OAPEC
Organization of Arab Petroleum Exporting Countries

Don't Waste

KISR
Kuwait Institute for Scientific Research

# النفاية البلاستيكية، الثروة المستدامة


د. سلطان السالم

باحث علمي / معهد الكويت للأبحاث العلمية



ندوة النفايات البلاستيكية والاقتصاد الدائري

28 تموز 2021 – دولة الكويت


KISR
Kuwait Institute for Scientific Research

- التعريفات و الاهمية للدولة من منظور "كويت 2035"
- أهم الاحصاءات والبيانات للنفاية الصلبة في دولة الكويت/العالم
- الاقتصاد الدائري ... هل نعي معنى الكلمة فعلا!!
- التقنيات المطورة في إنتاج الوقود والطاقة
- لمحة عن أهم نتائج مشاريع البحث والتطوير الخاصة بالبلاستيك في الكويت
- العائد التنموي و الاقتصادي للمشروع
- الخلاصة والاستنتاجات

# WASTE

## Liquid Waste

- Liquid by state of matter, coming from the source or point of origin as liquid or transformed as liquid.
- Common examples are rain water, drainage and cement truck wash water, waste water, chemicals and solvents.

## Recyclables

## Organic Waste

- Any type of organic waste, typically sourced from nature (Fruit & Veg).
- By nature, biodegradable, hence easily composted.

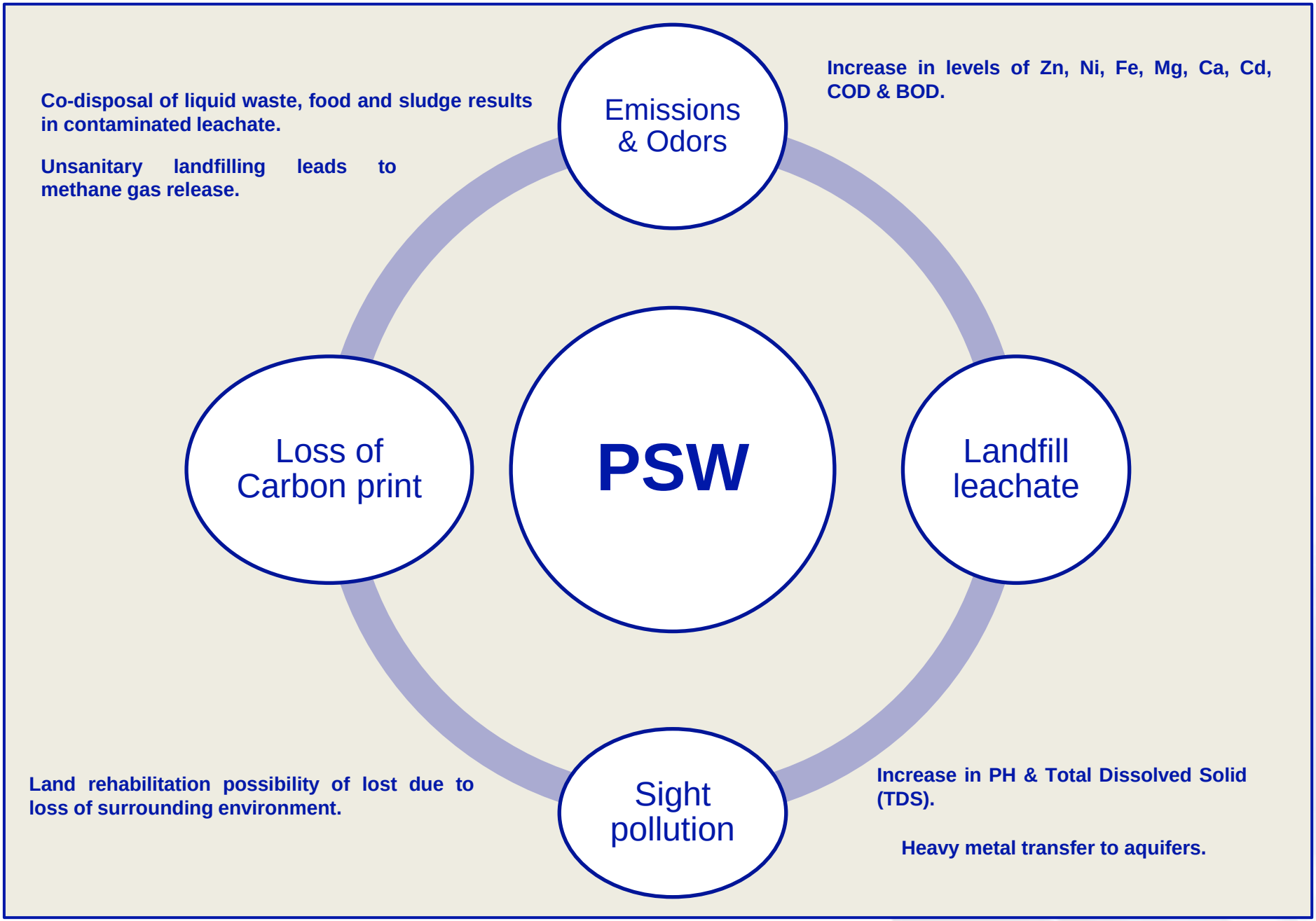
## Hazardous Waste

- Waste harmful to wellbeing and health, and urban environment.
- Flammable, reactive, corrosive and toxic waste are common examples.
- Fire extinguishers, batteries and thermometers are also hazardous waste types.

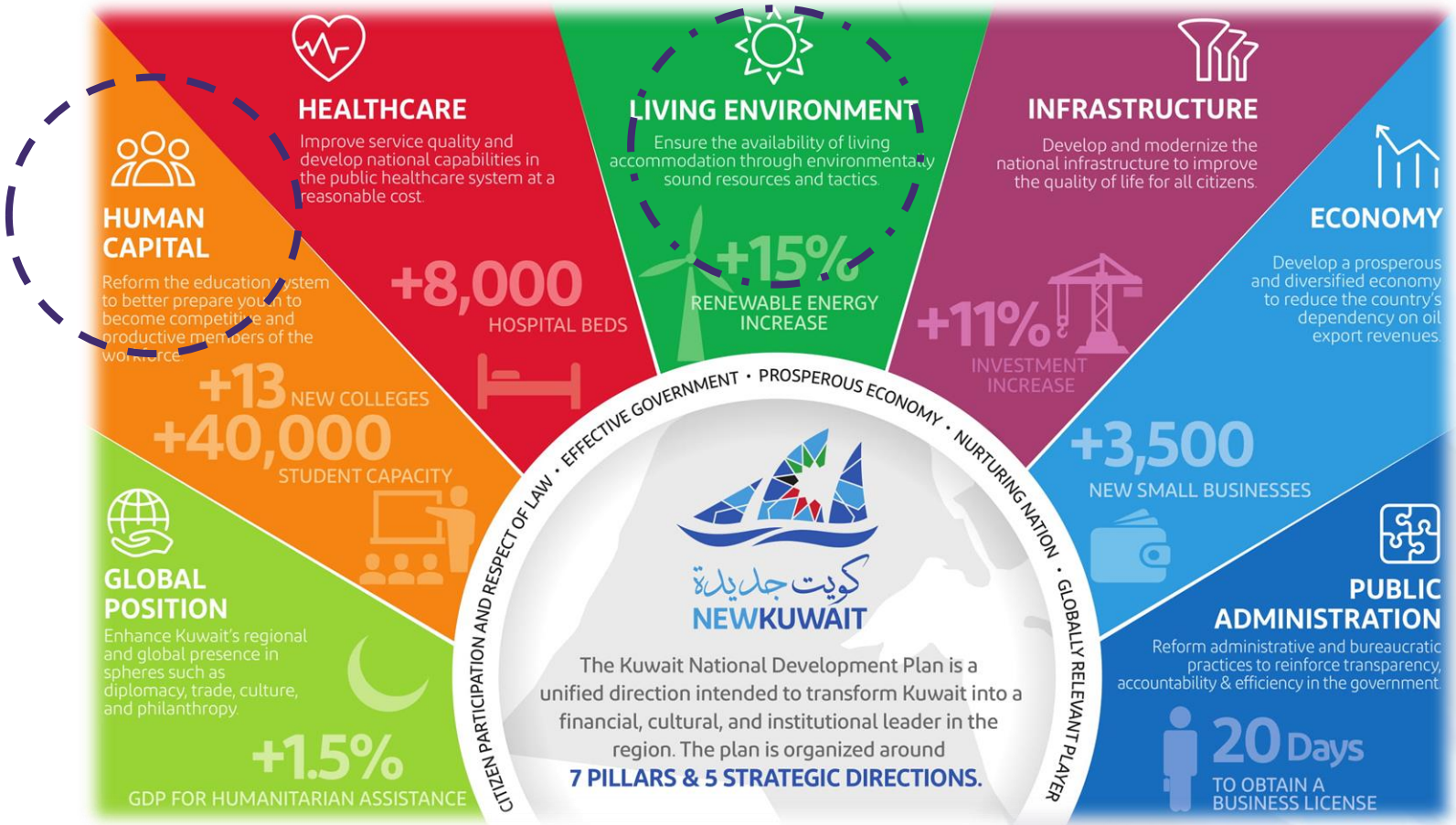
## Solid Waste

- Solid residue from households or industrial processes and scrap.
- Tyres, MSW, furniture, textiles and food residue.

