Could wastewater analysis be a useful tool for China?
<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The potential risk assessment for different arsenic species in the aquatic environment</td>
<td>Meng Du, Dongbin Wei, Zhuowei Tan, Aiwu Lin, and Yuguo Du</td>
</tr>
<tr>
<td>9</td>
<td>Synthesis of linear low-density polyethylene-g-poly (acrylic acid)-co-starch/organo-montmorillonite hydrogel composite as an adsorbent for removal of Pb(II) from aqueous solutions</td>
<td>Maryam Irani, Hanafi Ismail, Zulkifli Ahmad, and Maohong Fan</td>
</tr>
<tr>
<td>21</td>
<td>Research and application of kapok fiber as an absorbing material: A mini review</td>
<td>Yian Zheng, Jintao Wang, Yongfeng Zhu, and Aiqin Wang</td>
</tr>
<tr>
<td>33</td>
<td>Relationship between types of urban forest and PM2.5 capture at three growth stages of leaves</td>
<td>Thithanhthao Nguyen, Xinxiao Yu, Zhenming Zhang, Mengmeng Liu, and Xuhui Liu</td>
</tr>
<tr>
<td>42</td>
<td>Bioaugmentation of DDT-contaminated soil by dissemination of the catabolic plasmid pDOD</td>
<td>Chunming Gao, Xiangxiang Jin, Jingbei Ren, Hua Fang, and Yunlong Yu</td>
</tr>
<tr>
<td>51</td>
<td>Comparison of different combined treatment processes to address the source water with high concentration of natural organic matter during snowmelt period</td>
<td>Pengfei Lin, Xiaojian Zhang, Jun Wang, Yani Zeng, Shuming Liu, and Chao Chen</td>
</tr>
<tr>
<td>59</td>
<td>Chemical and optical properties of aerosols and their interrelationship in winter in the megacity Shanghai of China</td>
<td>Tingting Han, Liping Qiao, Min Zhou, Yu Qu, Jianfei Du, Xingang Liu, Shengrong Lou, Changhong Chen, Hongli Wang, Fang Zhang, Qing Yu, and Qiong Wu</td>
</tr>
<tr>
<td>80</td>
<td>Controlling cyanobacterial blooms by managing nutrient ratio and limitation in a large hypereutrophic lake: Lake Taihu, China</td>
<td>Jianrong Ma, Boqiang Qin, Pan Wu, Jian Zhou, Cheng Niu, Jianming Deng, and Hailin Niu</td>
</tr>
<tr>
<td>87</td>
<td>Reduction of NO by CO using Pd-CeTb and Pd-CeZr catalysts supported on SiO2 and La2O3-Al2O3</td>
<td>Victor Ferrer, Dora Finol, Roger Solano, Alexander Moronta, and Miguel Ramos</td>
</tr>
<tr>
<td>97</td>
<td>Development and case study of a science-based software platform to support policy making on air quality</td>
<td>Yun Zhu, Yanwen Lao, Carey Jiang, Chen-Jen Lin, Jia Xing, Shuxiao Wang, Joshua S. Fu, Shuang Deng, Junping Xie, and Shicheng Long</td>
</tr>
<tr>
<td>108</td>
<td>Modulation of the DNA repair system and ATR-p53 mediated apoptosis is relevant for tributyltin-induced genotoxic effects in human hepatoma G2 cells</td>
<td>Bowen Li, Lingbin Sun, Jiali Cai, Chonggang Wang, Mengmeng Wang, Huiling Qiu, and Zhenghong Zuo</td>
</tr>
<tr>
<td>115</td>
<td>Impact of dissolved organic matter on the photolysis of the ionizable antibiotic norfloxacin</td>
<td>Chen Liang, Huimin Zhao, Minjie Deng, Xie Quan, Shuo Chen, and Hua Wang</td>
</tr>
<tr>
<td>124</td>
<td>Enhanced bio-decolorization of 1-amino-4-bromoanthraquinone-2-sulfonic acid by Sphingomonas xenophaga with nutrient amendment</td>
<td>Hong Lu, Xiaofan Guan, Jing Wang, Jiti Zhou, Haikun Zhang</td>
</tr>
<tr>
<td>131</td>
<td>Winter survival of microbial contaminants in soil: An in situ verification</td>
<td>Antonio Bucci, Vincenzo Allocca, Gino Naclerio, Giovanni Capobianco, Fabio Divino, Francesco Fiorillo, and Fulvio Celico</td>
</tr>
<tr>
<td>139</td>
<td>Assessment of potential dermal and inhalation exposure of workers to the insecticide imidacloprid using whole-body dosimetry in China</td>
<td>Lidong Cao, Bo Chen, Li Zheng, Dongwei Wang, Feng Liu, and Qiliang Huang</td>
</tr>
</tbody>
</table>
CONTENTS

147  Biochemical and microbial soil functioning after application of the insecticide imidacloprid
Mariusz Cycon and Zofia Piotrowska-Seget

159  Comparison of three-dimensional fluorescence analysis methods for predicting formation of
trihalomethanes and haloacetic acids
Nicolás M. Peleato and Robert C. Andrews

168  The migration and transformation of dissolved organic matter during the freezing processes of water
Shuang Xue, Yang Wen, Xiujuan Hui, Lina Zhang, Zhaohong Zhang, Jie Wang, and Ying Zhang

179  Genomic analyses of metal resistance genes in three plant growth promoting bacteria of legume
plants in Northwest mine tailings, China
Pin Xie, Xiuli Hao, Martin Herzberg, Yantao Luo, Dietrich H. Nies, and Gehong Wei

188  Effect of environmental factors on the complexation of iron and humic acid
Kai Fang, Dongxing Yuan, Lei Zhang, Lifeng Feng, Yaqin Chen, and Yuzhou Wang

197  Resolving the influence of nitrogen abundances on sediment organic matter in macrophyte-dominated
lakes, using fluorescence spectroscopy
Xin Yao, Shengrui Wang, Lixin Jiao, Caihong Yan, and Xiangcan Jin

207  Predicting heavy metals’ adsorption edges and adsorption isotherms on MnO₂ with the parameters
determined from Langmuir kinetics
Qinghai Hu, Zhongjin Xiao, Xinmei Xiong, Gongming Zhou, and Xiaohong Guan

217  Applying a new method for direct collection, volume quantification and determination of N₂ emission
from water
Xinhong Liu, Yan Gao, Honglian Wang, Junyao Guo, and Shaohua Yan

225  Effects of water management on arsenic and cadmium speciation and accumulation in an upland rice cultivar
Pengjie Hu, Younan Ouyang, Longhua Wu, Libo Shen, Yongming Luo, and Peter Christie

232  Acid-assisted hydrothermal synthesis of nanocrystalline TiO₂ from titanate nanotubes: Influence of acids on
the photodegradation of gaseous toluene
Kunyang Chen, Lizhong Zhu, and Kun Yang

241  Air-soil exchange of organochlorine pesticides in a sealed chamber
Bing Yang, Baolu Han, Nandong Xue, Lingli Zhou, and Fasheng Li

251  Effects of elevated CO₂ on dynamics of microcystin-producing and non-microcystin-producing strains during
Microcystis blooms
Li Yu, Fanxiang Kong, Xiaoli Shi, Zhen Yang, Min Zhang, and Yang Yu

259  Sulfide elimination by intermittent nitrate dosing in sewer sediments
Yanchen Liu, Chen Wu, Xiaohong Zhou, David Z. Zhu, and Hanchang Shi

