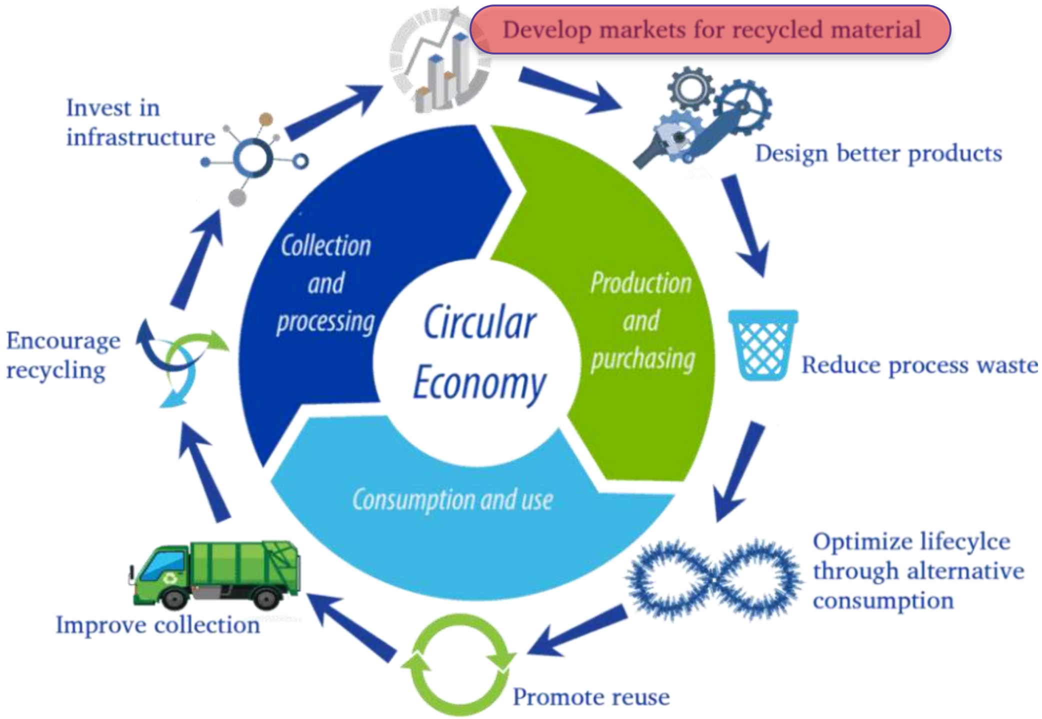


Image: Sustainable Global Resources Ltd. Recycling Council of Ontario

يهدف إلى

الانتفاء (تدريجيا) من الاقتصاد الخطي (المتلازم مع الريعي)

يطمح إلى تحقيق معدل (صفر) نفاية

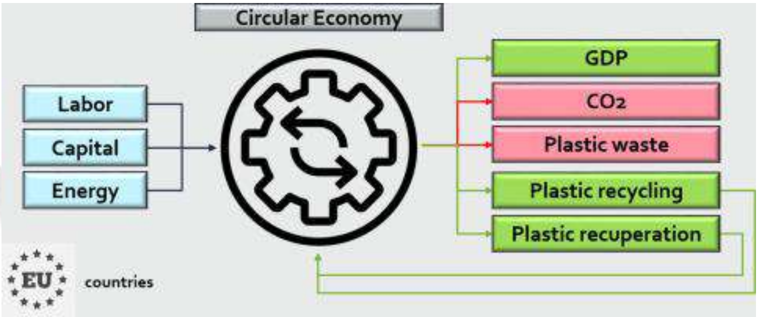
بذلك يحقق استدامة بيئية ومردود اقتصادي أصيل

يحقق تنوع لسلة الطاقة في البلدان النامية

بالنسبة إلى المصنعين، سيقضي على التكاليف والانبعاث البيئية الضارة من حيث استغلال لقيم رخيص القيمة

Image source: Icelog - Global product information management and syndication

الاقتصاد الدائري: خطوات وأهداف تقاس



الاتحاد الأوروبي بدأ بالتطبيق منذ نهاية الثمانينات بطريقة أو بأخرى.

الاستثمار والتطوير يكون في العمالة، التقنية ومصادر الطاقة بشكل آني.