Source: Al-Salem, 2019.




Associated environmental burdens of unsanitary landfilling and/or mismanaged plastics. Source: A-Salem et al. 2019.


HEALTHCARE
Improve service quality and develop national capabilities in the public healthcare system at a reasonable cost.
+8,000
HOSPITAL BEDS
LIVING ENVIRONMENT
Ensure the availability of living accommodation through environmentally sound resources and tactics.
+15%
RENEWABLE ENERGY INCREASE
INFRASTRUCTURE
Develop and modernize the national infrastructure to improve the quality of life for all citizens.
+11%
INVESTMENT INCREASE
ECONOMY
Develop a prosperous and diversified economy to reduce the country's dependency on oil export revenues.
+3,500
NEW SMALL BUSINESSES
PUBLIC ADMINISTRATION
Reform administrative and bureaucratic practices to reinforce transparency, accountability & efficiency in the government.
20 Days
TO OBTAIN A BUSINESS LICENSE
GLOBAL POSITION
Enhance Kuwait's regional and global presence in spheres such as diplomacy, trade, culture, and philanthropy.
+1.5%
GDP FOR HUMANITARIAN ASSISTANCE
HUMAN CAPITAL
Reform the education system to better prepare youth to become competitive and productive members of the workforce.
+13 NEW COLLEGES
+40,000
STUDENT CAPACITY
CITIZEN PARTICIPATION AND RESPECT OF LAW • EFFECTIVE GOVERNMENT • PROSPEROUS ECONOMY • NURTURING NATION • GLOBALLY RELEVANT PLAYER
كويت جديدة
NEWKUWAIT
The Kuwait National Development Plan is a unified direction intended to transform Kuwait into a financial, cultural, and institutional leader in the region. The plan is organized around
7 PILLARS & 5 STRATEGIC DIRECTIONS.

# موقع الدولة الجغرافي والاقتصادي

تتميز دولة الكويت بنمط حياة فريد من نوعه على مستوى العالم

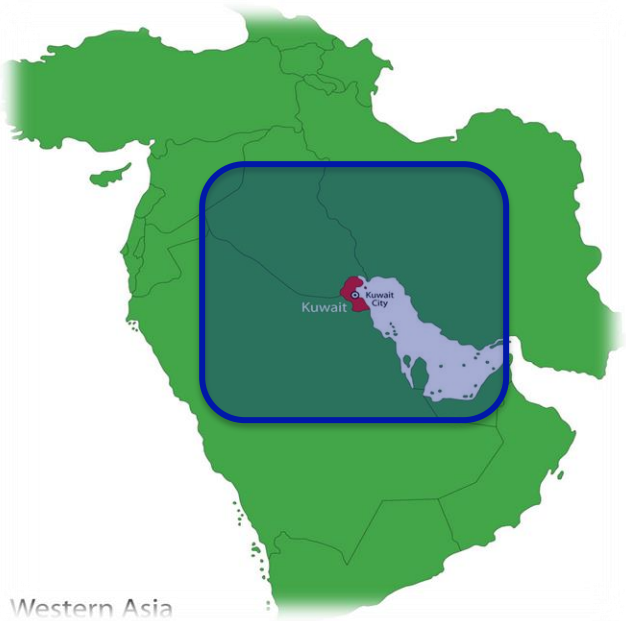
الناتج القومي 120 B US$ (2017)

عدد السكان 4.13 M Residents

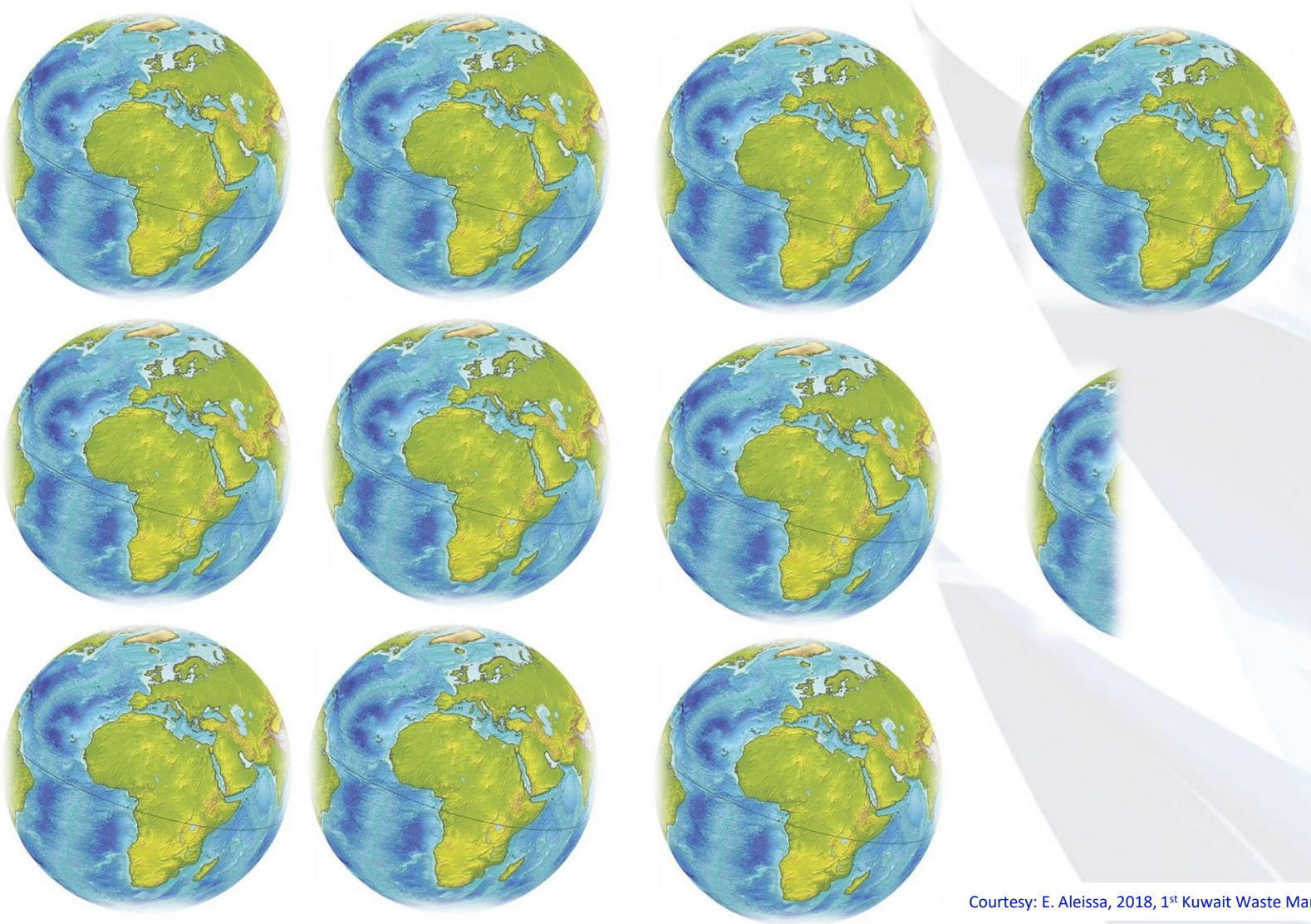
يرتبط إنتاج النفايات (عادة) بالناتج القومي للبلاد

تصنف الدولة حاليا النفايات الصلبة على أربع أصناف

النفايات العضوية تشكل قرابة ال 46% و النفايات البلاستيكية الصلبة قرابة ال 18%


# This is the price !!!

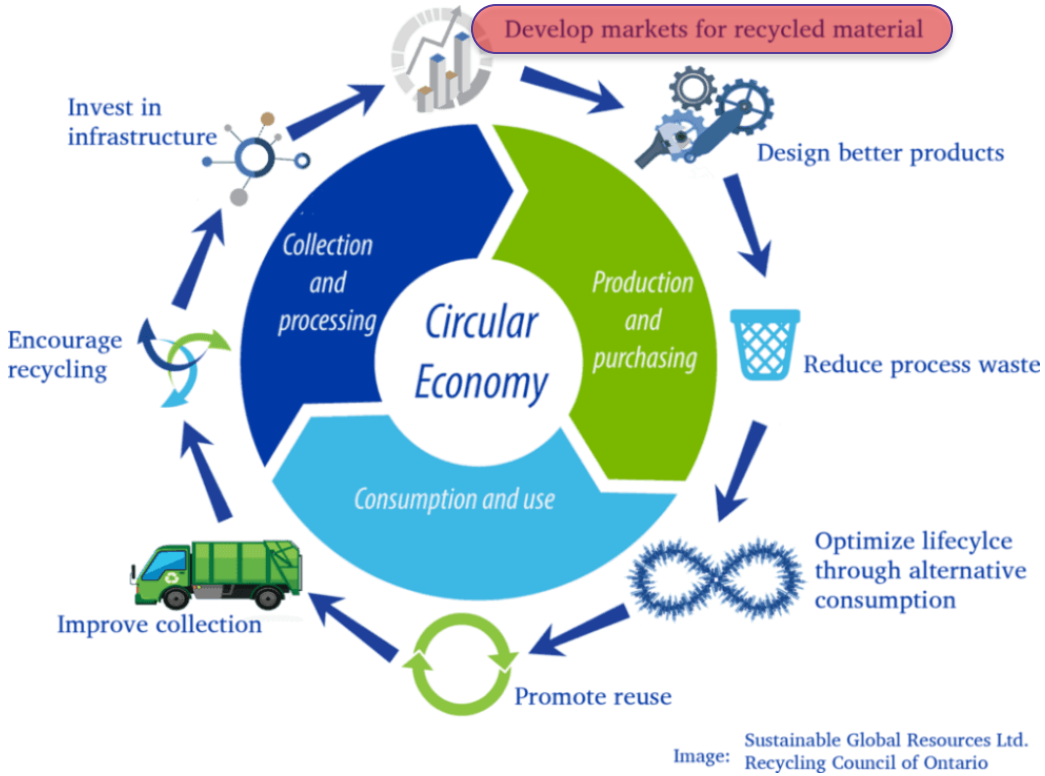


Courtesy: E. Aleissa, 2018, 1st Kuwait Waste Management Research Forum.