266  Steel slag carbonation in a flow-through reactor system: The role of fluid-flux
Eleanor J. Berryman, Anthony E. Williams-Jones, and Artashes A. Migdisov

276  Amine reclaiming technologies in post-combustion carbon dioxide capture
Tieliang Wang, Jon Hovland, and Klaus J. Jens

290  Do vehicular emissions dominate the source of C6-C8 aromatics in the megacity Shanghai of eastern China?
Hongli Wang, Qian Wang, Jianmin Chen, Changhong Chen, Cheng Huang, Liping Qiao, Shengrong Lou,
and Jun Lu

298  Insights into metals in individual fine particles from municipal solid waste using synchrotron radiation-based
micro-analytical techniques
Yumin Zhu, Hua Zhang, Liming Shao, and Pinjing He
Research and application of kapok fiber as an absorbing material: A mini review

Yian Zheng¹, Jintao Wang¹,², Yongfeng Zhu¹,², Aiqin Wang¹,*

¹. Center of Eco-materials and Green Chemistry, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000, China. E-mail: zhengyian@licp.cas.cn
². University of Chinese Academy of Sciences, Beijing 100049, China

ABSTRACT
Kapok fiber corresponds to the seed hairs of the kapok tree (Ceiba pentandra), and is a typical cellulosic fiber with the features of thin cell wall, large lumen, low density and hydrophobic–oleophilic properties. As a type of renewable natural plant fiber, kapok fiber is abundant, biocompatible and biodegradable, and its full exploration and potential application have received increasing attention in both academic and industrial fields. Based on the structure and properties of kapok fiber, this review provides a summary of recent research on kapok fiber including chemical and physical treatments, kapok fiber-based composite materials, and the application of kapok fiber as an absorbent material for oils, metal ions, dyes, and sound, with special attention to its use as an oil-absorbing material, one predominant application of kapok fiber in the coming future.

© 2014 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V.

Keywords:
Kapok fiber
Pretreatment
Composite material
Absorbing materials

Contents
Introduction ............................................................ 22
1. Structure and property of kapok fiber ............................................ 22
  1.1. Kapok fiber ....................................................... 22
  1.2. Chemical treatment .................................................. 23
    1.2.1. Alkali/acid treatment ............................................. 23
    1.2.2. Solvent treatment ............................................... 24
    1.2.3. Oxidation treatment .............................................. 24
    1.2.4. Acetylation ................................................... 24
  1.3. Physical treatment ................................................... 24
    1.3.1. Ultrasonic treatment ............................................. 24
    1.3.2. Radiation treatment ............................................... 25
2. Kapok fiber-based composite materials ........................................... 25
  2.1. Kapok fiber blending .................................................. 25

*Corresponding author. E-mail: aqwang@licp.cas.cn (Aiqin Ferrer).
Introduction

Kapok trees belong to the family of Bombacaceae and grow in Asia, Africa and South America. Kapok is a silky fiber that encloses the seeds of kapok trees (Ceiba pentandra), and the color is yellowish or light-brown with a silk-like luster. Kapok fiber is composed of single-celled plant hairs, in contrast to cotton, which is lignified and not attached to the seed grains.

Due to their unique features, kapok fiber-based materials have opened up possibilities for various new application fields. Therefore, kapok fiber and its composite materials have been gaining increasing attention in recent years. Conventionally, kapok fiber is used as stuffing for bedding, upholstery, life preservers and other water-safety equipment because of its excellent buoyancy (Zhang et al., 2013), and for insulation against sound and heat because of its air-filled lumen (Veerakumar and Selvakumar, 2012; Xiang et al., 2013). Due to its warmth retention properties, kapok fiber can be blended with other fibers to achieve apparel textiles with desired characteristics (Hong et al., 2012). As an important type of lignocellulosic plant fiber, kapok fiber has been used as a reinforcement material in polyester matrixes via hybridization with glass and sisal fabrics (Reddy et al., 2008, 2009). Also, kapok fiber can be added into thermoplastic cassava starch (TPCS) to reduce the water absorption of the TPCS/kapok fiber composite and enhance its stress at maximum load and Young’s modulus (Prachayawarakorn et al., 2013). The wax layer on its surface enables this fiber to show excellent hydrophobic-oleophilic characteristics, and accordingly, this fiber is receiving increasing interest as an oil-absorbing material (Wang et al., 2012a,b,c, 2013a,b,c,d; Huang and Lim, 2006; Lim and Huang, 2007a,b; Abdullah et al., 2010; Rengasamy et al., 2011) and in packaging paper requiring strength and water repellency (Chaiaarreki et al., 2012). Due to its natural microtuber structure, kapok fiber can also be used as a desirable template material (Zhang et al., 2010) or support candidate, for example as a catalyst carrier (Fan et al., 2012). In addition, this fiber is considered to be a potential starting material for the preparation of versatile activated carbon fibers (Chung et al., 2013) or as a second-generation source for bioethanol (Tye et al., 2012). With a focus on the structure and properties of kapok fiber, this review provides a summary of recent studies on chemical and physical treatments, kapok fiber-based composite materials, and recent applications of kapok fiber as an absorbent material for oils, metal ions, dyes, and sound.

1. Structure and property of kapok fiber

1.1. Kapok fiber

Kapok fiber is a highly lignified organic seed fiber and mainly consists of cellulose, lignin and xylan (Fengel and Przyklenk, 1986; Gao et al., 2012). The chemical composition of kapok fiber varies in different reports. One study found that kapok fiber was chemically composed of 64% cellulose, 13% lignin, and 23% pentosan on a weight basis (Kobayashi et al., 1977), while another found that kapok fiber was comprised of 35% cellulose, 21.5% lignin, and 22% xylan, with a high ratio of syringyl/guaiacyl units (4-6) and a high level of acetyl groups (13.0%) as compared with normal plant cell walls (about 2-4%) (Chung et al., 2008; Hori et al., 2000). The differences might be related to the differences in kapok sources and processing techniques. The crystallization degree of kapok fiber has been determined to be 35.90%, the specific birefringence is 0.017, and the bulk density is 0.30 g/cm³, considering its large lumen (Xiao et al., 2005a).

Kapok fiber is composed of two major layers with differing microfibrillar orientations. The outer layer is composed of cellulose microfibrils oriented transversely to the fiber axis, whereas the inner layer is composed of fibrils oriented nearly parallel to the fiber axis (Nilsson and Björdal, 2008). Optical microscopy and SEM observation found that kapok fiber shows a cylindrical shape, a surface without texture and thickening groins at the ends (Fengel and Wenzkowski, 1986). The surface of kapok fiber is smooth with a thick layer of wax, and the cross-section is oval to round with large lumen and thin wall (ca. 8–10 μm in diameter and ca. 0.8–1.0 μm in wall thickness) (Mwaikambo and Bisanda, 1999; Chung et al., 2008). This hollow structure differentiates the kapok fiber from other natural fibers and endows it with a porosity of more than 80% (Xiang et al., 2013). As another unicellular fiber, cotton fiber shows a compressed ribbon-like morphology, rolling in a helicoidal manner around the axis (Chung et al., 2008), as shown in Fig. 1.

