BRIEFING NOTE

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TECHNO-ECONOMIC FEASIBILITY ASSESSMENT ON THE VIABILITY OF USING WASTE PET (TRAYS AND COLOURED BOTTLES) TO PRODUCE METAL-ORGANIC FRAMEWORK (MOFS)

Jianwei Ren*, Xoliswa Dyosiba, Nicholas Musyoka, and Stanley Semelane
CSIR-Energy Centre, Pretoria

KEY FINDINGS

This project focused on the recovery of new, high-value products from coloured PET bottles and food trays, as they have been identified as a problematic fraction from the current waste PET recycling industry in South Africa. A process model was developed to cover the mass balance, which considered material flows, chemical build-up and energy requirements. The balance was based on a 1 kg/batch, and the scalability was proved at the later stage. The process would produce saleable metal-organic framework (MOF) products for the South African market. The analysis of economic appraisal and commercial viability showed that investing in MOFs will generate roughly a 5% Internal Rate of Return (IRR) on a production capacity of 10kg daily. Given the fact that these results are positive at a small-scale, it is recommended that this investment should proceed. The environmental and opportunity cost that is avoided has not been considered in the financial analysis. This can further strengthen the revenue side of this production. While a return of 5% is not the most attractive, the PET waste that would be redirected to this production contributes to the South African waste management strategy and climate change objectives. In addition, since the South African government bond of 10 years yields a return of 8.52% return, this initiative is competitive with a 5% IRR.

INTRODUCTION

Polyethylene terephthalate (PET), as a dominant packaging material, has impacted our lives since the 1960s with the global consumption reaching over 24 million tons per year. The disposal of waste PET has led to serious environmental problems. Chemical recovery faces huge challenges as a result of the complexity associated with the recycling methods coupled with low efficiency. The current low-value market of the downstream products from recycled PET and the low prices of virgin PET are major factors responsible for the low recycling rate of waste PET in South Africa. The PET recycling industry requires new processes and end-markets to gain more value out of PET waste. Governments internationally are also considering penalties on non-recycled plastics, for instance, France has created a new penalty system where items packaged in non-recycled plastic could cost up to 10% more, and taxes on waste to landfill will also be increased.

An attractive and high-value recycling option of depolymerising PET bottles to obtain terephthalic acid (BDC) which is then used as a linker for producing high value metal-organic frameworks (MOFs) has been demonstrated (Fig. 1). MOFs as a new generation of porous materials have been demonstrated in many industrial applications and their performance are much better than those incorporated with conventional materials such as zeolites and activated carbons.

The initial focus of this research was on the use of clear PET bottles and the work was conducted on a small-batch scale level. However, this was extended to include coloured PET bottles and food trays as these are recognized as problematic fractions in the PET recycling industry. In this project, the techno-economic feasibility assessment on the viability of coloured PET bottles and food PET to produce MOFs was conducted.

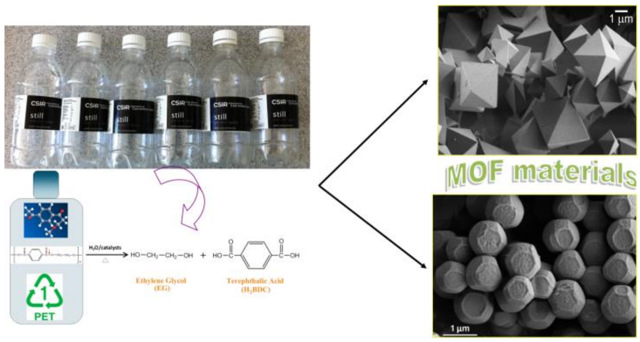

Figure 1: Convert waste PET into high value-added MOFs materials

RESULTS

Conversion of coloured bottles and trays to BDC

The X-ray diffraction (XRD) results show that the crystallinity of PETCO-sourced PET beads-derived BDC is very close to that of commercial Sigma-Aldrich BDC sample with a purity of 98%. As indicated by the XRD patterns, the crystallinity of the brown PET bottles derived-BDC sample is similar to that of the PET food trays-derived BDC sample, and the containing acid numbers are also nearly the same. In contrast, the crystallinity of the green PET bottles-derived BDC is the lowest with an acid number of only 192 mg NaOH/g. It can be seen that the purities of the different BDC samples are slightly different.