KISR
Kuwait Institute for Scientific Research


# الاقتصاد الدائري

KISR
Kuwait Institute for Scientific Research




## 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



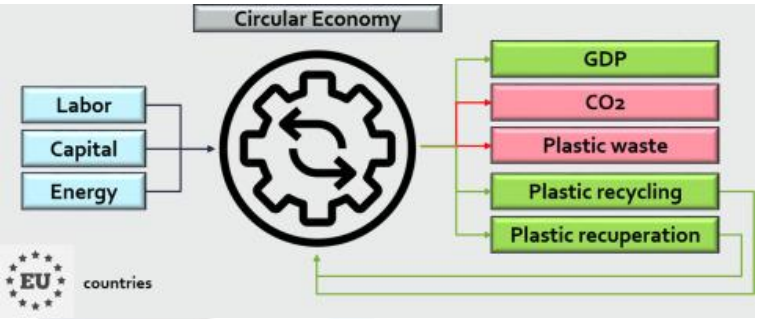
Image source: Icelog - Global product information management and syndication

# الاقتصاد الدائري: خطوات وأهداف تقاس

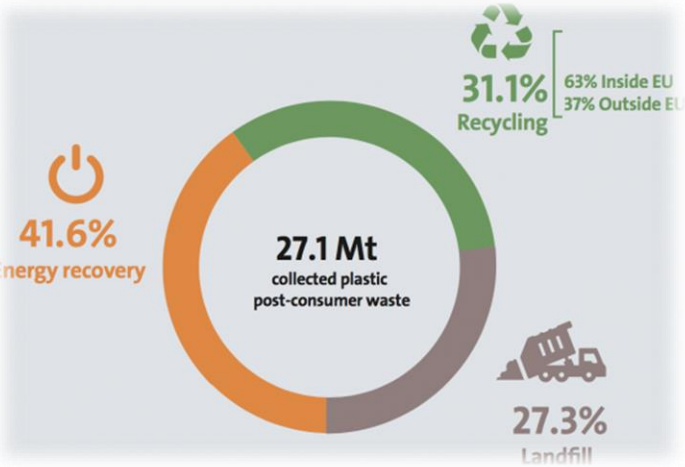
الاتحاد الأوروبي بدأ بالتطبيق منذ نهاية الثمانينات بطريقة أو بأخرى.

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

Robiana et al. 2020.



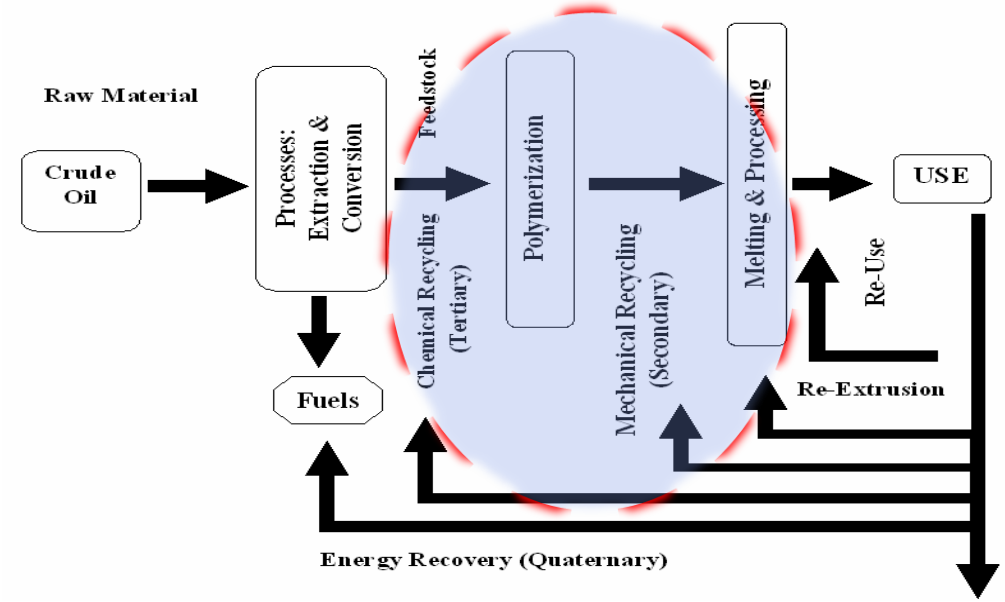





الاقتصاد الخطي: اقتصاد غير مستدام ينجم عنه تراكم للنفاية

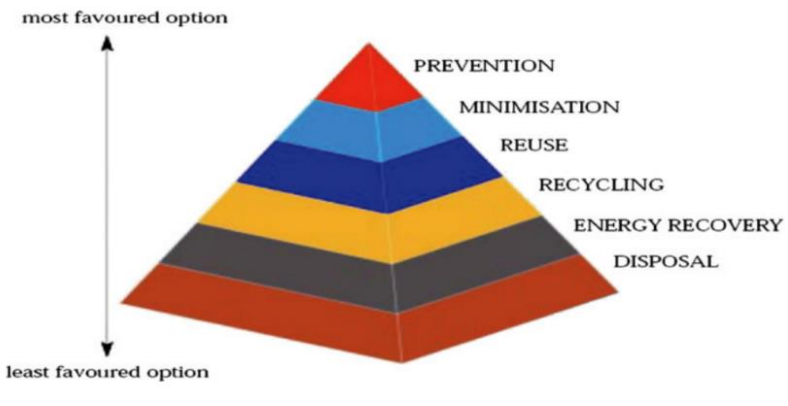
الاقتصاد الدائري: يحقق الاستدامة والعوائد الاقتصادية.

d'Ambrières 2019




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

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




Classic waste management hierarchy

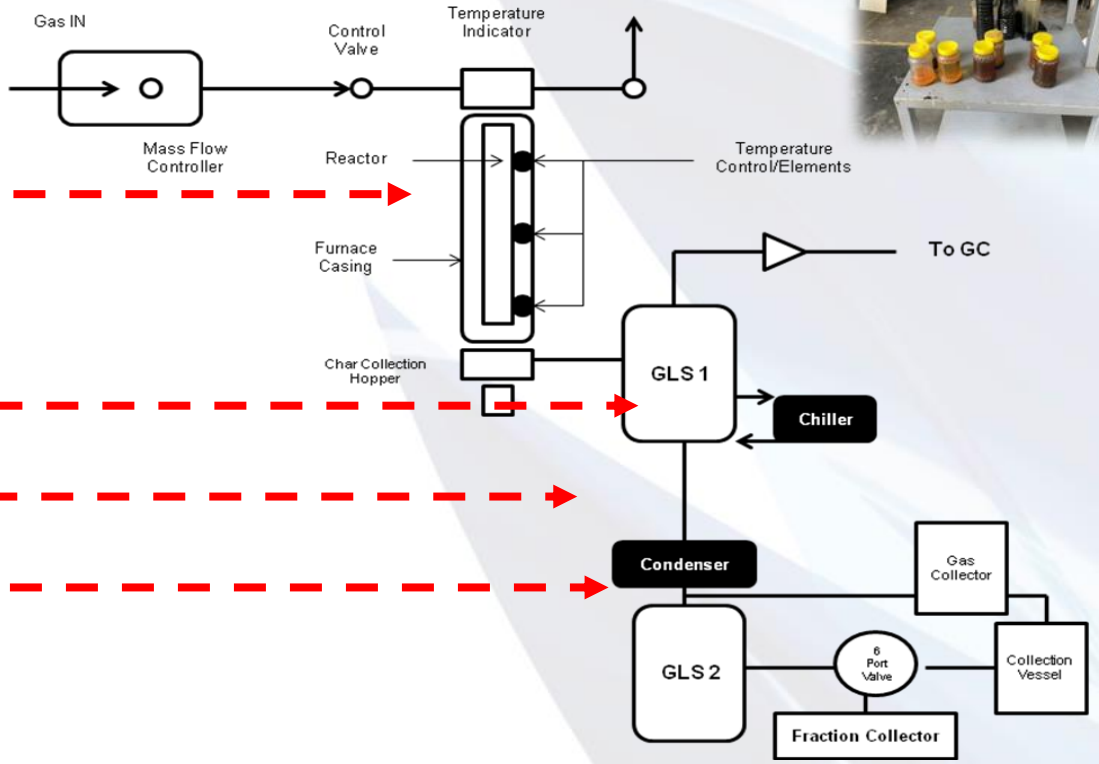
- There are no proper assessment studies in Kuwait.
- PSW is accumulating in landfills and is typically exported.
- PSW is estimated to be generated at an alarming rate of ~~150 ktpa (2001).~~

| 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.