Owing to its brittleness, low cohesivity and strength, pure kapok fiber cannot be spun like cotton fiber, but can be successfully blended with cotton fiber to form yarns. With an increase in kapok content, the yarn regularity and tenacity decrease while the yarn extensibility increases, in addition to reduced total cost of production for the yarns (Dauda and Kolawole, 2003). However, the large lumen and waxy surface are not favorable for the access of hydrophilic coloring agents. 
or dyes, and accordingly, a lower dyeing efficiency is observed for kapok fiber (Lou, 2011). Nevertheless, the combination of these features provides kapok fiber with better hydrophobic–oleophilic properties, which enables this fiber to be potentially used as a buoyancy material and oil-absorbing material.

To enhance the intrinsic properties or alter the surface characteristics, kapok fiber can be subjected to surface modification including: (1) chemical treatment, such as alkali/acid treatment, solvent treatment, oxidation treatment and acetyl treatment; and (2) physical treatment, such as ultrasonic treatment and radiation treatment. The interfacial properties can be improved by appropriate treatment of the kapok fiber, which gives rise to changes in physical and chemical interactions at the interface.

1.2. Chemical treatment

1.2.1. Alkali/acid treatment
Chemical treatment can give rise to continuous covalent bonds between the fiber surface and a matrix, or create some new binding sites according to the structure and characteristics of the reacting species. One of the most common and efficient methods of chemical treatment is alkali treatment of the fibers, which has been used to treat almost all natural fibers with successful results (John and Anandjiwala, 2008).

Alkali treatment of kapok fiber was originally used to remove lignin, pectin, wax and natural oils covering the outer surface of the fiber, which consequently improves its surface and mechanical properties for polymer applications (Wahi et al., 2013; Reddy et al., 2009). Sodium hydroxide is the most commonly used chemical for bleaching and/or cleaning the surface of kapok fiber. Alkali treatment has no obvious effect on the chemical composition of cellulose, but leads to an increase in the amount of amorphous cellulose at the expense of crystalline cellulose, changing the fine structure of the native cellulose I to cellulose II by a process known as alkalization (mercerization) (Liu and Wang, 2009, 2011). This process is accompanied by a significant de-esterification of the kapok fiber, resulting in a remarkable reduction in band intensity at 1740 and 1245 cm$^{-1}$ in the infrared spectrum for NaOH-treated kapok fiber compared with that of raw kapok fiber (Wang et al., 2012a). Furthermore, alkalization of kapok fiber changes the surface topography of the fiber (Mwaikambo and Ansell, 2002). For NaOH-treated kapok fiber, small fibrils, broken holes and shallow pits can be observed on its surface, while the raw kapok fiber exhibits a smooth surface, indicating the removal of surface wax from the kapok fiber and subsequent exposure of hydrophilic hydroxyl groups, which is advantageous in fiber–matrix adhesion, as it facilitates both mechanical interlocking and bonding reactions to chemicals such as resins and dyes (Mwaikambo and Ansell, 2002). Nevertheless, the removal of wax together with the collapse of the rigid, hollow structure may reduce the oil sorption capability. Data has shown that after 8 hr of alkali treatment, 26.3% reduction in sorption capacity for a model oil was observed as compared to the raw kapok fiber (Abdullah et al., 2010). In contrast, our study revealed that the oil absorbency is dependent on the treatment concentration, temperature and time for NaOH-treated kapok fiber, and an appropriate alkaline treatment is beneficial for the improvement of oil absorbency (Wang et al., 2012a). That is, care must be exercised in selecting the concentration of NaOH for alkalization of kapok fiber (Liu and Wang, 2011).

Acid treatment can also remove the plant wax from kapok fiber, which can be inferred from comparative FT-IR results showing changes in the absorption bands at 3410 and 2914 cm$^{-1}$ due to the exposure of cellulose hydroxyl groups in fiber walls, but no significant reduction in other absorption bands (Wang et al., 2012a). Wang et al. (2012a) have revealed, using toluene, chloroform, n-hexane and xylene as model oils, that HCl-treated kapok fiber shows better oil absorbency than NaOH-treated kapok fiber, through the removal of plant wax from the fiber surface. Tye et al. (2012) demonstrated that without pretreatment, kapok fiber can only yield 0.8% reducing sugar by enzymatic hydrolysis, while acid treatment can increase the yield of reducing sugar to 85.2%. Nevertheless, alkaline treatment is more effective in achieving a higher yield of reducing sugar (>100%). This is attributed to the fact that the alkali treatment influences not only the cellulosic components inside the kapok fiber, but also the noncellulosic components (hemicellulose, lignin, and pectin), while acid treatment can remove only hemicellulose, especially xylose, from the kapok fiber. In general, plant fiber with

![Fig. 1 – SEM images of kapok fibers (a) and degreased cotton fibers (b) (Xiang et al., 2013). Copyright 2013, reproduced with permission from Elsevier.](image-url)
low lignin content is more favorable for enzymatic hydrolysis, as lignin absorbs enzymes and, consequently, decreases enzyme activity. Therefore, alkali treatment is more effective in enhancing the conversion of cellulose from kapok fiber into glucose for the production of second-generation bioethanol (Tye et al., 2012).

1.2.2. Solvent treatment
Chloroform and ethanol are the two most common solvents for the pretreatment of kapok fiber. Chloroform was chosen as one of the solvents due to its hydrophobicity, similar to the waxy surface of kapok fiber. FT-IR spectra show an increase in absorption bands at 3410 and 2914 cm$^{-1}$ for chloroform-treated kapok fiber, but no obvious variation in other absorption bands, suggesting only wax removal from the kapok surface (Abdullah et al., 2010; Wang et al., 2012a). The difference between 4 and 8 hr extraction is not significant, with only slightly higher percentage of wax removal in the latter. However, as an oil-absorbing material, solvent-treated kapok fiber is expected to show reduced oil absorbency. After 8 hr of chloroform treatment, 2.1% reduction in sorption capacity is observed compared to the raw kapok fiber, though no major structural difference is observed (Abdullah et al., 2010). From the appearance, solvent-treated kapok fiber has lost its silky luster after the removal of surface wax. Apparently, solvent treatment impairs the hydrophobic–oleophilic characteristics of the kapok fiber; for example, using ethanol- or chloroform-treated kapok fiber as the filter medium, premature breakthroughs have been observed during the deep-bed filtration process (Lim and Huang, 2007a). In addition to chloroform and ethanol, a mixture of alcohol and benzene at 1:2 ratio is also used for the pretreatment of kapok fiber to obtain dewaxed kapok fiber (Mani et al., 2012).

1.2.3. Oxidation treatment
In order to alter the hydrophobicity of kapok fiber to hydrophilicity, oxidation treatment with NaClO$_2$ is commonly employed. This process can remove some phenolic compounds (especially lignin) from kapok fiber (Kang et al., 2007), and then, the lignin contents in kapok fiber can be reduced dramatically from 20.9% to 2.6%. This result is also verified by a decrease in the total alkaline nitrobenzene oxidation (NBO) yield from 78.4 mg/g of CWR (cell wall residues) for a control to 10.5 mg/g of CWR for a NaClO$_2$-treated sample (Chung et al., 2008). FT-IR spectra reveal that for NaClO$_2$-treated kapok fiber, the absorption bands around 1602 and 1504 cm$^{-1}$ nearly disappear, signifying the cleavage of the aromatic ring in lignin (Wang et al., 2012a).

