Application of ionic liquids in food and environment

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Abstract. Ionic liquids are substances composed entirely of cations and anions that have a low melting point and are usually liquid at or below room temperature. This paper introduces the application of ionic liquids in the field of food and environment field, the ionic liquids in food in the field of synthesis, food separation and purification, food pigment extraction as well as the environment in the field of wastewater treatment, air treatment, soil remediation and waste resource utilization research progress were reviewed, and the prospect of development is forecasted.

Keywords: Ionic liquids; Food; Environment; application.

1. Application of ionic liquids in food industry

1.1. Application in synthesis

1.1.1. Synthetic perfume. Isoamyl cinnamate is a flavor that can be used as a deodorant. Li[1] studied the synthesis of Isoamyl cinnamate by transesterification catalyzed by 1-butyl-3-methylimidazole-p-toluenesulfonate ionic liquid under microwave irradiation, the conversion of Isoamyl cinnamate was 59.24% under the conditions of cinnamic acid 0.01 mol, molar ratio of ester to alcohol 1:14, amount of catalyst 14% of reactant mass, microwave power 400W and reaction time 30 min. Coumarin plays an important role in synthetic organic chemistry and is also an important perfume. Harjani et al. [2] discovered that 3-ethoxycarbonyl was synthesized coumarin by the Knoevenagel condensation of 2-hydroxyarylaldehydes with diethyl malonate in [Bmim]AlClx ionic liquid for the first time, with the yield of 78-92%.

1.1.2. Synthetic plasticizer. The currently widely used phthalate plasticizers have a certain degree of toxicity, and acetyl tributyl citrate is considered to be a qualified substitute for phthalate plasticizers because of its good safety and excellent plasticity. Guo et al.[3] studied the synthesis of acetyl tributylic citrate with acetic anhydride and self-made tributyl citrate as raw materials and [NH(CH3)2:CO]HSO4 acidic ionic liquid as catalyst. The molar ratio of acetic anhydride and tributyl citrate was 1:2 and the reaction temperature was 60°C, the yield can reach 98.7%. In addition, the yield can still reach 98.2% after 5 times of recovery.
1.2. Application in separation and purification

1.2.1. Separation and purification of pigments. In the separation and purification of food pigments, ionic liquids can be used alone as extractants. Liu et al. [4] used 1-butyl-3-methylimidazole bromide ([Bmim]Br) as the extractant and used microwave-assisted extraction of anthocyanins from cinnamon. It was found that the optimal process conditions of dealing with 20.0 g sample were 230W microwave irradiation power, 15min microwave extraction time and 10 liquid-solid ratio, the procyanidin yield is 4.58 ± 0.21%. Wu et al. [5] used 1-octyl-3-methylimidazole tetrafluoroborate ([C8mim][BF4]) as the extractant to separate and enrich beverages, sugar-containing and gelatin-containing sweets by dispersive liquid phase microextraction of the six synthetic food colorants, with a standard recovery rate of 95.8%-104.5%.

1.2.2. Separation and purification of fats and oils. Calvano et al. [6] studied equimolar amounts of tributylamine (TBA) and α-cyano-4-hydroxycinnamic acid (CHCA) to prepare ionic liquid TBA-CHCA to extract hazelnut oil mixed in olive oil, and detected by matrix-assisted laser desorption ionization time of flight mass spectrometry (MALDI-TOF-MS), the detection limit of hazelnut oil is 0.1%.

1.3. Application in natural pigment extraction

The extraction of curcumin from turmeric by ionic liquid N,N-dipropyl ammonium N′,N′-dipropylcarbamate (DPCARB) was studied by Sahne et al.[7]. By adding 0.2 mol/L of sodium acetate buffer and 1% to 5% of α-amylase and amylosidase, shaking at 130 r/min for a certain period of time, the curcumin yield increased from 3.58% to 5.73%.

2. Application of ionic liquids in environmental field

2.1. Application in wastewater treatment

2.1.1. Dyeing Wastewater. The pollutants of printing and dyeing wastewater mainly come from the dyes and chemicals used in the dyeing and finishing process of fiber materials, the discharge of printing and dyeing wastewater also causes environmental pollution and waste of resources, so it is very necessary to extract dyes from the printing and dyeing wastewater at one time. Lin et al.[8] studied the hydrophobic ionic liquid 1-butyl-3-methylimidazole hexafluorophosphate ([Bmim][PF6]) to recover weak acid blue 6B from printing and dyeing wastewater, and the recovery rate can reach 95%. Lawal et al.[9] modified peanut shells and AC with 1-methyl-3-decahexyl imidazole ionic liquid, prepared ILNS and ILAC and used them to adsorb Congo red (CR) and reactive blue 4(RB) from aqueous solutions. The modified materials (ILNS and ILAC). showed improved adsorption capacities of 136.4 and 150.0 mg/g for CR and 290.0 and 364.4 mg/g for RB respectively.

