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Ionic Liquid Synthesis in the Sustainable Recovery of Anthracene and Barite Resources

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Abstract

Material flow and reuse options are critical to development, especially since waste management initiatives imbibe a systematic approach to analyse recovery options to minimise environmental impacts. This study investigates the novel use of 1-propyl-3-methylimidazolium bromide (propIMIMBr) ionic liquid in the sustainable recovery of anthracene and barite derivatives in drilling waste. Quantitative and qualitative research methods were adopted to investigate the separation and recovery of barite and anthracene from a mixture using propyIMIMBr ionic liquid as a solvent. Initially, the mixture containing 0.2g of anthracene and barite underwent stirring at 1000 rpm with 2g of propyIMIMBr for 20 minutes at room temperature. This process effectively dissolved barite into the propyIMIMBr ionic liquid while keeping anthracene insoluble. Quantitatively transferring the viscous mixture to a membrane filtration apparatus facilitated the separation, with the ionic liquid and dissolved barite precipitating into a vacuum flask, leaving anthracene as a dry residue on a 50mm filter paper. Recovery of the ionic liquid involved washing the precipitate with acetone, followed by decantation and membrane filtration to remove barite traces. The residues of barite collected weighed 0.36g, indicating the presence of anthracene impurities. The precipitated ionic liquid in acetone was then dried under vacuum, yielding a dry residue. The recovered

ionic liquid matched the reference spectrum closely, indicating successful recovery. However, both barite and anthracene were recovered with impurities of each other, as no organic solvent capable of dissolving both substances was available. Additionally, the solvent's viscosity hindered attempts to dissolve barite using ethanolamine. In conclusion, this study highlights the efficacy of using propyIMIMBr ionic liquid for the selective separation of barite and anthracene while suggesting areas for further optimisation and exploration in solvent choice and purification techniques.

Keywords: anthracene, barite, material recovery, propyIMIMBr ionic liquid, selective separation, waste management.

Introduction

Clean processes for material recovery, also called green chemistry, are sustainable waste management that enables a steady supply of critical chemicals through waste material recovery. It envisages novel applications integrating methods for optimising material flow and reducing waste (Arun et al., 2024 & Ncube et al., 2022). The revolution towards a clean environment is becoming a global reality, and adopting a material recovery protocol proffers solutions to efficiently extract materials, especially chemicals, that can be innovatively reused in manufacturing (Arun et al., 2024). Oil field wastes contain several pollutants, such as petroleum hydrocarbons, inorganic and organic and can harm the environment. Thus, novel technologies are required to recover the oil for other industrial applications (Patni & Ragunathan, 2022). Many studies have investigated innovative technologies for high-grade recycling (Cramer, 2018), and different drivers determine waste management solutions in diverse industries. Amongst them are material efficiency, strict regulations and sustainable development (Wierink et al., 2010). Sustainable waste management strategies advocate for a clean environment, mitigating adverse impacts from a mixed waste stream and guaranteeing natural resource protection (Perkumienė et al., 2023).

Pollution Control and Resource Management

Improper waste management can cause environmental contamination and social issues (Ferronato & Torretta, 2019). Effective waste management strategies

improve opportunities for localised recycling, thereby boosting sustainable development (Ferronato et al., 2019). Making raw materials much more resource-efficient is essential and synonymous with climate change mitigation (Hagelüken & Goldmann, 2022). Recycling is one of the critical actions driving an increase in the recovery rate (Hopewell et al., 2009). Barite is a common weighting material used in the oil and gas industry, and it is significant in drilling mud to control mud density (Al Jaberi et al., 2023). However, excessive barite mining can threaten the lives of the locals close to the mining sites through the uncontrolled release of pollutants, which are the leading causes of severe health hazards (Afolayan et al., 2020). World barite resources are about 2 billion tons, with over 80% used as a weighting agent in drilling fluids (Garside, 2020; Research Drive, 2020 & USGS, 2019). Finding a replacement for barite raw materials in the production of drilling fluid is complex, as consumption is expected to grow due to strategic developments in the oil and gas field (Boyarko & Bolsunovskaya, 2023).