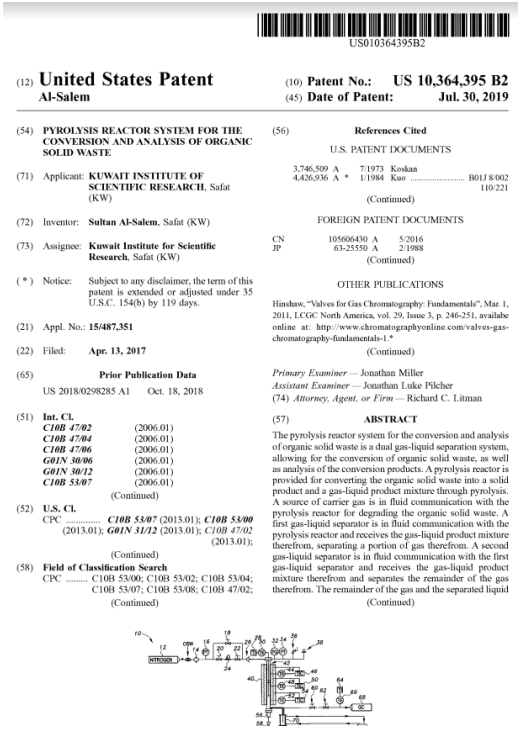
# تقنيات مطورة

# P-KISR-06-11: Establishing Waste Management Research Unit (WMRU)



**Project P-KISR-06-11**

**'Establishment of the Waste Management Research Unit (WMRU)'**



US010364395B2

(12) **United States Patent**
**Al-Salem**

(10) **Patent No.: US 10,364,395 B2**
(45) **Date of Patent: Jul. 30, 2019**

(54) **PYROLYSIS REACTOR SYSTEM FOR THE CONVERSION AND ANALYSIS OF ORGANIC SOLID WASTE**

(71) Applicant: **KUWAIT INSTITUTE OF SCIENTIFIC RESEARCH**, Safat (KW)

(72) Inventor: **Sultan Al-Salem**, Safat (KW)

(73) Assignee: **Kuwait Institute for Scientific Research**, Safat (KW)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 119 days.

(21) Appl. No.: **15/487,351**

(22) Filed: **Apr. 13, 2017**

(65) **Prior Publication Data**

US 2018/0298285 A1 Oct. 18, 2018

(51) **Int. Cl.**

| | |
|---|---|
| ***C10B 47/02*** | (2006.01) |
| ***C10B 47/04*** | (2006.01) |
| ***C10B 47/06*** | (2006.01) |
| ***G01N 30/06*** | (2006.01) |
| ***G01N 30/12*** | (2006.01) |
| ***C10B 53/07*** | (2006.01) |

(Continued)

(52) **U.S. Cl.**
CPC ..... ***C10B 53/07*** (2013.01); ***C10B 53/00*** (2013.01); ***G01N 31/12*** (2013.01); *C10B 47/02* (2013.01);

(Continued)

(58) **Field of Classification Search**
CPC ..... C10B 53/00; C10B 53/02; C10B 53/04; C10B 53/07; C10B 53/08; C10B 47/02;

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,746,509 A 7/1973 Koskan
4,426,936 A * 1/1984 Kuo ..... B01J 8/002 110/221

(Continued)

FOREIGN PATENT DOCUMENTS

CN 105606430 A 5/2016
JP 63-25550 A 2/1988

(Continued)

OTHER PUBLICATIONS

Hinshaw, "Valves for Gas Chromatography: Fundamentals", Mar. 1, 2011, LCGC North America, vol. 29, Issue 3, p. 246-251, availabe online at: http://www.chromatographyonline.com/valves-gas-chromatography-fundamentals-1.*

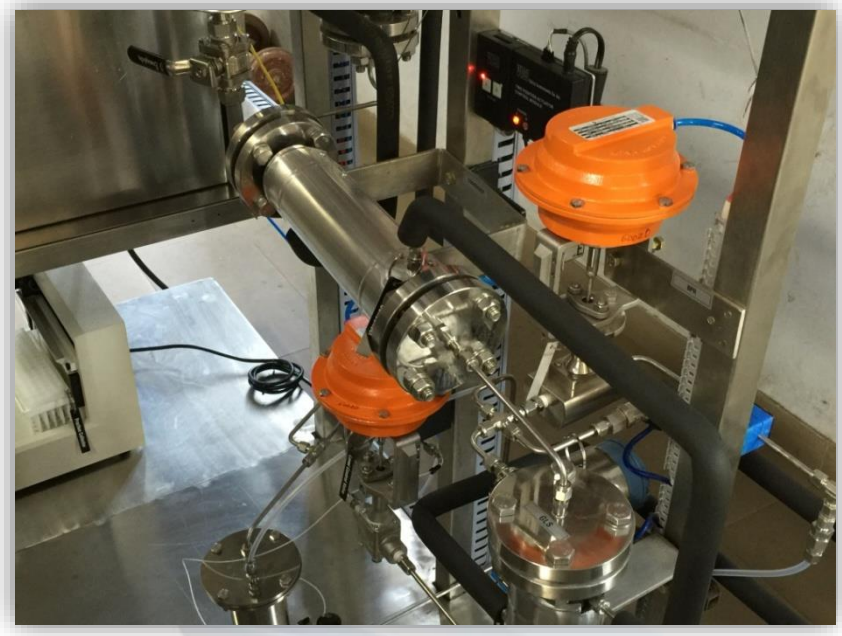
(Continued)

*Primary Examiner* — Jonathan Miller
*Assistant Examiner* — Jonathan Luke Pilcher
(74) *Attorney, Agent, or Firm* — Richard C. Litman

(57) **ABSTRACT**

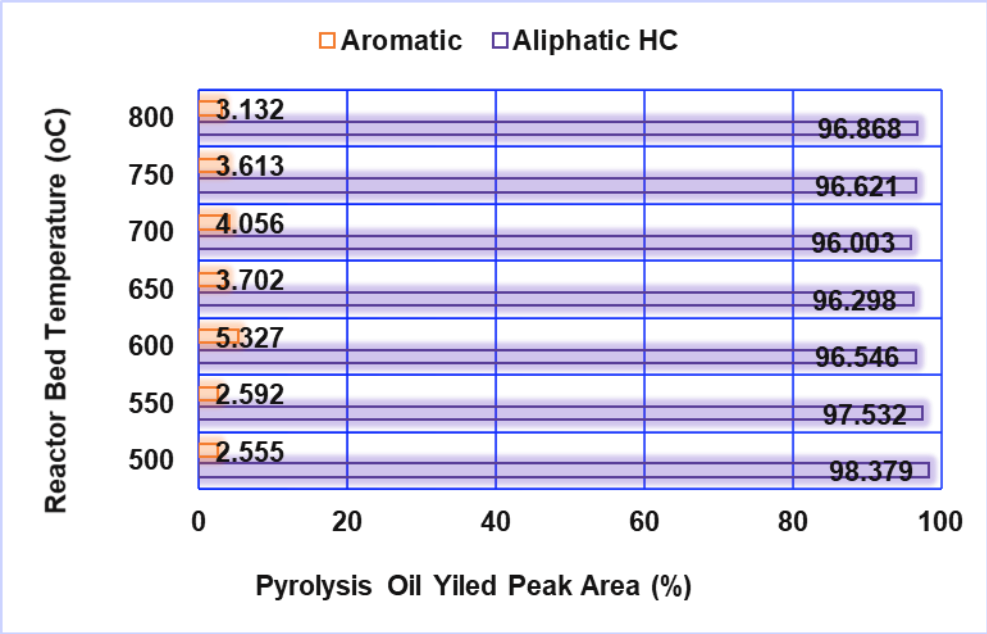
The pyrolysis reactor system for the conversion and analysis of organic solid waste is a dual gas-liquid separation system, allowing for the conversion of organic solid waste, as well as analysis of the conversion products. A pyrolysis reactor is provided for converting the organic solid waste into a solid product and a gas-liquid product mixture through pyrolysis. A source of carrier gas is in fluid communication with the pyrolysis reactor for degrading the organic solid waste. A first gas-liquid separator is in fluid communication with the pyrolysis reactor and receives the gas-liquid product mixture therefrom, separating a portion of gas therefrom. A second gas-liquid separator is in fluid communication with the first gas-liquid separator and receives the gas-liquid product mixture therefrom and separates the remainder of the gas therefrom. The remainder of the gas and the separated liquid