The NaClO$_2$ treatment is an effective approach to alter the surface nature of kapok fiber. As studies have revealed, a water drop shows a large contact angle on raw kapok fiber ($\theta = 116^\circ$), while a water drop sinks rapidly into kapok fiber treated with NaClO$_2$, to form a large spreading radius on the surface (Wang et al., 2012b). Furthermore, NaClO$_2$ treatment is effective in changing the aggregate structure and expanding the amorphous region in kapok fiber, with a decrease in the crystallinity index from 35.34% to 26.97% for untreated and NaClO$_2$-treated kapok fiber, respectively (Wang et al., 2012a). Subsequently, NaClO$_2$-treated kapok fiber shows higher oil absorbency, with percentage increases of 19.8%, 30.0%, 21.5% and 24.1% for toluene, chloroform, n-hexane and xylene, respectively. In addition, NaClO$_2$-treated kapok fiber exhibits better reusability, suggesting its great potential for oil recovery (Wang et al., 2012a). Due to the hydrophilic characteristics introduced by delignification, NaClO$_2$-treated kapok fiber can be (i) directly designed to remove the cationic dye methylene blue (MB) from aqueous solution, with the adsorption capacity of 110.13 mg/g (Liu et al., 2012a); (ii) grafted with glycidyl methacrylate (GMA) under irradiation with Co-60 gamma rays, such that the resulting grafted product will be provided with new functions such as ion exchange and adsorption properties, with the original properties remaining intact (Kang et al., 2007). After a series of oxidation treatments, i.e. NaClO$_2$–NaO$_2$–NaClO$_2$ treatment, the resulting oxidized kapok fiber can be used as an excellent adsorbent for heavy metals. This enhanced adsorption for heavy metal ions onto chemically oxidized kapok fiber can be attributed to the generation of –COOH groups (Chung et al., 2008). Tang et al. (2012) have observed that with TEMPO (2,2,6,6-tetramethyl-1-piperidinylxilo) oxidation, the amount of Cd attached onto kapok fiber/CdS nanocomposite is higher than that of untreated kapok fibers, and the CdS nanoparticles attached onto the kapok fiber/CdS nanocomposites with TEMPO oxidation disperse more evenly and have more uniform diameters.

1.2.4. Acetylation
In contrast to oxidation treatment, acetylation is a rather attractive method for modifying the surface of kapok fiber to render it more hydrophobic. The main principle of the method is to react the hydroxyl groups (OH) of the fiber with acetyl groups (CH$_3$CO), because the acetyl group shows higher hydrophobicity than the hydroxyl group (John and Anandijwala, 2008). The kapok fiber can be acetylated with and without a catalyst to graft acetyl groups onto the cellulose structure. FT-IR analysis shows that after acetylation, the absorption intensities at around 1742 cm$^{-1}$ (stretching vibration of the carbonyl group C=O in esters), 1375 cm$^{-1}$ (C–H bending vibration in –O(C==O)–CH$_3$), 1244 cm$^{-1}$ (C–O stretching vibration in esters) and 2910 cm$^{-1}$ are observed to increase (Wang et al., 2013a). Furthermore, the crystallinity index is observed to decrease from 34.34% for raw fiber to 22.90%–29.42% for acetylated fiber with increasing concentration of acetic anhydride. That is, a higher concentration of acetic anhydride causes a decrease in the aggregate structure of lignocellulose (Wang and Wang, 2013). Therefore, successful acetylation is expected to not only improve the performance of kapok fiber composites by promoting better fiber-to-resin bonding (Mwaikambo and Ansell, 1999), but also enhance the oil sorption capacity due to the increase in surface roughness (Wang et al., 2013a).

1.3. Physical treatment
1.3.1. Ultrasonic treatment
In recent years, ultrasonic treatment has been applied in textile pre-treatment processes for degumming, desizing, scouring and bleaching, etc., Chen and Xu (2012) investigated the influence of ultrasonic treatment with water on the morphological structure, chemical composition, weight loss, tensile properties, compression properties, capillary effect and contact angle of kapok/cotton blended yarns by comparing the properties before and after ultrasonic treatment. The results showed that no appreciable changes in the morphological structure and chemical
composition of the fiber were observed after ultrasonic treatment. The weight loss of the yarns was about 6%, and most was from kapok flocs. The percentage of hollowness was lowered to some extent, and the yarns became fluffy. The breaking strength of the yarns became very low, while the hydrophobic characteristics showed no significant changes. Also, the studies by Tang et al. indicated that when kapok fiber is pretreated by ultrasound waves, more $\gamma$-Fe$_2$O$_3$ or CdS nanoparticles can be attached onto the surface of kapok fiber via in situ reaction. Therefore, ultrasonic pretreatment is an effective method for the preparation of kapok fiber nanocomposites, such as kapok fiber/CdS (Tang et al., 2012) and kapok fiber/$\gamma$-Fe$_2$O$_3$ (Tang et al., 2008).

1.3.2. Radiation treatment

Even though kapok fiber is applicable in various industrial fields, it has a serious disadvantage which is its extreme sensitivity to spark or flame. By using gamma rays, a flame-resistant kapok fiber can be developed. During the radiation process, hydrophobic compounds can be removed and methoxyl groups from lignin can be cleaved, by which kapok fiber can be converted into a flame-resistant fiber to widen its applications (Chung et al., 2009). However, the radiation does not produce morphological change, and the fine hollow tube shape of kapok fiber is still preserved.

2. Kapok fiber-based composite materials

2.1. Kapok fiber blending

As one of the important lignocellulosic plant fibers, kapok fiber is considered unfit for textile fabrics. However, the weavability of kapok fiber can be improved by blending with other fibers, such as cotton fiber (Chen and Xu, 2012). Compared with pure cotton, kapok/cotton blended fiber shows similar moisture permeability and lower air permeability, and better warmth-retention and water vapor transmission properties owing to the highly porous structure of the kapok fiber. With increasing content of kapok fiber in the blended fabrics, the composite retains the good warmth properties (Wei et al., 2008; Cui et al., 2010). However, the yarn regularity and tenacity as well as the dyeability decrease, though the yarn extensibility increases (Dauda and Kolawole, 2003; Liu and Wang, 2009). The mercerization treatment can transform a certain portion of cellulose I into cellulose II, thus decreasing the crystallinity of the blended yarns. Compared to cotton fiber, a more moderate alkali treatment condition should be chosen in the mercerization process for kapok fiber (Liu and Wang, 2011).

Due to its low density and hydrophobic characteristics, kapok fiber has many advantages when used as buoyancy material. However, the buoyancy tends to decline after the material has been used or stored for a long time, as it becomes compressed due to fiber migration. Consolidating kapok fiber into webs with low-melting fiber can improve the buoyancy behavior of kapok fiber assemblies, obtain compression resistance and provide a higher buoyancy factor (Xiao et al., 2005b; Shi et al., 2009). In order to enhance the reusability of kapok fiber as an oil-absorbing material, a composite of kapok fiber and pig hair was developed. The flexibility of pig hair is greater than that of kapok fiber, so the composite has a higher elasticity and good reusability as an oil-absorbing product (Liu et al., 2012b). The use of kapok fiber with polypropylene fiber for the development of sound-absorptive nonwoven materials has also been explored. The sound absorption coefficient and noise reduction coefficient values obtained indicate that kapok fiber composites exhibit very good sound absorption behavior in the frequency range of 250–2000 Hz. An uncompressed kapok/polypropylene nonwoven composite with 30:70 blend ratio having high bulk density and low porosity was found to give the best performance when used by providing an air gap behind the composite (Veerakumar and Selvakumar, 2012). To reduce the moisture uptake and improve the mechanical properties, kapok fiber can also be blended with thermoplastic starch (Prachayawarakorn et al., 2013).

