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Separation and structural characterization of the value-added chemicals from mild degradation of lignites: A review

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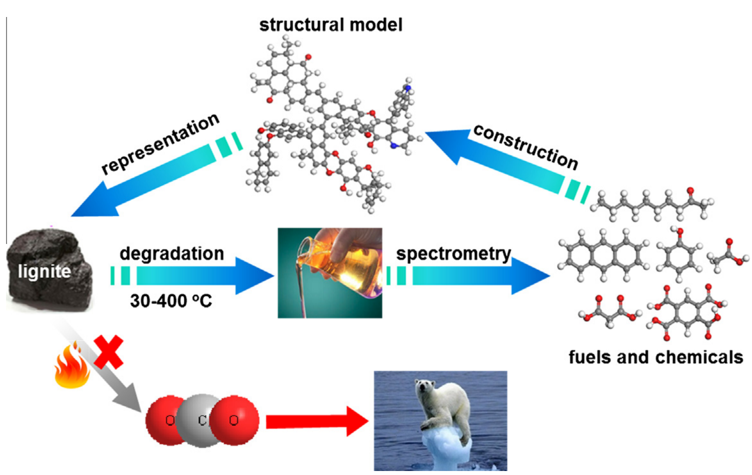
HIGHLIGHTS

- Review on mild and eco-friendly degradation ways (<400 °C) of lignites is provided.
- Clean fuels and value-added chemicals can be produced from lignites by mild degradation.
- Value-added chemicals are characterized by various advanced analytical techniques.
- Mild, eco-friendly, efficient, and novel lignite conversions need to be developed.

GRAPHICAL ABSTRACT



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ABSTRACT

Lignite utilizations are limited due to the disadvantages of lignites such as high moisture content, high ash yield, and low calorific value. Direct combustion and other conventional utilization processes of lignites emit a huge amount of CO_2, leading to catastrophic global warming. Accordingly, mild and eco-friendly utilization technologies should be paid attention to overcome the disadvantages. Separation and structural characterization of organic species in degraded lignites are crucial for producing clean liquid fuels and value-added chemicals. Several molecular and network structural models for lignites have been proposed since 1976 based on the characteristics of the organic species from lignites. Since then, great progress has been achieved in this area, while reviews on the advances have rarely reported. This review focuses on mild (<400 °C) and low-CO_2-emission chemical degradation methods for separating and characterizing value-added chemicals (VACs) from lignites, including low-temperature extraction (LTE), thermal dissolution (TD), extraction in ionic liquids (ILs), and mild oxidation. LTE gives low extract yields for lignites due to strong noncovalent interactions between the soluble organic species (SOSs) and macromolecular network in lignites. Such interactions can be significantly disrupted by TD around 300 °C, leading to dissolving much more SOSs (almost ash-free) which can be used as clean fuels for gas turbines or valuable precursors for chemicals and carbon materials. ILs could be promising green solvents for separating valuable SOSs from lignites. Mild oxidation also proved to be an effective approach

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Nomenclature

1-MN	1-methylnaphthalene	HL	Huolinguole lignite
AAs	alkanoic acids	HHV	higher heating value
ADAs	alkanedioic acids	ILs	ionic liquids
ASAP/TOFMS	atmospheric solid analysis probe/time of flight mass spectrometry	LCO	light cycle oil
ASCs	alkyl side chains	LDI	laser desorption ionization
ATCAs	alkanetricarboxylic acids	LTE	low-temperature extraction
BPCAs	benzene polycarboxylic acids	MALDI/TOFMS	matrix-assisted laser desorption ionization/time of flight mass spectrometry
CMNO	crude methylnaphthalene oil	MEAA	methoxyethoxy acetic acid
CP/MAS	cross-polarization and magic angle spinning	MEF	methanol-extractable fraction
CQ	crude quinoline	NMRS	nuclear magnetic resonance spectrometry
CS_2/NMP	carbon disulfide/*N*-methyl-2-pyrrolidinone	OCCs	oxygen-containing chemicals
CSAAs	chloro-substituted alkanoic acids	OFGs	oxygen-functional groups
DARTIS/ITMS	direct analysis in real-time ionization source coupled to ion-trap mass spectrometry	ONCs	organonitrogen compounds
DBE	double bond equivalent	RICO	ruthenium ion-catalyzed oxidation
EEF	ethanol-extractable fraction	SCAAs	short-chain aliphatic acids
ER	extraction residue	SL	Shengli lignite
ESI FTICRMS	electrospray ionization Fourier transform ion cyclotron resonance mass spectrometry	SOSs	soluble organic species
FD/MS	field desorption/mass spectrometry	TD	thermal dissolution
FTIRS	Fourier transform infrared spectrometry	THF	tetrahydrofuran
GC/MS	gas chromatography/mass spectrometry	VACs	value-added chemicals
HAHCs	heavy aromatic hydrocarbons	XANES	X-ray absorption near edge structure spectrometry
HHAHCs	hydrotreated heavy aromatics hydrocarbons	XL	Xianfeng lignite
		XPS	X-ray photoelectron spectrometry

for understanding macromolecular structures of lignites and simultaneously producing VACs such as short-chain aliphatic acids and benzenepolycarboxylic acids. Special attention has also been paid to the application of advanced analytical techniques for characterizing the VACs from mild degradation of lignites. Important information on functional groups, carbon and hydrogen forms, molecular mass distributions, and molecular compositions of the VACs can be characterized by using different analytical techniques presented in the review.

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