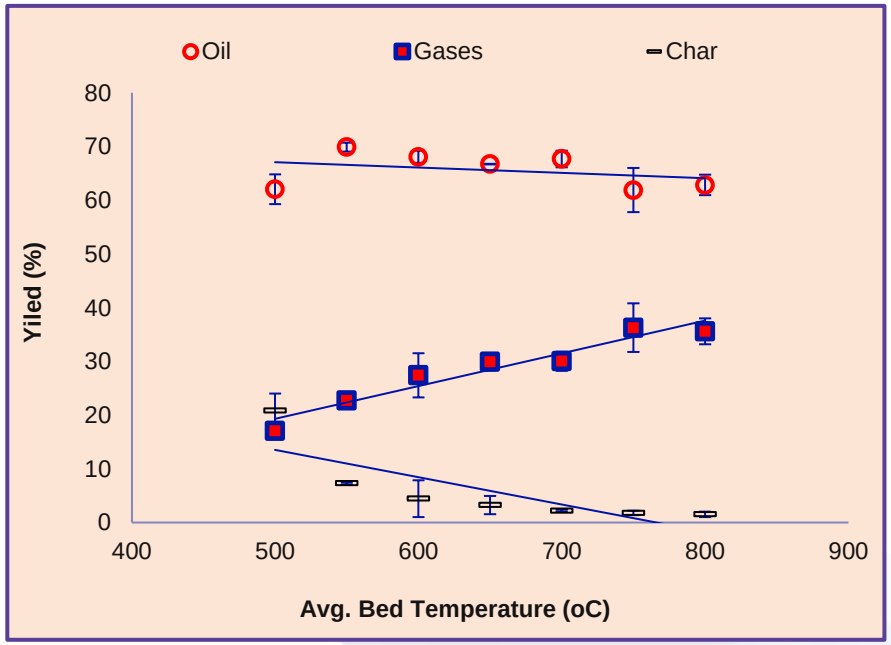
(Continued)



# Obtaining What ?!

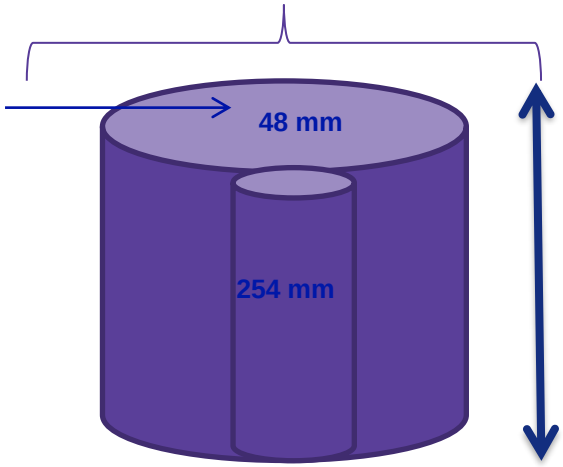
# Results: Mass Balance & Product Yield




**Product evolution with respect to reactor mean bed temperature**

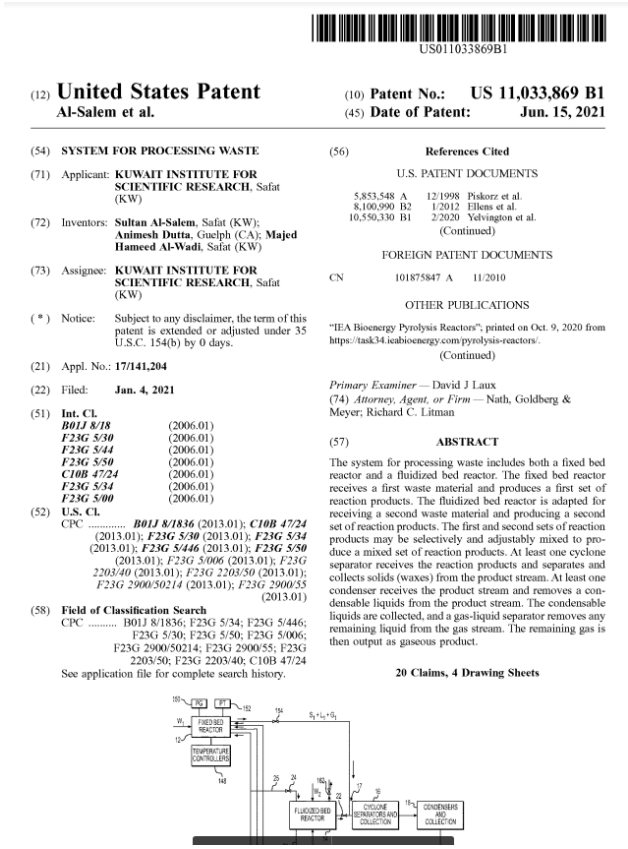
$$Q = \frac{\Delta T}{\sum R_i} = \frac{T_E - T_B}{\frac{\ln\left(r_2 / r_1\right)}{2\pi k} + \frac{1}{h_i}}$$




# P-KISR-06-11: Establishing Waste Management Research Unit (WMRU)

KISR
Kuwait Institute for Scientific Research

- This pilot plant has higher heat and mass transfer and could provide optimum conditions for pyrolysis of used plastic.
- The transport properties were improved by encroaching the respective boundary layers by the presence of particulate matter.



US011033869B1

(12) **United States Patent**
**Al-Salem et al.**

(10) **Patent No.: US 11,033,869 B1**
(45) **Date of Patent: Jun. 15, 2021**

(54) **SYSTEM FOR PROCESSING WASTE**

(71) Applicant: **KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH**, Safat (KW)

(72) Inventors: **Sultan Al-Salem**, Safat (KW); **Animesh Dutta**, Guelph (CA); **Majed Hameed Al-Wadi**, Safat (KW)

(73) Assignee: **KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH**, Safat (KW)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/141,204**

(22) Filed: **Jan. 4, 2021**

(51) **Int. Cl.**

| | |
|---|---|
| ***B01J 8/18*** | (2006.01) |
| ***F23G 5/30*** | (2006.01) |
| ***F23G 5/44*** | (2006.01) |
| ***F23G 5/50*** | (2006.01) |
| ***C10B 47/24*** | (2006.01) |
| ***F23G 5/34*** | (2006.01) |
| ***F23G 5/00*** | (2006.01) |

(52) **U.S. Cl.**
CPC ..... ***B01J 8/1836*** (2013.01); ***C10B 47/24*** (2013.01); ***F23G 5/30*** (2013.01); ***F23G 5/34*** (2013.01); ***F23G 5/446*** (2013.01); ***F23G 5/50*** (2013.01); *F23G 5/006* (2013.01); *F23G 2203/40* (2013.01); *F23G 2203/50* (2013.01); *F23G 2900/50214* (2013.01); *F23G 2900/55* (2013.01)

(58) **Field of Classification Search**
CPC ..... B01J 8/1836; F23G 5/34; F23G 5/446; F23G 5/30; F23G 5/50; F23G 5/006; F23G 2900/50214; F23G 2900/55; F23G 2203/50; F23G 2203/40; C10B 47/24
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 5,853,548 | A | 12/1998 | Piskorz et al. |
| 8,100,990 | B2 | 1/2012 | Ellens et al. |
| 10,550,330 | B1 | 2/2020 | Yelvington et al. |

(Continued)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| CN | 101875847 | A | 11/2010 |

OTHER PUBLICATIONS

"IEA Bioenergy Pyrolysis Reactors"; printed on Oct. 9, 2020 from https://task34.ieabioenergy.com/pyrolysis-reactors/.

(Continued)

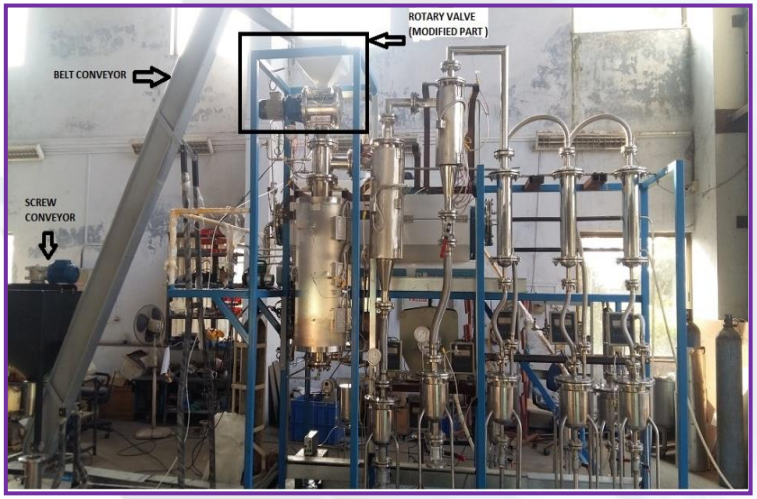
*Primary Examiner* — David J Laux
(74) *Attorney, Agent, or Firm* — Nath, Goldberg & Meyer; Richard C. Litman

(57) **ABSTRACT**

The system for processing waste includes both a fixed bed reactor and a fluidized bed reactor. The fixed bed reactor receives a first waste material and produces a first set of reaction products. The fluidized bed reactor is adapted for receiving a second waste material and producing a second set of reaction products. The first and second sets of reaction products may be selectively and adjustably mixed to produce a mixed set of reaction products. At least one cyclone separator receives the reaction products and separates and collects solids (waxes) from the product stream. At least one condenser receives the product stream and removes a condensable liquids from the product stream. The condensable liquids are collected, and a gas-liquid separator removes any remaining liquid from the gas stream. The remaining gas is then output as gaseous product.