Due to the advantages of design flexibility, cost effectiveness, lack of health-hazard problems and recycling possibilities, kapok fiber has been used as a reinforcement for polymeric resins. Studies have shown that kapok fiber can be hybridized with glass and sisal fabrics in a polyester matrix to enhance the impact strength of hybrid composites substantially (34%) (Reddy et al., 2008). The mechanical properties of kapok/polyester composites have been found to be better than those of kapok/sisal polyester composites (Reddy et al., 2009). Cotton–kapok fabric–polyester composites provide a new class of materials that have demonstrated industrial potential. The increase in flexural strength and modulus obtained as the fiber volume fraction increases shows the promise of these composites for commercial use, as design applications frequently involve bending rather than tensile modes. Comparative analysis shows that addition of kapok fiber into viscose/polyester blended fabric improves the warmth retention, resistance to ultraviolet radiation and crease recovery, whereas the air permeability, drapability, abrasive resistance and wettability deteriorate (Hong et al., 2012). Considering the processing advantages and good technical properties, kapok fiber-reinforced epoxy composites have also been developed to investigate their dielectric constant and dielectric loss values (Mani et al., 2012). The potential of using kapok fiber reinforcement in polymer matrices for end uses not requiring extreme mechanical properties has been demonstrated (Mwaikambo et al., 2000; John and Anandjiwala, 2008). Moreover, these positive results obtained using kapok fiber will revamp the commercial value of this fiber with additional advantages for the environment (Mwaikambo and Bisanda, 1999).

2.2. Kapok fiber fillers

The increasing demand for these cellulose materials as fillers in a wide variety of matrices derives from their desirable properties such as low cost, renewability, biodegradability and favorable specific properties compared with conventional matrix fillers, like glass and carbon fibers. The application of cotton–kapok fiber as reinforcing material in unsaturated polyester resin has been investigated, after first treating the kapok fiber with 5% sodium hydroxide to improve its wetting ability by extracting the non-cellulose substances to improve the fiber-matrix adhesion. Cotton–kapok fiber-polyester composites constitute a new class of materials that has demonstrated industrial potential. With increasing fiber content in the composite, the
flexural strength and modulus are also improved (Mwaikambo and Bisanda, 1999). By suspended emulsion polymerization, a series of polybutylmethacrylate (PBMA)/kapok fiber composites have been prepared and used as oil-absorbing materials, where kapok fiber is used as a filler to construct a network with a low crosslinking and a loose structure. Under the optimum polymerization conditions of amount of initiator 0.4 wt.%, amount of crosslinker 1.0 wt.%, amount of emulsifier 2.0 wt.%, and content of KF 8.0 wt.%, the composite exhibits the best oil absorbency, at 14.6 g/g for toluene and 26.0 g/g for chloroform, while the pure PBMA resin exhibits oil absorbency of only 9.2 g/g in toluene and 15.6 g/g in chloroform (Wang et al., 2013b).

2.3. Kapok fiber grafting

Due to the presence of hydroxyl groups, kapok fiber can be grafted to provide the resulting product with certain functions or to facilitate further modification. Prior to the grafting reaction, kapok fiber is generally subjected to a pretreatment (such as with NaClO2) to render it hydrophilic. Under irradiation with Co-60 gamma rays, the grafting of styrene, glycidylmethacrylate (GMA) or acrylic acid (AAc) onto kapok fiber has been achieved, and the grafting yield increases with increasing temperature, reaction time, monomer concentration and radiation dose (Kang et al., 2007; Cho et al., 2007). Combining the advantages of natural plant fibers and synthetic polymers, kapok fiber-grafted polystyrene can be obtained under the optimum preparation conditions of initiator concentration 1.77 mmol/L, monomer concentration 0.16 mol/L, reaction temperature 80°C and reaction time 2 hr, and the resulting grafted polymer shows a fast absorption rate and high absorption capacity for chloroform and toluene. The absorption equilibrium can be reached within about 15 min, with an oil absorption capacity of 65.4 and 43.2 g/g for chloroform and toluene respectively (Wang et al., 2012c). By simultaneous free-radical graft copolymerization and cross-linking reactions, kapok fiber-grafted poly(sodium acrylate) superabsorbent hydrogel has also been developed in our laboratory. The incorporation of kapok fiber can improve the water absorption capacity and gel content, and the hydrogel with 10 wt.% kapok fiber shows the best swelling properties, with controlled water absorbency from 196 to 356 g/g in distilled water and from 39 to 61 g/g in 0.9 wt.% NaCl solution (Shi, 2012).

2.4. Coated kapok fiber

Due to coverage by small amount of plant wax, the surface of kapok fiber is smooth, which makes it difficult to effectively retain oils in fiber assemblies. To enhance the oil sorption property, surface modification of kapok fiber using materials with low surface free energy to prepare a hydrophobic surface can endow the resulting materials with new lipophilic properties, leading the resulting materials to be more valuable for oil spill cleanup.

Using PBMA and polystyrene (PS) as the modification agents, two kinds of oil absorbers with high sorption capacity were prepared by a facile solution-immersion process. The coated

Fig. 2 – Pictures of water droplet (dyed with methylene blue) on (a) raw, (b) treated, and (c) superhydrophobic kapok fiber surface; oil droplet (dyed with oil red O) on (a1) raw, (b1) treated, and (c1) superhydrophobic kapok fiber surface (Wang et al., 2012b). Copyright 2012, reproduced with permission from Elsevier.
Kapok fibers showed higher oil-absorbing capacities than the raw kapok fiber for gasoline, diesel, soybean oil, and paraffin oil, and the oil sorption capacity of the coated fiber was up to 80 times its weight. The absorbed oils can be easily recovered by a simple vacuum filtration process and the recovered coated fiber can still be used for several cycles without an obvious loss in oil sorption capacity (Wang et al., 2013c). As is known, silica coatings made by the condensation between the hydroxyl groups of hydrolyzed silanes and those present on the surface of cellulose show an excellent adhesion on cellulosic materials. Hence, it is feasible to turn the surface of kapok fiber from hydrophobicity to superhydrophobicity by the incorporation of silica nanoparticles onto the surface of kapok fiber by a sol–gel method and subsequent hydrophobic modification using hydrolyzed dodecyltrimethoxysilane (DTMS). As shown in Fig. 2, the blue-colored water drop shows a large contact angle on raw kapok fiber ($\theta = 116^\circ$), while the water drop sinks rapidly into the NaClO$_2$-treated kapok fiber. The kapok fiber coated by silica hydrosol with subsequent hydrolyzation of DTMS has a larger contact angle of $151^\circ$. When a red-colored oil drop is applied on the surface, the drop sinks completely into the three kinds of kapok fiber within a very short time. Different from raw and NaClO$_2$-treated fibers, the external surface of coated fibers is densely covered by silica nanoparticles without any interstices, while the internal hollow lumen is not blocked by the silica nanoparticles (Wang et al., 2012b). This coated kapok fiber can quickly absorb diesel and soybean oil up to above 46.9 and 58.8 g/g, with an improvement in oil sorption capacity of 46.6% and 20.2% compared with raw kapok fiber. This coated fiber also exhibits excellent oil/water selectivity in the cleanup of oil over water. Furthermore, hydrophobically modified nano-silica can disperse well in PBMA solution based on the hydrophobic–hydrophobic effect and then coat the surface of kapok fiber to create a new surface with nanometer-sized roughness. The constructed hierarchical micro- and nanostructures of the surface will offer more micro-areas to facilitate the retention of oils in the kapok fiber assembly (Wang et al., 2013d).