Technical feasibility of converting waste PET-derived BDC to MOF UiO-66(Zr)

Several characteristic reflection signals in Fig. 2a confirmed the successful synthesis of MOF UiO-66(Zr) from different waste PET-derived BDC when compared to the simulated XRD pattern. The relative crystallinities of the obtained MOF UiO-66(Zr) samples are comparable to that from commercial BDC feedstock from Sigma-Aldrich. However, the Zr-MOF sample synthesized from green PET bottles-derived BDC shows the lowest relative crystallinity.

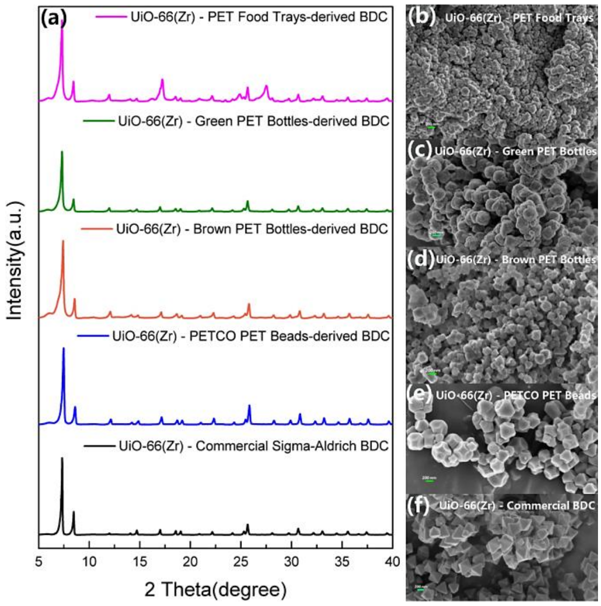

Figure 2: (a) XRD patterns, and (b-f) SEM images of the Zr-MOF samples prepared from different BDC sources

The N_2 and H_2 sorption isotherms indicate that all the PET-derived MOF UiO-66(Zr) materials have relatively lower N_2 and H_2 adsorption levels, but the obtained values are comparable to that from the commercial feedstock as well as other previously developed MOF UiO-66(Zr) materials. As MOF UiO-66(Zr) samples were also synthesized from the coloured PET bottles-derived BDC, where the effects of additives and colourants should be taken account on the textural properties of the prepared MOF UiO-66(Zr). The experimental results suggested that the MOF UiO-66(Zr) samples from the clear PET food trays-derived BDC have the lower textural properties than those from the clear PET beads-derived BDC. The reason could be the effects of additives and colourants from the green and brown coloured bottles.

MOFs financial modelling results

Production costs have been evaluated by adding up fixed costs, (depreciation rates), operating and maintenance (O&M), and variable operating and maintenance (VOMs). Data utilised have been collected from literature sources and calculation for the infrastructure energy and water usage have been estimates using utility tariffs respectively. These assets have a total capital cost of R652,194. The estimated revenue from a 10kg MOF production is R1,585,920 with additional revenue from PET derived BDC that is approximately R2,000 per kg. The operations and maintenance costs have been considered as a percentage of capital cost. The variable fixed operations and maintenance have been represented by 2.5% of the capital cost.

Commercial viability

Investing in MOFs will generate roughly a 5% IRR on a production capacity of 10kg daily. Given the fact that these results are positive at a small-scale, it is therefore recommended that this investment should proceed. The environmental and opportunity cost that is avoided has not been considered in the financial analysis. This can further strengthen the revenue side of this production. While a return of 5% is not the most attractive, the PET waste that would be redirected to this production contributes to the South African waste management strategy and climate change objectives. In addition, the South African government bond of 10 years yields a return of 8.52% return and this initiative is competitiveness with a 5% IRR.

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