**20 Claims, 4 Drawing Sheets**



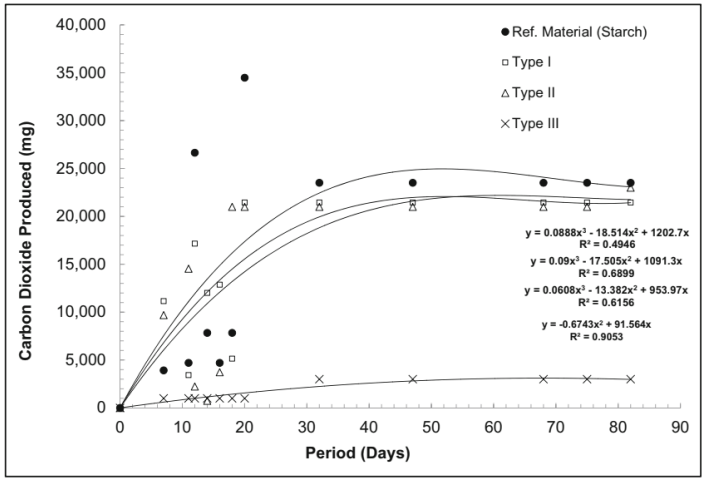


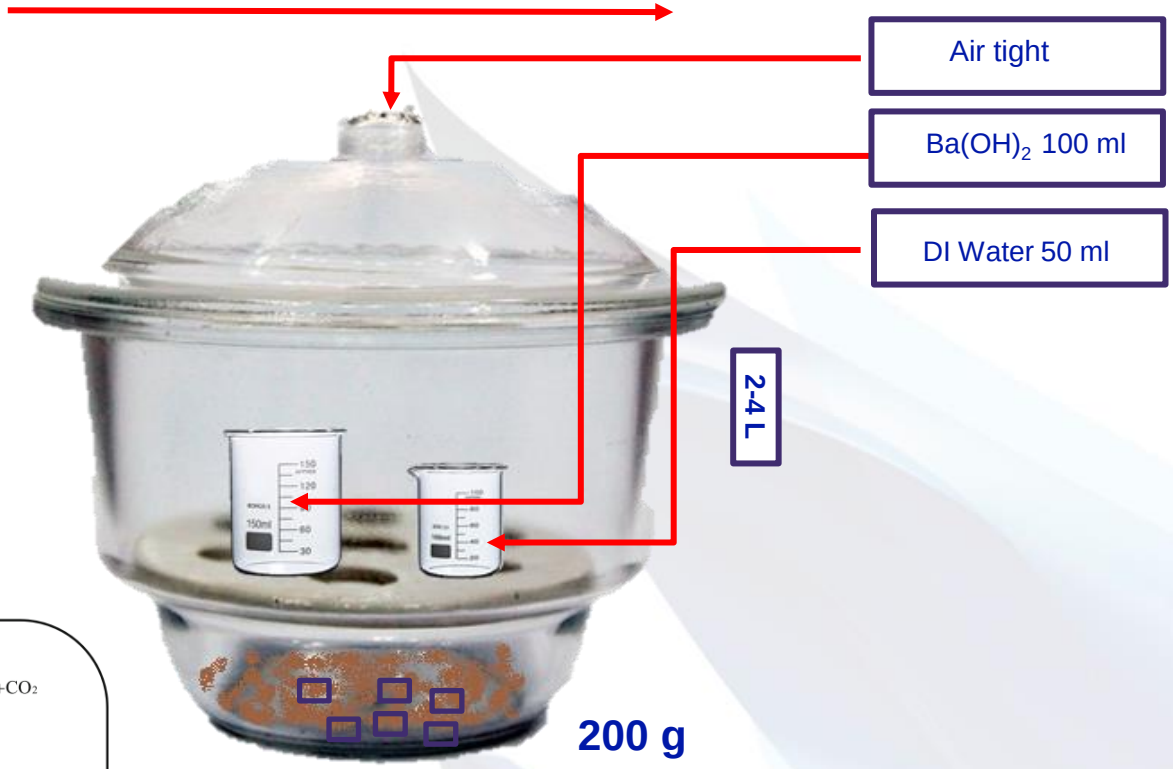
# EM097C: Investigating Biodegradable Bags Standards and Properties Under Kuwait's Environmental Conditions

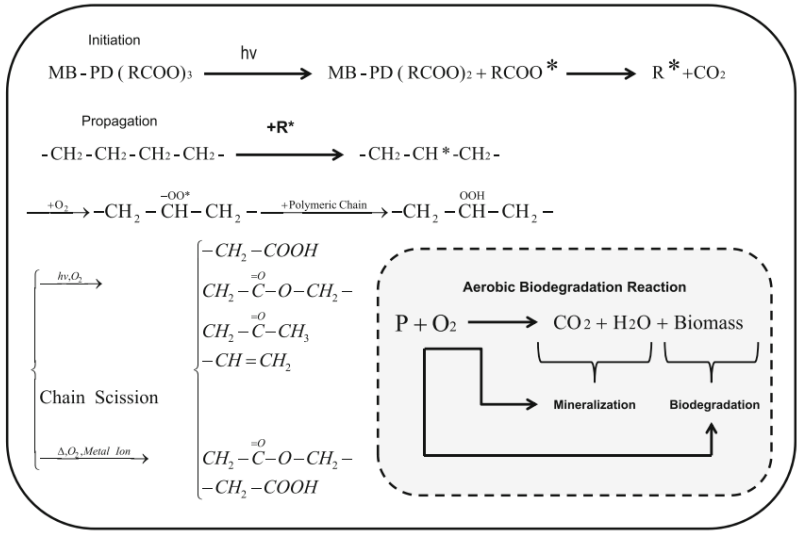
# EM065K: Development of biodegradable polyolefin based bags standards for the state of Kuwait

بلدية الكويت
Kuwait Municipality

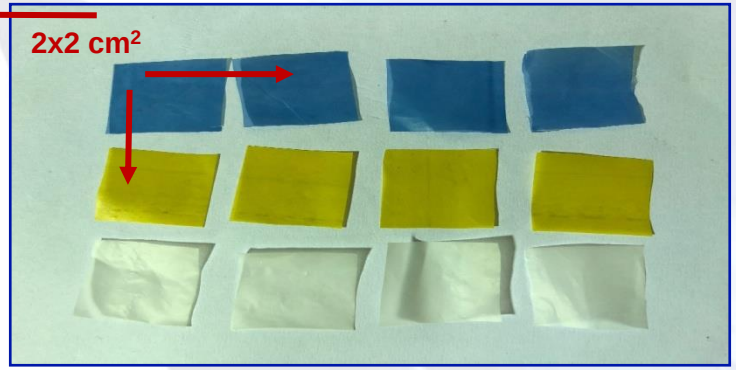
KISR
Kuwait Institute for Scientific Research




Schematic degressive abiotic reaction of polymeric material (P) combined with metal based prodegradant (MB-PD) under heat (Δ), light (hv) or oxygen (O2). Adapted from Koutny et al. (2006). Note to reader: R; Radical, PD; Prodegradant



Journal of Polymer Research (2019) 26:157
https://doi.org/10.1007/s10965-019-1822-5

SHORT COMMUNICATION

Check for updates

## Determination of biodegradation rate of commercial oxo-biodegradable polyethylene film products using ASTM D 5988

S. M. Al-Salem[1] · H. H. Sultan[1] · H. J. Karam[1] · A. T. Al-Dhafeeri[2]

Received: 16 March 2019 / Accepted: 27 May 2019


Journal of Environmental Management 250 (2019) 109475

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

## Insights into the evaluation of the *abiotic* and *biotic* degradation rate of commercial pro-oxidant filled polyethylene (PE) thin films

S.M. Al-Salem[a,*], A. Al-Hazza'a[b], H.J. Karam[a], M.H. Al-Wadi[a], A.T. Al-Dhafeeri[c], A.A. Al-Rowaih[a]

[a] Environment & Life Sciences Research Centre, Kuwait Institute for Scientific Research, P.O. Box: 24885, Safat, 13109, Kuwait
[b] Energy & Building Research Centre, Kuwait Institute for Scientific Research, P.O. Box: 24885, Safat, 13109, Kuwait
[c] Water Research Centre, Kuwait Institute for Scie Research, P.O. Box: 24885, Safat, 13109, Kuwait

Journal of Polymers and the Environment
https://doi.org/10.1007/s10924-020-01776-x

ORIGINAL PAPER

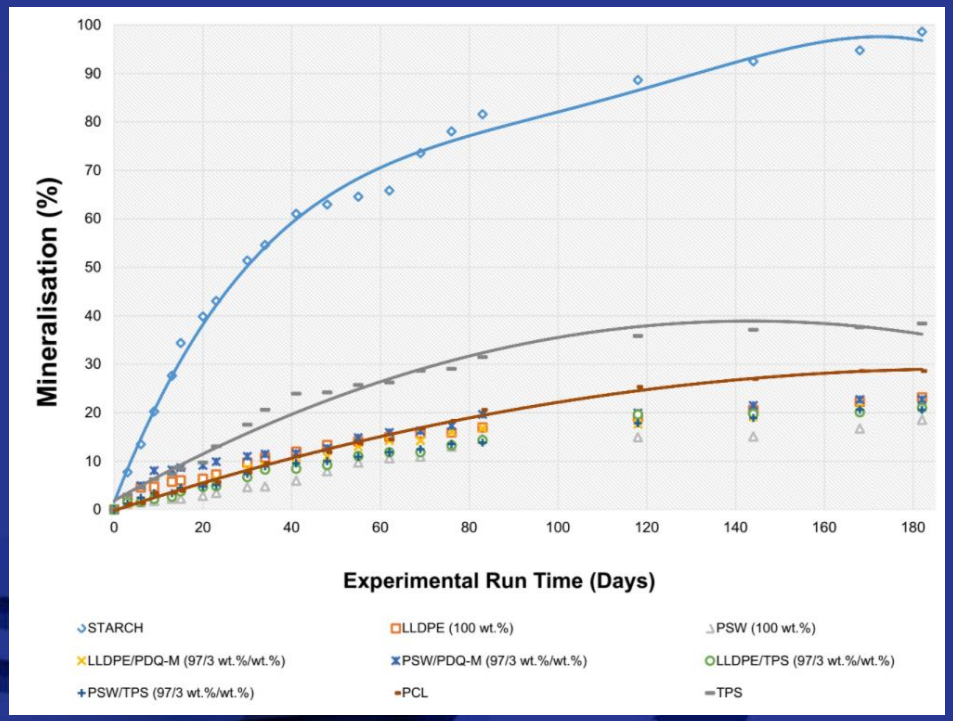
Check for updates

## Identification of Commercial Oxo-Biodegradable Plastics: Study of UV Induced Degradation in an Effort to Combat Plastic Waste Accumulation