In order to modify the surface of kapok fiber to load more Au nanoparticles, the surface of kapok fiber is first modified with polyacrylonitrile (PAN) coating to improve the hydrophilicity and adsorption ability via a cetyltrimethylammonium bromide (CTAB)-assisted self-assembly method (Fig. 3). The in situ prepared PAN on the kapok surface forms a thin polymer coating layer. At the same time, there are many PAN particles formed in the dispersion, and these PAN particles deposit on the fiber surfaces, depending on the amount of CTAB used. This constructed PAN coating improves the specific surface area and hydrophilicity of the composite, and can be used as a catalyst carrier for Au nanoparticles (Fan et al., 2012). However, this coated composite cannot be formed effectively by immersing the kapok fiber directly into PAN solution. In that case, the polymer prefers to either aggregate in the gaps between neighboring kapok fibers or form threads hanging among the fibers. Our previous study revealed that in an acid aniline solution, kapok-fiber-oriented polyaniline can be directly prepared via in situ polymerization of aniline monomer. This may be ascribed to the fact that under acid conditions, the kapok fiber surface converts from hydrophobic to hydrophilic.

3. Applications as absorbing materials

3.1. Oil-absorbing material

Owing to its hollow lumen and waxy surface, kapok fiber shows hydrophobic–oleophilic characteristics, and kapok fiber assemblies possess good buoyancy and cannot be sunk in mixtures of oil and water (Rengasamy et al., 2011). Therefore, kapok fiber can be potentially applied as a filter product for deep-bed filtration to achieve oil/water separation. As shown in Fig. 4, a typical diesel/water separation process indicates that the dynamic behavior of oil/water separation in kapok filters is classified into four stages: infiltration, separation, displacement and equilibrium (Huang and Lim, 2006). In addition to excellent oil/water separation, the kapok filters have excellent capability for reducing COD and turbidity during the process (Rahmah and Abdullah, 2010). The kapok fiber can retain stability after fifteen cycles of reuse with only 30% of sorption capacity reduction (Abdullah et al., 2010). Kapok fiber can selectively absorb significant amounts of oil (40 g/g of fiber) from an oil suspension in freshwater and

---

Fig. 3 - Schematic illustration of the fabrication of kapok-PAN microtubes (Fan et al., 2012). Copyright 2012, reproduced with permission from Elsevier.
seawater (Hori et al., 2000), with high oil-to-water sorption (O/W) ratios ranging from 19.35 to 201.53 (Ali et al., 2012).

For kapok fiber, the hollow structure is beneficial due to its large effective porosity, and the waxy surface can enhance its oil adherence ability. First, the oils are absorbed by hydrophobic interactions and van der Waals forces between the oils and the waxy surface. Secondly, the oils enter the kapok assemblies and penetrate into the kapok lumens through internal capillary movement. The amounts of oil absorbed and retained within the kapok assemblies depend on the oleophilicity of the kapok fiber and the physical characteristics of the model oils including but not limited to density, viscosity, surface tension and contact angle with the kapok surface (Lim and Huang, 2007b). Economically, kapok is relatively cheap compared to polypropylene. Environmentally, kapok fiber can be recovered from discarded bedding, upholstery, and life preservers for reuse as an oil-absorbing material. Due to its biodegradability, kapok fiber can be ultimately disposed of for biomass energy recovery, thus leaving no secondary waste to pollute the environment.

For further improvement of oil sorption properties, the kapok fiber can be coated to show a new lipophilic property. Using PBMA and PS as the modification agents, two kinds of oil absorbents with high sorption capacity were prepared by a facile solution-immersion process. Compared with raw kapok fiber, the coated kapok fibers showed higher oil-absorbing capacities for gasoline, diesel, soybean oil and paraffin oil, with an oil sorption capacity of up to 80 times their weight (Wang et al., 2013c). Grafting copolymerization or esterification modification is also effective in increasing the hydrophobicity of kapok fiber to enhance its oil sorption capacity (Wang et al., 2012c, 2013a). More importantly, the oil sorption capacity of kapok fiber can be further enhanced by modifying its smooth surface into a rough surface with hierarchical micro- or nano-structures (Wang et al., 2013d). As shown schematically in Fig. 5, hydrophobic-modified nano-silica can be uniformly dispersed in PBMA solution via the hydrophobic–hydrophobic effect. After the coating process, a new surface with hierarchical micro- and nano-structures is created. The nano-meter sized roughness is derived from the combined silica nanoparticle-rough PBMA deposit sediment with low surface energy, which will offer more micro-areas that facilitate the retention of oil in the fiber assembly. Accordingly, more oils can be retained in the fiber assembly. To change the surface properties from hydrophobicity into superhydrophobicity, the surface of kapok fiber can also be coated by the incorporation of silica nanoparticles and subsequent hydrophobic modification using hydrolyzed DTMS (Wang et al., 2012b). This superhydrophobic fiber can quickly absorb diesel and soybean oil up to above 46.9 and 58.8 g/g. For comparison purposes, Table 1 lists some kinds of oil-absorbing materials made from kapok fiber and its composites.

3.2. Metal ion-absorbing material

Kapok fiber shows a poor affinity toward metal ions, but it can adsorb an extractant used in metal solvent extraction and serve as the support for the impregnated metal adsorbent. Higa et al. (2011) employed 2-ethylhexyl phosphonic acid mono-2-ethylhexyl ester as the extractant to obtain a solvent-impregnated kapok fiber, and concluded that the kapok fiber possessed a higher impregnation ability for the extractant than conventional solvent-impregnated resins, such as cross-linked polystyrene and crosslinked polymethacrylic ester, and thus solvent-impregnated kapok fibers showed a higher adsorption ability for Eu(III) (0.685 mmol/g) (Zhou et al., 2010). The ability to remove Bi(III), Cd(II), Cu(II), Fe(III), Ni(II), Pb(II), and Zn(II) from an aqueous nitrate medium with bis(2-ethylhexyl) phosphoric acid (D2EHPA)-impregnated kapok fiber (SIF) in comparison with D2EHPA-impregnated resin using XAD7HP as the support (SIR) and solvent extraction with D2EHPA dissolved in a nonpolar organic solvent (SX) was evaluated, and the results indicate that SIF is more advantageous than SIR and SX in terms of the amount of D2EHPA necessary to achieve a certain removal percentage, and better than SIR in terms of removal rate (Huynh and Tanaka, 2003).

In order to alter the hydrophobicity of kapok fiber to hydrophilicity, a series of chemical modifications on the kapok fiber, e.g. oxidative treatments with NaClO2–NaIO4–NaClO2, have been performed. First, NaClO2 treatment was employed to break the phenolic compounds, particularly the lignins. Second, periodate oxidation was conducted on the

---

**Fig. 4** – Observation of 2.5% diesel/water separation by kapok filter with packing density of 0.07 g/cm³: (a) water front advancement, (b) diesel front advancement, and (c) filter column at breakthrough (Lim and Huang, 2007a).