Polycyclic aromatic compounds such as anthracene have the potential to bioaccumulate in soils, and food sources (Chen & Yuan, 2012), which makes such places vulnerable to these effects (Ediagbonya et al., 2022). The adaptation of ionic liquid proffers a potential opportunity for selectively recovering anthracene for possible reuse in manufacturing pesticides, plastics, medications and pigments (Wania & Mackay, 1996). Over the years, there has been a rise in aromatic compounds, which is of concern due to their toxic properties (Patel et al., 2020) and regarded as one of the most prevalent organic pollutants (Ukaogo & Igwe, 2015). Tricyclic aromatic hydrocarbons are tricky to separate due to similar characteristics and boiling points, particularly anthracene (Bei et al., 2023). Some studies have proven the simultaneous removal of heavy metals and anthracene biodegradation (Goswami et al., 2017). Anthracene derivatives are used extensively in biology, chemical sensors, and optoelectronic materials as fluorescent probes (Lu et al., 2006). Anthracenes are currently the subject of research in several areas, investigating their use in the biological field (Baviera & Donate, 2021) and their application in light-emitting diodes (Huang et al., 2012), organic field-effect transistors (Chen et al., 2018), polymeric materials (Van & Du Prez, 2018), solar cells (Kivrak et al., 2017), and many other organic materials (Fang et al., 2017 & Zhao et al., 2017).

Conversion of Waste to Resources

The reuse of drilling waste for cement manufacturing, road construction and landfilling after treatment by stabilisation and solidification is effective in converting oil field wastes into a reusable resource globally (Tuncan et al., 2004; Boutemeur et al., 2003; Page et al., 2003 & Schumacher et al., 1991). Some studies have shown the potential for raw materials recovery and reuse of the different waste components (water and soil condensate) to power the drilling equipment on the platform (Foroutan et al., 2018). Meanwhile, the solids can be treated to produce a lightweight aggregate for manufacturing (Ayati et al., 2019). This finding is critical as many seasonal factories produce low-grade ceramic bricks, often not meeting the requirements (Klimova et al., 2022). Effective waste management is a continuous process which adapts novel technologies to maximise material recovery (Onwukwe & Nwakaudu, 2012). Solvent extraction is another treatment technology explored for material recovery from drilling waste. It utilises low boiling point organic solvents in the extraction of the residual hydrocarbon while the extraction liquid is evaporated for recycling (Shuchao et al., 2018). The new trend is converting waste materials from the oil industries to valuable resources for other purposes (Esosa & Omoregbe, 2020). Thus, life cycle assessment of drilling waste management technologies enables expert assessment and comparison of the drilling waste treatment option that is most viable (Ilinykh et al., 2023).

Sustainability of Chemicals in the Environment

High-density waste drilling fluid contains significant amounts of recyclable weighting reagents, which, if disposed can directly pollute the environment (Li et al., 2024). Scientists consistently develop solutions to turn drilling waste into environmentally friendly resources (Zha et al., 2017). Drilling waste management is closely associated with sustainable development as it provides suitable decisions in adopting a methodology for reducing waste (Mehta et al., 2018). The waste disposal sector offers hope for environmental sustainability, the potential to generate substantial income for any economy, and opportunities for effective waste management (Okedu et al., 2022).

Separation processes are critical in the chemical industry for separation, especially for hydrocarbons and aromatics, using ionic liquid solvents, which has shown future direction and opportunities (Yu et al., 2024). Drilling wastes are complex mixtures that make it difficult to extract valuable components. However, applying ionic liquids, especially from the imidazolium family, has shown positive results (Pazhoohan & Hezave, 2024). Some other ionic liquids, such as poly ionic liquids, have been synthesised and used for crude oil emulsion separation (Abdullah & Al-Lohedan, 2024). The novel functionalities of imidazolium-based ionic liquids and their characteristics make them high-efficiency extraction solvents for removing pollutants from complex mixtures (El-Nagar et al., 2024).

Room-temperature ionic liquids characteristically comprise asymmetric organic cations (Rauber et al., 2023) and have evolved as an important solvent-cum-electrolyte in many applications as a result of their high thermal stability and exceptional electrochemical activity (Banga et al., 2020). Many room-temperature ionic liquids possess good conductivity and an optimum electrochemical window, making them suitable for electrochemical sensor applications, including environmental monitoring (Paul et al., 2019). Applying ionic in the separation process depends on systematically studying ionic liquid extraction selectivity (Zhang et al., 2019). In this study, an imidazolium-based ionic liquid, 1-propyl-3-methylimidazolium bromide (propylMIMBr), is investigated for extraction and recovery of standard drilling waste components – anthracene and barite, form a simulated mixture.

MATERIALS AND METHODS

Table 1 outlines the conditions employed in the individual components' solubility testing, separation, and recovery processes for barite and anthracene using 1-propyl-3-methylimidazolium bromide (propyIMIMBr) ionic liquid.