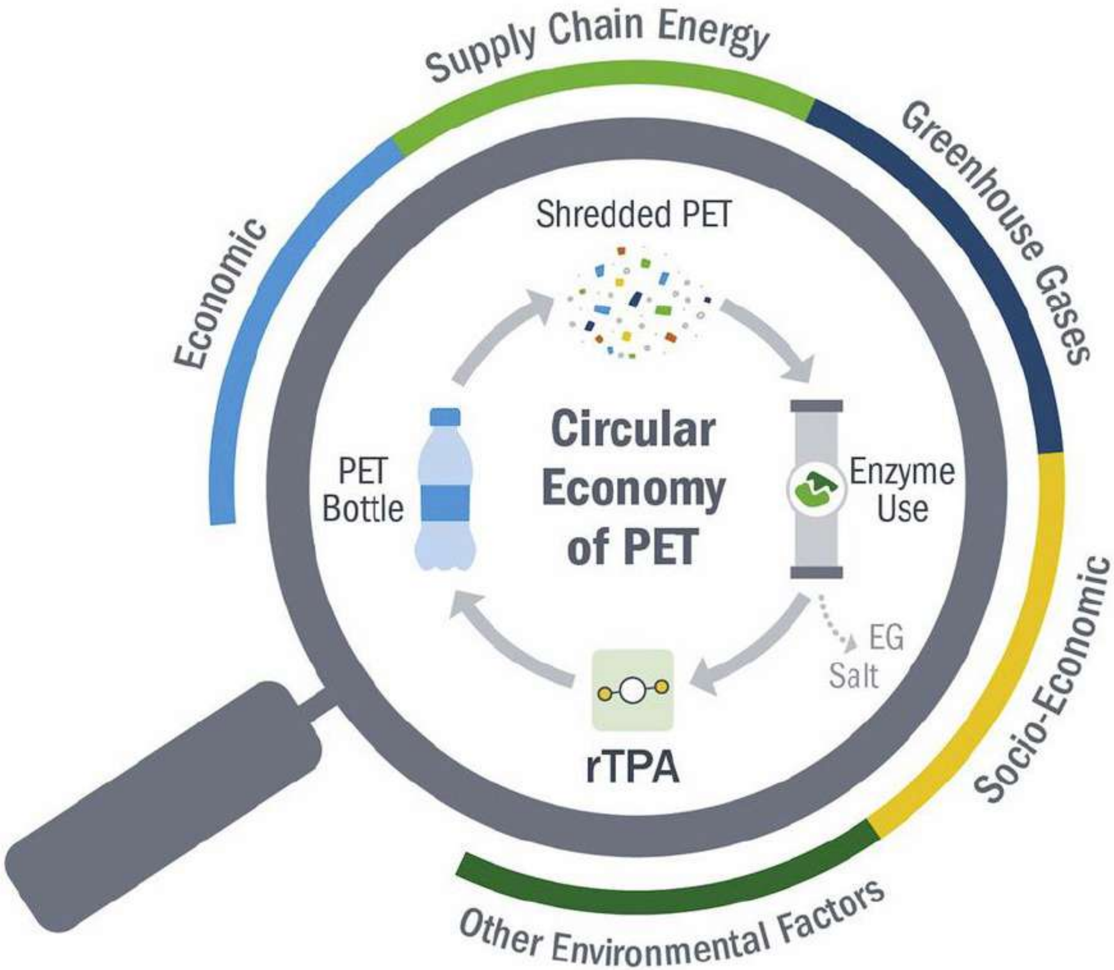
Robiana et al. 2020.

الاقتصاد الخطي: اقتصاد غير مستدام ينجم عنه تراكم للنفاية

الاقتصاد الدائري: يحقق الاستدامة والعوائد الاقتصادية.