Ana Antelava[1] · Achilleas Constantinou[1,2,3] · Ali Bumajdad[4] · George Manos[2] · Raf Dewil[5] · S. M. Al-Salem[6]



KISR
Kuwait Institute for Scientific Research




**Biodegradation Extent (%) as a Function of Test Time (Days) for Virgin and Waste Plastics Studied in This Work Showing the Positive Control Material (Starch), PCL and TPS for Comparative Assessment**

Review Article

WM&R

Waste Management & Research
1–4
© The Author(s) 2020
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/0734242X20978444
journals.sagepub.com/home/wmr
SAGE

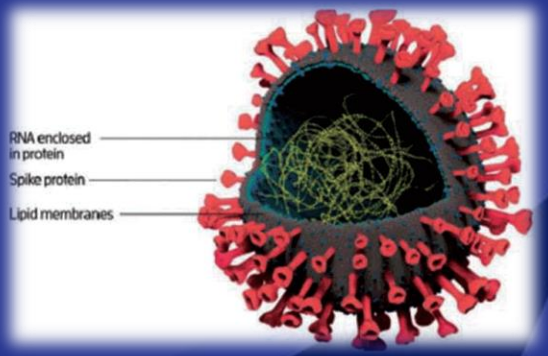
## Can plastic waste management be a novel solution in combating the novel Coronavirus (COVID-19)? A short research note

Sultan Majed Al-Salem[1], Mohammed Sherif El-Eskandarani[1] and Achilleas Constantinou[2,3,4]

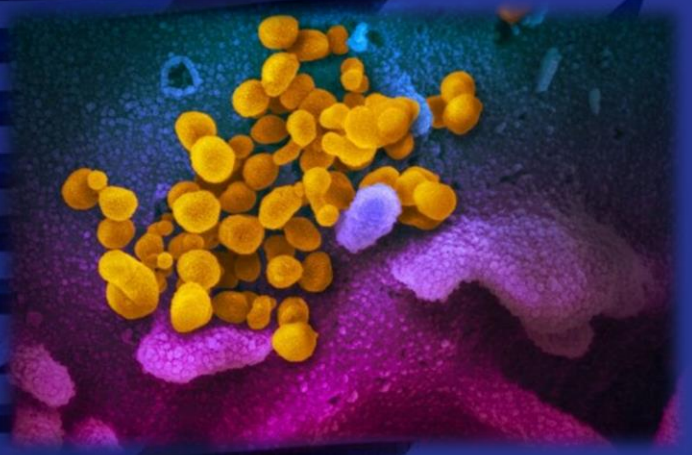
KISR
Kuwait Institute for Scientific Research

The use of thermoplastics as substrates for antiviral (and even antimicrobial) surfaces follows suit to past works on the development of antimicrobial binding agents.

Preferred antiviral or antimicrobial agents incorporated where 2,4,4'- trichloro-2'-hydroxy-diphenyl ether, 3-(4-chlorophenyl)-1- (3,4-dichlorophenyl) urea, silver ions, and salts and mixtures thereof. The recent COVID-19 outbreak has also revived work on Chloroquine as a new antiviral agent originating from quinine compound which is naturally abundant in Cinchona trees.



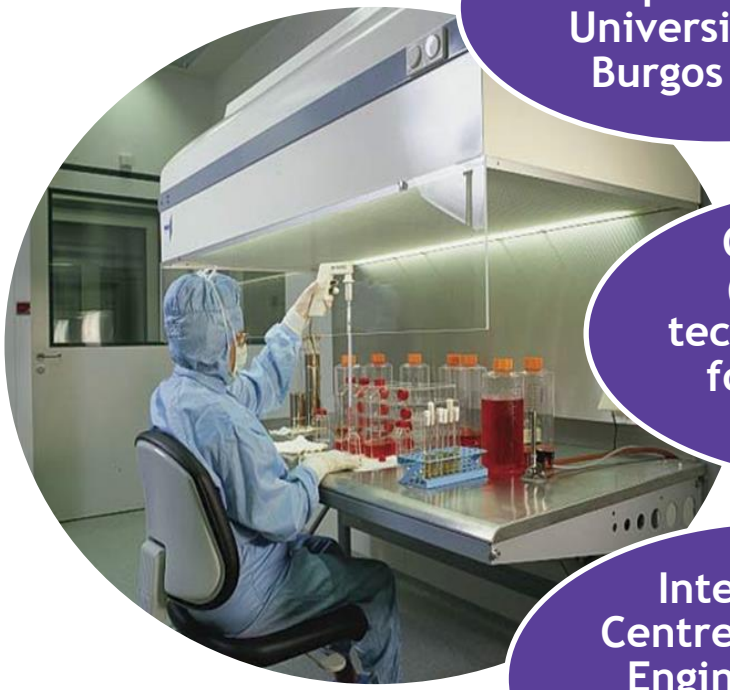

COVID-19 could be destroyed by ethanol (62-71 percent), hydrogen peroxide (0.5 percent) or sodium hypochlorite (0.1 percent) that break the delicate envelope that surrounds the tiny microbe. OUM Editorial 2020.



Nano-coat technology. Source: Global insights 2020.

# *In vitro* Growth of Coronavirus

KISR
Kuwait Institute for Scientific Research

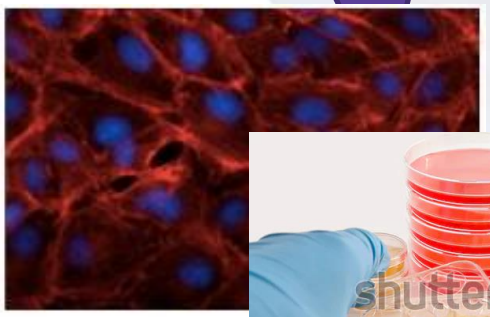


Microbiology Department, Universidad de Burgos - Ubu

Campden BRI (Science and technology for the food and drink industry)

International Centre for Genetic Engineering and Biotechnology, Trieste Italy

Vero cells derived from the kidney of an African green monkey, the most extensively used cell lines for virology studies




**Class III Biosafety Lab**

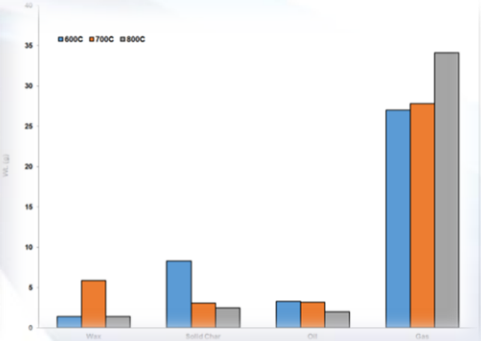
KISR
Kuwait Institute for Scientific Research