2.1.2. Organic Wastewater. Ionic liquids can remove many organic pollutants in wastewater. Zhu et al.[10] immobilized 1-butyl-3-vinylimidazolium bromide ionic liquid on the surface of silica and synthesized an ionic liquid functionalized polymer (IL-P) and IL-P on 2,4-di The removal of four phenols including chlorophenol (2,4-DCP), bisphenol A (BPA) and 2,4-dinitrophenol (2,4-DNP) was studied. The results showed that the adsorption equilibrium can be reached within 15-60 minutes, and the maximum adsorption capacity of IL-P for 2,4-DCP, BPA, 2,4-DNP and 2-NP is 239.7mg/g and 68.39mg/g, 56.86mg/g and 64.28mg/g, respectively.

2.1.3. Heavy metal wastewater. In recent years, the use of ionic liquids to remove heavy metal ions in wastewater has been reported. Zhang et al.[11] studied the extraction performance of the complexing agent EDTA-assisted hydrophobic ionic liquid Aliquat 336(trioctyl methyl ammonium chloride) for Cu²⁺ in simulated wastewater, the removal rate of Cu²⁺ can reach 88.7%. Fuerhacker et al.[12] studied the treatment ability of heavy metals in wastewater by the quaternary ammonium salt-phosphate-based
ionic liquid trihexyl (tetradecyl) thiosalicylic acid phosphine \([\text{PR}_4][\text{TS}]\), trihexyl (tetradecyl) phosphine 2-(methyl) Thio)benzoic acid \([\text{PR}_4][\text{MTBA}]\), trioctyl methyl ammonium thiosalicylate \([\text{A336}][\text{TS}]\) and trioctyl methyl ammonium 2-(methyl thio) benzoic acid \([\text{A336}][\text{MTBA}]\). At a dosing rate of 20 g/L, \([\text{PR}_4][\text{TS}]\) has removal rates of 46-95%, 97%, 56-92% and 58-76% for Cu, Zn, Pb and Cd respectively, \([\text{PR}_4][\text{MTBA}]\) has removal rates of 78-99%, 20-43%, 85-99% and 0- 26% for Cu, Zn, Pb and Cd respectively, \([\text{A336}][\text{MTBA} ]\) is also as efficient as \([\text{PR}_4][\text{MTBA} ]\).

2.2. Application in atmospheric treatment

The pollutants in the atmosphere mainly include VOC, NH\(_3\), SO\(_2\), CO\(_2\) and other gases. Ionic liquids have a good development prospect in the field of air pollution prevention and control. Fahri et al.\[13\] synthesized four new bio-based ionic liquids using choline chloride and fatty acids as raw materials, hexyl choline levulinate, octyl choline levulinate, hexyl choline lactate and octyl choline lactate, and studied the adsorption performance of ionic liquid on toluene, and methyl ethyl ketone and other voc gases. Chol-C\(_8\)-Lev is the most effective solvent for toluene adsorption, with an adsorption ratio of 156. None of the solvents studied adsorbed better than water for methyl ethyl ketone. The solvent can be recycled with constant capacity during five times of adsorption and desorption. Wang et al.\[14\] used ionic liquid \([\text{Bmim}][\text{NTf}_2]\) as an absorbent to remove volatile organic compounds (VOCs). With a toluene concentration of 300ppm, a flow rate of 50 mL/min, and a temperature of 20\(^\circ\)C, the maximum absorption rate of \([\text{Bmim}][\text{NTf}_2]\) to toluene is 98.3%, and the ionic liquid can be recycled at least 5 times during the adsorption process.

Qi et al.\[15\] used proton ethanolamine hydrochloride (EACl), weak acidic resorcinol (Res) and neutral glycerol (Gly) to form a ternary DESs (eutectic solvent) to efficiently and reversibly absorb NH\(_3\), and found that at 293K and 0.1MPa, it can absorb 0.240g NH\(_3\) (EACl: Res: Gly=1: 4: 5) / g DES, it has abundant hydrogen bonding sites to absorb NH\(_3\) without breaking structure.