Copyright 2007, reproduced with permission from Elsevier.
Kapok fiber shows a relatively homogeneous hollow tube morphology, which can be anticipated to direct the growth orientation of polyaniline via in situ rapid polymerization. Polyaniline carries large amounts of amine and amine functional groups, and thus is expected to have attractive interactions with negatively charged anions because of its innate cationic nature. Compared with polyaniline, polyaniline-coated kapok fiber shows a comparable adsorption capacity for Cr(VI), but faster adsorption kinetics, with a rate constant twice than that of polyaniline. Coexisting Cu(II) and Ni(II) ions had no obvious effects on Cr(VI) adsorption, suggesting that the as-prepared kapok fiber/polyaniline can be used as a highly efficient and economically viable adsorbent for selective Cr(VI) removal (Zheng et al., 2012a). Furthermore, the kapok fiber can guide the polymerization orientation of allylthiourea, a sulfur-containing species with an unsaturated aliphatic chain, and the resulting material exhibits high adsorption capacity for Au(III) via an adsorption-coupled reduction pathway (Zheng et al., 2014). To enhance the chemical activity, kapok fiber can also be coated with PAN for subsequent adsorption. The resulting kapok fiber/PAN microtubes can stabilize Au nanoparticles due to the coordination interaction between metal atoms and ligand heteroatoms (Fan et al., 2012). All the results promise that this low-cost, widely available and environmentally friendly natural fiber will find practical application in the removal of heavy ions from polluted water.

3.3. Dye-absorbing material

Kapok fiber contains high contents of cellulose and lignin, and these components show high affinity to dyes in aqueous solution. However, kapok fiber has not been investigated for its adsorption characteristics for dyes to the same extent as other agro-products, due to the fact that the waxy layer on the surface of kapok fiber makes it water repellent. Therefore, kapok fiber has to be pretreated to make it hydrophilic before it is used to remove dyes from aqueous solution. When treated with sodium chlorite, kapok fiber transforms from hydrophobic to hydrophilic, and simultaneously, the lignin can be removed from kapok fiber, leading the amorphous region present in kapok fiber to expand (Wang et al., 2012a). Wang et al. used a response surface methodology (RSM) based on the three-level three-factorial Box–Behnken design to study the effects of three variables, including NaClO2 content, acetic acid content and reaction temperature, on the adsorption capacity for MB. They found that the resulting optimum adsorbent shows a good adsorption capacity for MB (110.13 mg/g) (Liu et al., 2012a).

Because of the thin wall and large lumen, kapok fiber can be used as a natural bio-template to fabricate a series of microtubes with high length/diameter ratio and controllable wall thickness and morphology (Zhang et al., 2010). This fabrication is possible not only for inorganic materials, such as SiO2 microtubes and carbon microtubes, but also for some polymers, such as poly(pyrrrole) and poly(aniline). The oriented growth of these polymers on kapok fiber can not only produce a unique kapok fiber-aligned morphology, but also provide kapok fiber with tailored functional groups. Wang et al. found that kapok fiber-oriented polyaniline shows good adsorption performance for three sulfonated dyes including Congo Red...
and 137.00 mg/g for phenol (Rong and Zhou, 2009). The adsorption capacity has been determined to be 274.11 mg/g for MB in wastewater treatment to adsorb MB and phenol, and the maximum adsorption efficiency was achieved after 70 min, the resulting activated carbon fiber can be employed in the removal of organic pollutants.

After activation with diammonium hydrogen phosphate at 650°C, activated hollow carbon fibers (KAHCF) have been prepared from kapok fibers. These fibers are eco-friendly adsorbents compared to kapok-derived activated hollow carbon fibers (KAHCF) without activation, steam-activated KAHCF showed a higher surface area (600-800 m²/g) and larger hollow pore volume, depending on steam activation time (Chung et al., 2013; Wang et al., 2008). Compared to activated hollow carbon fibers (KAHCFs) without activation, steam-activated KAHCF showed a higher surface area (600-800 m²/g) and larger hollow pore volume, depending on steam activation time (Chung et al., 2013; Wang et al., 2008).

Experimental results indicated that a significant amount of MB is adsorbed on the KAHCF at different temperatures and pH values. After activation with diammonium hydrogen phosphate at 650°C for 70 min, the resulting activated carbon fiber can be employed in wastewater treatment to adsorb MB and phenol, and the maximum adsorption capacity has been determined to be 274.11 mg/g for MB and 137.00 mg/g for phenol (Rong and Zhou, 2009).

### 3.4. Sound-absorbing material

Kapok fiber has a hollow structure, with a fiber wall of 16.5 ± 2.4 μm, a lumen diameter of 14.5 ± 2.4 μm and a fiber length of 25 ± 5 μm (Huang and Lim, 2006). This special structure is beneficial for sound absorption since it increases the chance of friction between sound waves and fibers. Combined with its excellent chemical stability, these properties make kapok fiber a promising light weight and environmentally-friendly sound-absorbing material for noise reduction.

Previous studies have revealed that the kapok fiber shows an excellent acoustical damping performance, and that the sound absorption coefficients of kapok fibrous assemblies are significantly affected by the bulk density, thickness and arrangement of kapok fibers, but less dependent on the fiber length. Compared with assemblies of commercial glass wool and degreased cotton fibers, kapok fiber assemblies with the same thickness but much smaller bulk density may have similar sound absorption coefficients (Xiang et al., 2013). The sound absorption coefficients of kapok fibrous assemblies are significantly affected by the bulk density, thickness and arrangement of kapok fibers, but less dependent on the fiber length. Compared with assemblies of commercial glass wool and degreased cotton fibers, kapok fiber assemblies with the same thickness but much smaller bulk density may have similar sound absorption coefficients (Xiang et al., 2013).