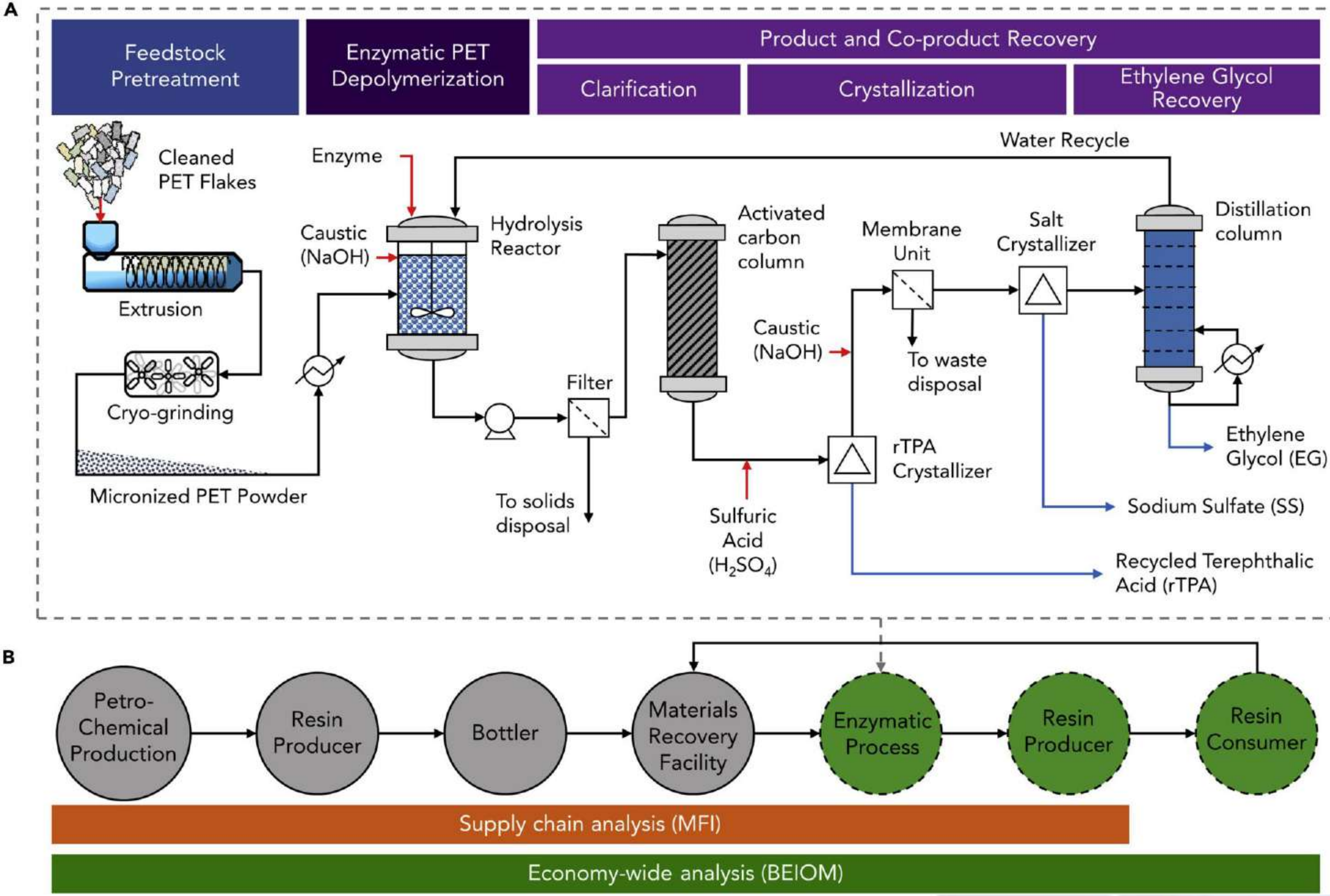
d'Ambrières 2019

The Circularity of PET



Singh et al. (2021)

The Circularity of PET



الاقتصاد الدائري: خطوات وأهداف تقاس

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Product	Price (€/t)*	Process	Feedstock	Intermediate/final products
Ethene	692–1,084	TC	Ethane, propane, naphtha, gas oil	PE manufacture (>50 wt%), antifreeze, polyester fibers, PVC, PS plastic and foam, soaps, plastics, detergents
Propene	692–1,279	TC	Ethane, propane, naphtha, gas oil	Polypropylene, plastics, fibres, foams, Cumene (IP), C_4 alcohols, oligomers, soaps, detergents
Butadiene	602–1,656	TC, DH	Ethane, propane, naphtha, gas oil (TC), butane/ butenes (DH)	Styrene-butadiene rubber (tyres), other elastomers, nylon monomers
Benzene	710–922	CR, HDA	Naphtha (CR), Toluene (HDA)	Styrene (IP), Cumene (IP), Cyclohexane (IP), polyurethanes
Toluene	582–828	CR	Naphtha	Gasoline octane enhancer, benzene (IP), TNT (explosive)
Xylenes	597–862	CR	Naphtha	Gasoline, benzene, solvents, PET, textile fibres, photographic film, soft drink bottles, plasticisers, unsaturated polyester resins, alkylated resins

Thermal reaction	Catalytic reaction
High production of C_1 and C_2 gases	High production of C_3s and C_4s
Olefins less branched	Olefins are a primary product and more branched (isomerization)
Some diolefins at high temperature	Gasoline selectivity high
Gasoline selectivity poor (wide Mw distribution)	Aromatics produced by naphthalene dehydrogenation and olefin cyclisation
Reactions slow compared to catalytic	Larger molecules more reactions
Unconverted residues from polyolefins	Pure aromatics don't react
	Paraffins produced by H_2 transfer
	Some isomerisation occurring
	Unsuitable catalysts can yield excessive coke or gas

Butler et al. 2011.