2.3. Application in soil remediation

2.3.1. Organic matter (pesticide) pollutes the soil. Soil organic pollutants are mainly chemical pesticides, chemical pesticides are rich in organophosphorus pesticides, organochlorine pesticides, amines, etc, ionic liquids can efficiently and greenly extract pesticides from the soil. Javiera et al.\[16\] used 1-butyl-3-methylimidazole (Bmim+) as the cation, and different amino acid AAs such as L-cysteine (L-Cys), L-alanine (L-Ala), L -Proline (L-Pro), with L-histidine (L-HI), L-phenylalanine (L-Phe), L-serine (L- Ser), L-glycine (L-Gly) ), L-Methionine (L-Met) and L-Asparagine (L-Asp) as anions, synthesized a series of ionic liquids (Bmim[AA]) and degraded the organophosphorus pesticide paraoxon. The results showed that the half-life of Bmim[AA] to degrade paraoxon is Bmim[Gly]<Bmim[Met]<Bmim[Ala]<Bmim[Cys]<Bmim[Phe]<Bmim[Pro]<Bmim[His]<Bmim[Asp]<Bmim[Ser]<L-[Pro]. The degradation efficiency of paraoxon in Bmim[AA] is high. Yan et al.\[17\] used 1-butyl-3-methylimidazolium tetrafluoroborate as the extraction solvent and ammonium hexafluorophosphate as the ion pairing agent, and studied the simultaneous extraction of isopropyl sulfide, cyanamide, isopropyl sulfide and oxadiazole in soil by homogeneous ionic liquid microextraction, with the recoveries of 74.2%-97.9%.

2.3.2. Heavy metals contaminated soil. The heavy metals in common contaminated soils mainly include copper, cadmium, lead, zine and other elements with significant biological toxicity. At present, there have been some reports on the use of ionic liquids for the remediation of heavy metal contaminated soils. Guo et al. \[18\] designed and synthesized a hydrophobic functionalized ionic liquid \([\text{Na}_{4444}][\text{AOT} ]\) based on bis (2-ethylhexyl) sulfosuccinate anion using sodium bis (2-ethylhexyl) sulfosuccinate sulfonate as raw materials and studied the extraction ability of Cd from soil under ultrasonic conditions. The results showed that under ultrasonic conditions, \([\text{Na}_{4444}][\text{AOT} ]\) can extract more than 95.08% Cd from aqueous solution and more than 62.75% Cd from soil. Using \([\text{Na}_{4444}][\text{AOT} ]\) significantly reduces the bioavailability of Cd in the soil and its hydrophobicity separates Cd from the soil solution with minimal damage to the
soil. Liu et al. [19] prepared acetamide-citric acid low eutectic ionic liquid and studied its extraction effect on Cu from soil. The results showed that at 35°C, the extraction rate of Cd reached 99.51% at a concentration of 2mol/L, and was compared with other ionic liquids with the same concentration, as shown in the figure below. (a. Acetamide-citric acid b. Acetamide-oxalic acid c. Acetamide-malic acid d. Acetamide-tartaric acid)

![Fig.1](image-url)

2.4. Application in the utilization of waste resources

Waste includes electronic waste, waste paper, domestic waste, etc. Ionic liquid can be used to effectively recycle waste. Zhang et al. [20] used ionic liquid 1-carboxymethyl-3-methylimidazolium hydrogen sulfate ([CM-MIM][HSO₄]) as the leaching agent and studied the process of Cu leaching from waste printed circuit boards. The results showed that the leaching rate is 94.30% with a solid-to-liquid ratio of 1/20, a leaching time of 2h, and a temperature of 80°C.

Yan et al. [21] prepared 1-(4-butyl sulfonic acid)-3-methyl imidazole hydrogen sulfate [(N-but-SO3H)MIm][HSO4] immobilized ionic liquid by sol-gel technology and impregnation method and evaluated its catalytic performance. The results showed that when the catalyst was used to catalyze the esterification of waste cooking oil with high free fatty acid content, biodiesel with a yield of up to 94.7% can be obtained through the alkyl-catalyzed transesterification, and the waste can be recycled.

3. Conclusion

Ionic liquids in food in the field of synthesis, separation and purification of food, food pigment extraction and environment in the field of wastewater treatment, air management, soil restoration, waste utilization, etc have a preliminary study, but the research is not deep enough. Ionic liquids are expensive and have high viscosity, which restrict the application of ionic liquids in food and the environment. With the in-depth research on ionic liquids as green solvents and emerging functional materials, more advanced research results will be applied to food and the environment.

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