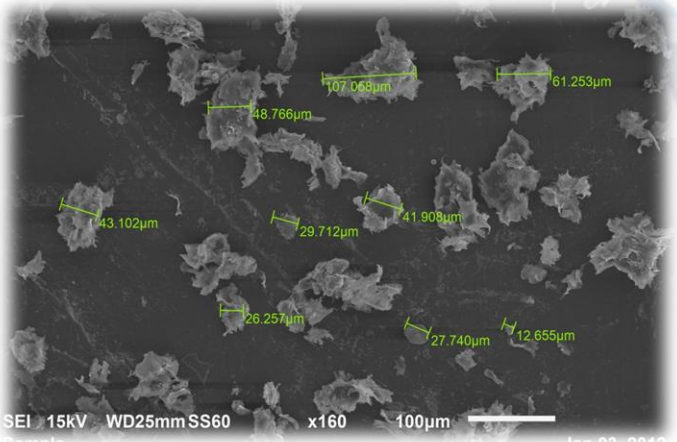
Aston University
Birmingham

UNIVERSITY OF BIRMINGHAM

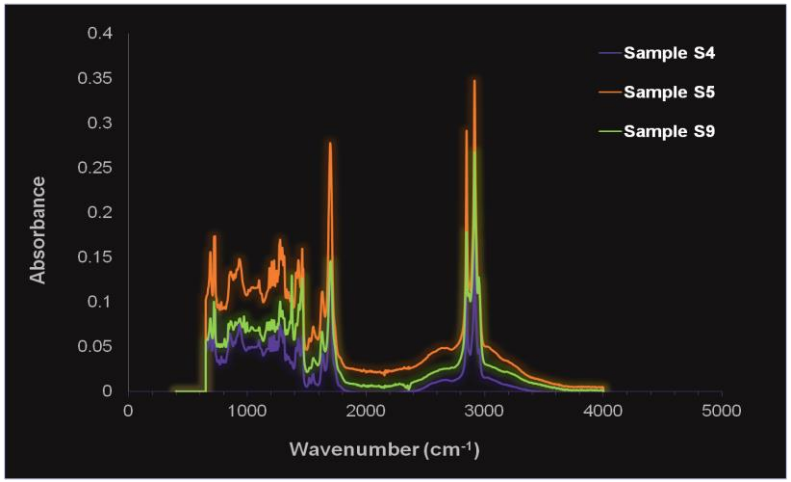

KISR
Kuwait Institute for Scientific Research

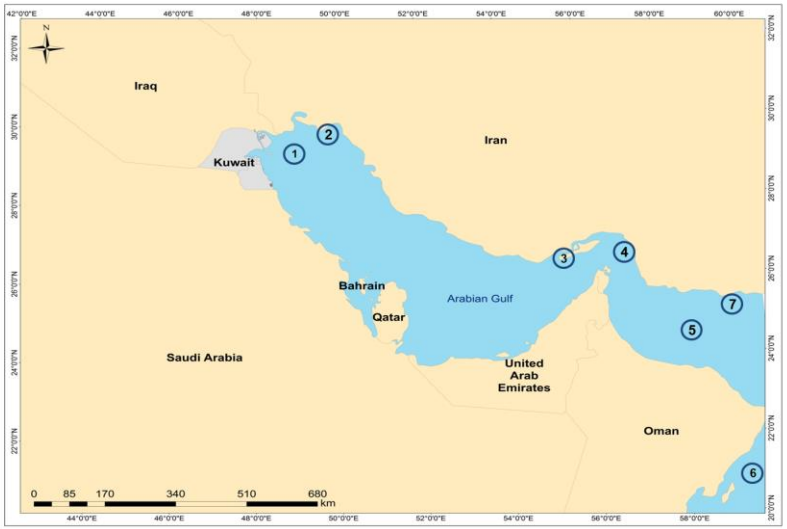
# EM103C: Solar Powered Fast Pyrolysis For Producing Bio-Oils From Municipal Solid Waste In The State Of Kuwait

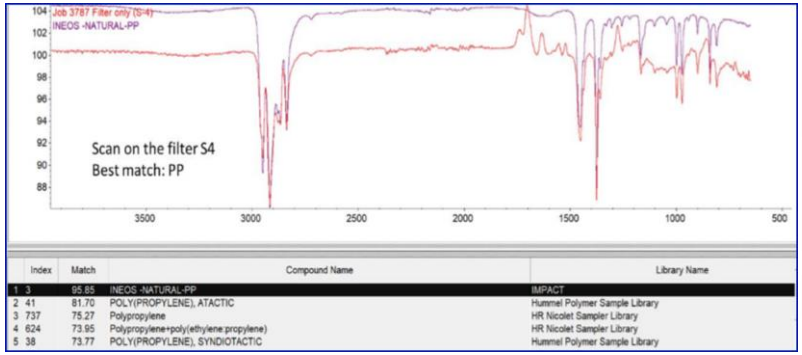


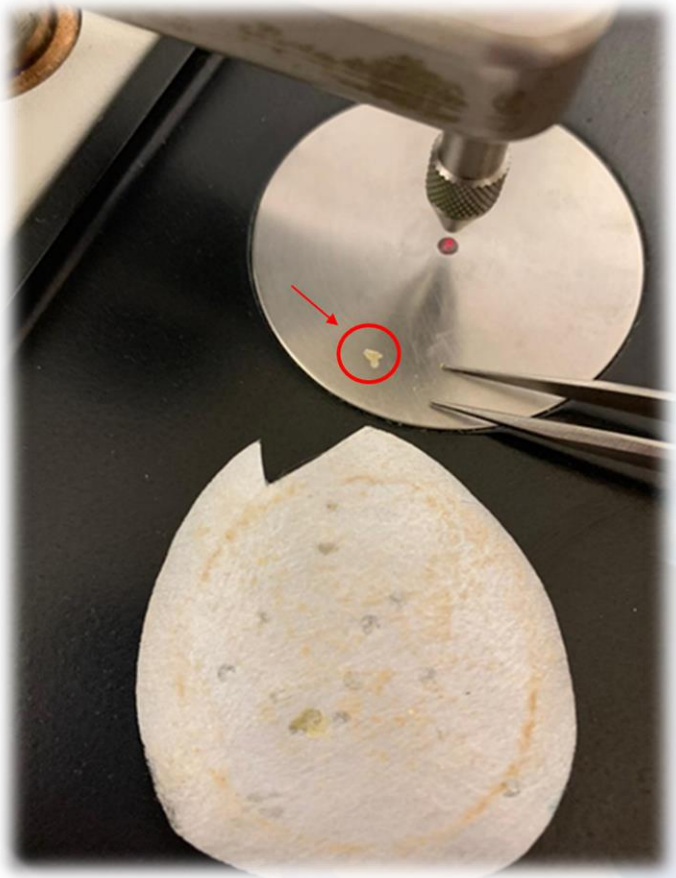



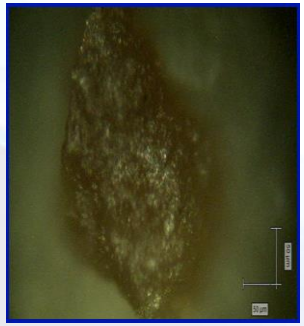

KISR
Kuwait Institute for Scientific Research





| Fish Species | Microplastic size (mm) |
|---|---|
| Acanthopagrus latus/Sparidae | 1.57 |
| Eleutheronemaa tetradactylum/Polynemidae | 0.96 |
| Lutjanus quinquelineatus | 0.96 |

# اقتصاديات الحجم لدولة الكويت

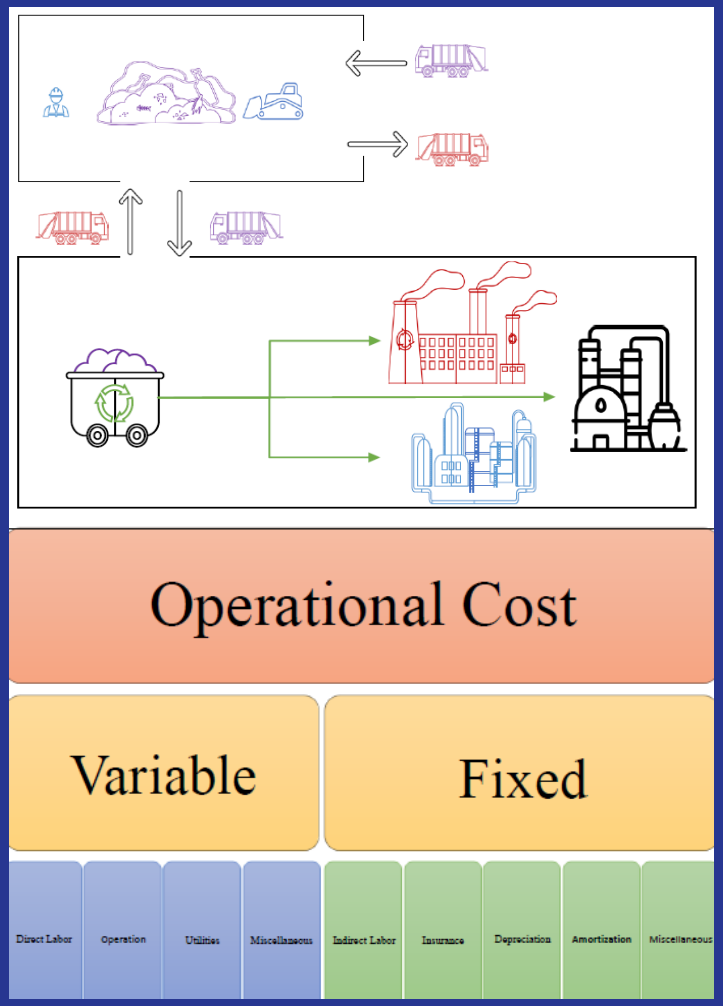
KISR
Kuwait Institute for Scientific Research

The third scenario applies the MRF, IU, and pyrolysis technology through applying low temperature pyrolysis (LTP) in processing HW.

The LTP station **capital cost is estimated to be around 13 Million KD** with 25 TPA of production capacity. Additionally, the **total capital cost for this scenario will be around 177 Million KD** around 10 Million KD over the second scenario.

Likewise, this **scenario generates revenues around 50 Million KD with NCF around 17 Million in the first year which increases to reach around 42 Million KD in the 20th year.**

**The economic indicators of this scenario are very promising with an IRR at 9%, NPV at around 85 Million (higher than the second scenario) and PBP at 10 Years.**



KISR
Kuwait Institute for Scientific Research

UNIVERSITY of GUELPH

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

KFAS
مؤسسة الكويت للتقدم العلمي
Kuwait Foundation for the Advancement of Sciences

KISR
Kuwait Institute for Scientific Research

# DON’T WASTE, WASTE


감사합니다 Natick

Grazie Danke Ευχαριστίες Dalu Obrigado

Thank You Köszönöm

Tack

Спасибо Dank Gracias

谢谢 Merci Seé ありがとう

شكراً