Characterization of the hydrochar and process wastewater recovered after hydrothermal pretreatment of diaper waste

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1. Introduction

Disposable diaper is one of the absorbable hygiene products (AHPs) which is widely used to absorb urine or faecal matter from infants and the elderly. Such diapers are used widely over biodegradable diaper due to economics, easy availability and simple in use (Nonwovens industry, 2017; URL 1; URL 2). However, diaper waste (DW) are degraded in several hundred years for decomposition at landfill sites. Thermal treatment options such as incineration may cause emission of various organic and inorganic compounds into air if adequate temperature is not maintained.

Hydrothermal treatment (HT) is a relatively new technology for the valorization of organic waste in which the materials with high moisture content and organic content such as DW may be pretreated. The literature of the pretreatment of DW is limited (Budyk and Fullana, 2019). Hence, the study was undertaken to understand the efficacy of the proposed pretreatment on the products formed after HT.

2. Experimental Methods

The HT runs were carried out with disposable diaper soaked either in water or urine in a high pressure reactor of 2 L capacity at a temperature of 200°C for 1 h duration. The solids, i.e., hydrochar (HC) were separated by filtering out by vacuum filtration whereas the process wastewater (PW) was stored in a refrigerator for further analysis. The runs, HT-1 and HT-2, were performed with water soaked disposable diaper (~30 g) (tap water = 1.5 L and 1 L, respectively) while HT-3 was carried out with a disposable diaper (~30 g) and synthetic urine (181 mL) which simulated to DW. The HC samples recovered after the pretreatment were characterized for moisture content, volatile matter, ash content and calorific value using the standard techniques (American Public Health Association (APHA), 2012; American Society for Testing and Materials (ASTM), 2019, 2021) whereas the recovered liquid samples (i.e., PW) were subjected to the analysis of various chemical parameters by standard methods (APHA, 2012; Willis *et al.*, 1996).

3. Results and Discussion

The physicochemical characteristics of HC and PW after HT are shown in Table 1. After pretreatment, the solids were reduced by ~32-41%. The lower calorific value (LCV) of the hydrochar samples was ~22-24 MJ/kg which is considerably higher than that of refuse derived fuel.

Table 1. Physicochemical characteristics of hydrochar and PW after HT of DW

	HT-1	**HT-2**	**HT-3**
Initial conditions	Disposable diaper & 1.5 L tapwater	Disposable diaper & 1 L tapwater	Disposable diaper & 181 mL urine
Hydrochar			
Solids reduction (%)	39.3	40.8	32.3
LCV (MJ/kg)	21.9 ± 2.8	23.3 ± 0.6	24.1 ± 1.0
Moisture content (%)	14.6 ± 1.7	12.4 ± 2.4	8.9 ± 1.3
Volatile matter (on dry basis, %)	96 ± 3.5	94 ± 2	82 ± 1.6
Fixed carbon (on dry basis, %)	1 ± 0.8	0.3 ± 0.1	8 ± 0.8
Ash content (on dry basis, %)	3 ± 2.9	5 ± 1.9	10 ± 1.2
C (%)	46.2	43.4	42.1
H (%)	5.9	6.3	5.3
O (%)	47.0	44.8	40.9
N (%)	0.1	0.1	0.3
Process wastewater			
pH	6.3	6.3	8.9
Electrical conductivity, EC (µS/cm)	1607	2510	3721
BOD_5 (mg/L)	333 ± 21	739 ± 43	2670 ± 107
COD (mg/L)	4948 ± 156	6579 ± 495	38470 ± 618
Total organic carbon, TOC (mg/L)	1683± 42	3015 ± 19	15231 ± 1367
TKN (mg/L)	1425 ± 25	1552 ± 27	6601 ± 82

The 5 day biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) of the PW samples were 333-2670 mg/Land 4948-38470 mg/L. The samples can be termed as 'non-biodegradable' in nature due to very low BOD_5/COD ratio of 0.07-0.11 whereas total kjedahl nitrogen (TKN) concentration was in the range of 1425-6600 mg/L. After HT treatment, the formation of chlorinated hydrocarbons, aromatic hydrocarbons or nitrogenous compounds (such as aniline) is predicted which may be responsible for low biodegradabilty, hence suitable treatment/ recovery processes need to be identified. The carbon balance calculations showed solubilisation of ~24-26% of carbon from a disposable diaper.

4. Conclusions

The results revealed that the hydrochar samples have good calorific value and can be used as co-fuel in energy intensive industries. The process wastewater should be treated suitably before subjecting to anaerobic treatment for biogas generation. However, a detailed study is needed to determine feasibility of the pretreatment.

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