#### Table 1 – Different oil-absorbing materials made from kapok fiber and its composites.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Systems</th>
<th>Oil type, absorbency (g/g) or removal ratio (%)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw kapok fiber</td>
<td>Static</td>
<td>Machine oil, 40</td>
<td>Hori et al. (2000)</td>
</tr>
<tr>
<td>Raw kapok fiber</td>
<td>Static</td>
<td>Diesel oil, 31 ± 0.81</td>
<td>Zhou et al. (2010)</td>
</tr>
<tr>
<td>Raw kapok fiber</td>
<td>Static</td>
<td>Diesel oil, 19.35; crude oil, 25.71; new engine oil, 60.51; used engine oil, 49.94</td>
<td>Ali et al. (2012)</td>
</tr>
<tr>
<td>Raw kapok fiber</td>
<td>Static</td>
<td>Toluene, 30.4; chloroform, 40.2; xyylene, 29.2; n-hexane, 21.1; gasoline, 34.1; diesel, 38.9; soybean oil, 50.6; paraffin oil, 54.3</td>
<td>Wang et al. (2012a, 2013c)</td>
</tr>
<tr>
<td>Raw kapok fiber</td>
<td>Static</td>
<td>Diesel oil, 36; hydraulic oil, 43; engine oil, 45 at 0.02 g/cm³</td>
<td>Lim and Huang (2007b)</td>
</tr>
<tr>
<td>Raw kapok fiber</td>
<td>Static</td>
<td>Diesel oil, 36.7; used engine oil, 50.8; new engine oil, 47.4 at 0.02 g/cm³</td>
<td>Abdullah et al. (2010)</td>
</tr>
<tr>
<td>Raw kapok fiber</td>
<td>Static</td>
<td>High density oil, 12.6; diesel oil, 11.8 with the porosity of 0.95</td>
<td>Rengasamy et al. (2011)</td>
</tr>
<tr>
<td>HCl-treated kapok fiber</td>
<td>Static</td>
<td>Toluene, 35.5; chloroform, 51.8; xyylene, 34.8; n-hexane, 25.2</td>
<td>Wang et al. (2012a)</td>
</tr>
<tr>
<td>NaClO₃-treated kapok fiber</td>
<td>Static</td>
<td>Toluene, 36.4; chloroform, 52.3; xyylene, 35.5; n-hexane, 26.2</td>
<td>Wang et al. (2012a)</td>
</tr>
<tr>
<td>PBMA-coated kapok fiber</td>
<td>Static</td>
<td>Gasoline, 59.5; diesel, 64.9; soybean oil, 83.2; paraffin oil, 80.3</td>
<td>Wang et al. (2013c)</td>
</tr>
<tr>
<td>PS-coated kapok fiber</td>
<td>Static</td>
<td>Gasoline, 62.3; diesel, 67.8; soybean oil, 80.3; paraffin oil, 83.3</td>
<td>Wang et al. (2013c)</td>
</tr>
<tr>
<td>PBMA/SiO₂-coated kapok fiber</td>
<td>Static</td>
<td>Diesel oil, 64.5; soybean oil, 87.1; crude oil, 68.3; 150SN, 77.9; 20cst, 82.3</td>
<td>Wang et al. (2013d)</td>
</tr>
<tr>
<td>Acetylated kapok fiber</td>
<td>Static</td>
<td>Diesel oil, 34.1–35.9; soybean oil, 49.8–53.9</td>
<td>Wang et al. (2013a)</td>
</tr>
<tr>
<td>Superhydrophobic kapok fiber</td>
<td>Static</td>
<td>Diesel oil, 46.9; soybean oil, 58.8</td>
<td>Wang et al. (2012b)</td>
</tr>
<tr>
<td>kapok fiber</td>
<td>Static</td>
<td>Chloroform, 65.4; toluene, 43.2</td>
<td>Wang et al. (2012c)</td>
</tr>
<tr>
<td>PS-coated kapok fiber</td>
<td>Static</td>
<td>toluene, 14.6; chloroform, 26.0 with 8% KF</td>
<td>Wang et al. (2013b)</td>
</tr>
<tr>
<td>Raw kapok fiber</td>
<td>Deep-bed filtration</td>
<td>100% for diesel/water mixture and &gt;99.4% for hydraulic oil/water mixture</td>
<td>Huang and Lim (2006)</td>
</tr>
<tr>
<td>Raw kapok fiber</td>
<td>Deep-bed filtration</td>
<td>&gt;99% in 2.5% diesel/water influent</td>
<td>Lim and Huang (2007a)</td>
</tr>
</tbody>
</table>
4. Conclusions and future perspectives

In recent years, kapok fiber has received increasing attention as an eco-friendly material for its intrinsic advantages. Despite the increasing attention to kapok fiber, the difficulty in spinning of kapok fiber still limits its fabrication possibilities for broader applications. This can be partially solved by combining kapok fiber with other polymer matrices to achieve different kinds of composite materials. To improve the physical and chemical interactions at the interface and achieve composite materials with better performance, kapok fiber should be pretreated by chemical or physical means to enhance the intrinsic properties or alter the surface characteristics. Due to the limited number of studies reported, there are various aspects of kapok fiber research and development that remain open for further work. With the focus on this green cellulosic fiber, more studies should be carried out to expand the application fields for kapok fiber by taking advantage of its combination of high hollowness and hydrophobic–oleophilic characteristics. We believe that the development of novel technologies or methods in the future will promote the further utilization of this plant fiber and its composite materials, and this may open up promising new possibilities in the field of kapok fiber for high-added-value applications.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (Nos. 21107116, 21477135).

REFERENCES


Editorial Board of Journal of Environmental Sciences

Editor-in-Chief
X. Chris Le
University of Alberta, Canada

Associate Editors-in-Chief
Jiuhui Qu
Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China
Shu Tao
Peking University, China
Nigel Bell
Imperial College London, UK
Po-Keung Wong
The Chinese University of Hong Kong, Hong Kong, China

Editorial Board

Aquatic environment
Baoyu Gao
Shandong University, China
Maohong Fan
University of Wyoming, USA
Chihpin Huang
National Chiao Tung University
Taiwan, China
Ng Wun Jern
Nanyang Environment & Water Research Institute, Singapore
Clark C. K. Liu
University of Hawaii at Manoa, USA
Hokyong Shon
University of Technology, Sydney, Australia
Zijian Wang
Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China
Zhiwu Wang
The Ohio State University, USA
Yong Cai
Florida International University, USA

Environmental toxicology and health
Jingwen Chen
Dalian University of Technology, China
Jianying Hu
Peking University, China
Guibin Jiang
Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China

Environmental catalysis and materials
Tsuyoshi Nakanishi
Gifu Pharmaceutical University, Japan

Environmental analysis and method
Zongwei Cai
Hong Kong Baptist University, Hong Kong, China

Municipal solid waste and green chemistry
Pinjing He
Tongji University, China

Terrestrial environment
Christopher Anderson
Massey University, New Zealand
Zaocong Cai
Nanjing Normal University, China
Xinbiao Feng
Institute of Geochemistry, Chinese Academy of Sciences, China
Hongping Hu
Hunan Agricultural University, China
Kin-Che Lam
The Chinese University of Hong Kong
Hong Kong, China
Erwin Klumpp
Research Centre Juelich, Agrosphere Institute
Germany

Environmental biology
Yong Cai
Florida International University, USA
Henner Hollett
RWTH Aachen University, Germany
Jae-Seong Lee
Sungkyunkwan University, South Korea
Christopher Rensing
University of Copenhagen, Denmark
Bojan Sedmak
National Institute of Biology, Slovenia
Lirong Song
Institute of Hydrobiology, Chinese Academy of Sciences, China
Chunxia Wang
National Natural Science Foundation of China

Environmental catalysis and materials
Hong He
Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China
Jinhua Li
Tsinghua University, China

Copyright © Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V. and Science Press. All rights reserved.
Aims and scope

Journal of Environmental Sciences is an international academic journal supervised by Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. The journal publishes original, peer-reviewed innovative research and valuable findings in environmental sciences. The types of articles published are research article, critical review, rapid communications, and special issues.

The scope of the journal embraces the treatment processes for natural groundwater, municipal, agricultural and industrial water and wastewaters; physical and chemical methods for limitation of pollutants emission into the atmospheric environment; chemical and biological and phytoremediation of contaminated soil; fate and transport of pollutants in environments; toxicological effects of terrorist chemical release on the natural environment and human health; development of environmental catalysts and materials.

For subscription to electronic edition

Elsevier is responsible for subscription of the journal. Please subscribe to the journal via http://www.elsevier.com/locate/jes.

For subscription to print edition

China: Please contact the customer service, Science Press, 16 Donghuangchenggen North Street, Beijing 100717, China. Tel: +86-10-64017032; E-mail: journal@mail.sciencep.com, or the local post office throughout China (domestic postcode: 2-580).

Outside China: Please order the journal from the Elsevier Customer Service Department at the Regional Sales Office nearest you.

Submission declaration

Submission of the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere. The publication should be approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out. If the manuscript accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder.

Editorial

Authors should submit manuscript online at http://www.jesc.ac.cn. In case of queries, please contact editorial office, Tel: +86-10-62920553, E-mail: jesc@rcees.ac.cn. Instruction to authors is available at http://www.jesc.ac.cn.