The case at hand

	5 YEARS	10 YEARS	15 YEARS
	Sum	Sum	Sum
Revenues	€34.497	€67.977	€101.457
COGS	€-	€-	€-
Direct Margin	€34.497	€67.977	€101.457
OPEX	€-2.258	€-4.449	€-6.640
EBITDA	€29.112	€58.836	€88.560
Depreciation/Amortization	€-2.164	€-4.814	€-7.464
Financial Cost	€-3.869	€-4.475	€-4.475
Taxable Amount			
Taxes	€-4.141	€-10.601	€-16.017
Net Income	**€19.021**	**€39.030**	**€60.688**

ACTUALS	Sum	Sum	Sum
Depreciation/Amortization	€2.164	€4.814	€7.464
Operating Cash-Flow	€21.185	€43.844	€68.152
Delta CAPEX	€-22.575	€-22.575	€-22.575
Principal loan	€10.559	€2.000	€2.000
Free Cash Flow	**€9.169**	**€23.269**	**€47.577**
Cumulated Free Cash	**€9.085**	**€23.185**	**€47.493**

DISCOUNTED	Sum	Sum	Sum
Discount factor			
Disc. free cash flow	**€7.951**	**€15.830**	**€27.991**
Cum. free cash flow	**€7.951**	**€15.830**	**€27.991**

Kuwait Institute for Scientific Research

Don't Waste Waste

Thank You

Bio Sketch: Dr. S.M. Al-Salem

Dr. Sultan Al-Salem graduated from Kuwait University, College of Engineering & Petroleum, holding a BSc (2005) and a MSc (2007) degrees in Chemical Engineering, where he started his career as a teaching assistant (full-time grad student) and a research engineer. He then joined the Petrochemical Processes Program Element in the Kuwait Institute for Scientific Research (KISR) as a Research Assistant in August, 2006.

His work experience has linked him with a number of projects in the crude oil refining and petrochemicals area, air pollutants monitoring, dispersion and chemical mass balance (CMB) modelling, cancer risk and environmental impact assessment. He earned his PhD from the Department of Chemical Engineering of the prestigious University College London (UCL) in 2013, with a scholarship sponsored by the Government of the State of Kuwait through KISR. He held the position of an Assistant Research Scientist at the Petroleum Research Centre (PRC) of KISR from July 2013 to July 2015.

Dr. Al-Salem specializes in polymer degradation kinetics, which is a particular research interest of his. He is also interested in polymers weathering, Plastic Solid Waste (PSW) management, reactor design, downstream intensification processes, Waste Management, thermal engineering, life cycle assessment (LCA), biodegradable polymers and gas engineering. Dr. Al-Salem has authored/co-authored a number of book chapters, refereed journal and conference papers. He currently holds the position of a Research Scientist at the Environment & Life Sciences Research Centre (ELSRC) of KISR working on a number of research projects and pursuing a number of major R&D works. He is also the Environmental Pollution & Climate Program (EPCP) manager from 2019. He has established the Waste Management Research Unit (WMRU) at KISR and is currently supervising this research unit. He also established and wrote the Waste Management & Valorisation Research Program Strategy in KISR's 9th Strategic Plan based on his idea that was initiated prior. He has led various R&D projects with a number of clients including KISR, EQUATE Petrochemical Company, Kuwait Municipality and KFAS; and participated/developed over fifteen research activities. Dr. Al-Salem is also recognized as the first Professional Ethics in the Workplace trainer in the State of Kuwait where he has developed a curriculum dedicated for the subject matter; and has developed various unique training courses for KISR including Energy from Plastic Waste and Plastics & the Environment. He is also currently the Associate Editor of the reputed Journal of Environmental Management (Elsevier) and served as one for Waste Management (Elsevier). He is currently a board member for Environmental Challenges (Elsevier). He has also served as a consultant to the Kuwait Foundation for the Advancement of Sciences (KFAS). Dr. Al-Salem holds two registered patents at the USTPO in thermo-chemical conversion of plastic solid waste and polymers. Dr. Al-Salem is also the senior author of one of the highest cited papers (about 1000 citations to date) in chemical engineering, which is recognized by Elsevier for his review manuscript published in Waste Management back in 2009. He is also the recipient of various research awards.