Table 1: Extraction of Anthracene and Fluoranthene from propyIMIMBr IL Mixture

Two-component mix	Condition	Separation	Recovery
ionic liquid, anthracene and barite mixture	ionic liquid – 2g anthracene – 0.2g barite– 0.2g Mix – room temperature. Stirring – 1000rpm Duration – 20min	a. Membrane filtration: Transfer the mixture quantitatively using a glass rod into the membrane filtration apparatus. b. Precipitate ionic liquid and barite, leaving anthracene on the filter paper c. C. Wash the barite–ionic liquid mixture several times with acetone (in beaker 1) to recover barite. d. Decant ionic liquid-acetone mixture into another sizable beaker (beaker 2) and transfer to the rotary evaporator globe for further recovery e. Barite is recovered dry (in beaker 1)	Transfer the ionic liquid-acetone mixture to the rotary evaporator globe and run at 40°C; spin at 9 rpm for 45 minutes until a dry residue is obtained.
ionic liquid, anthracene and barite mixture	Heating - 60°C Stirring – 1000rpm Duration – 20min	Same separation protocol	Same recovery protocol
ionic liquid, anthracene and barite mixture	Heating – room temperature Stirring – 1000rpm Duration – 20min	Same separation protocol	Same recovery protocol

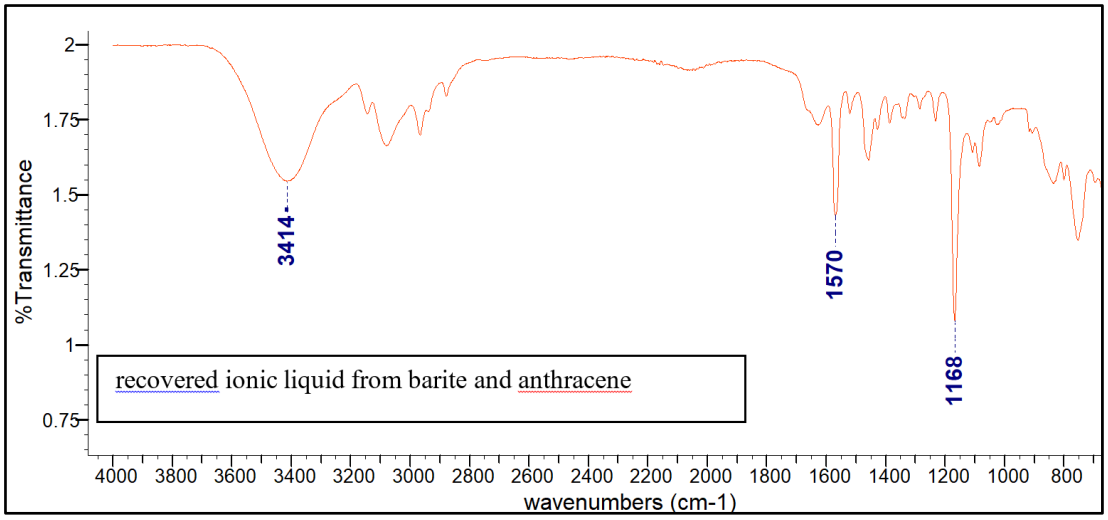
In this investigation, a mixture comprising 0.2g of anthracene and barite underwent stirring at 1000 rpm with 2g of propyIMIMBr ionic liquid for 20 minutes at room temperature to dissolve barite into the ionic liquid while maintaining anthracene

insolubility. Subsequently, the viscous mixture was quantitatively transferred to a membrane filtration apparatus using a glass rod. The residual mixture in the test tube was rinsed with acetone and transferred into a Buchner funnel. During filtration, the ionic liquid and dissolved barite precipitated into a vacuum flask, leaving a dry residue of anthracene on a 50 mm-sized filter paper. This method effectively separated barite from anthracene, facilitating subsequent analysis of the isolated components.

In order to recover the ionic liquid from the precipitate, the mixture is washed several times with acetone. Subsequently, the aqueous layer containing the ionic liquid is decanted and filtered using membrane filtration to remove barite traces. The residues of barite on the filter paper and test tube are collected and weighed, yielding 0.36g, which is higher than the quantity used in extraction (0.2g). This finding suggests that some anthracene impurities are present in the recovered product. The precipitated ionic liquid in the acetone mixture is dried under a 40-60°C vacuum for about 45 minutes until a dry residue of the ionic liquid emerges.

RESULT

At the end of the analysis, the researcher recovers the ionic liquid in a very high yield of 1.54g, closely matching the reference spectrum as represented in **Figure 1**. Barite is recovered in high yield but with impurities of anthracene, which cannot be removed as no organic solvent dissolves anthracene. The recovery of anthracene also includes impurities of barite, which cannot be removed due to the absence of an organic solvent capable of dissolving barite. The results of the recovered barite and anthracene are depicted in **Figure 2**. An attempt was made to dissolve the barite using ethanolamine; however, the solvent's viscosity hindered the removal of impurities.



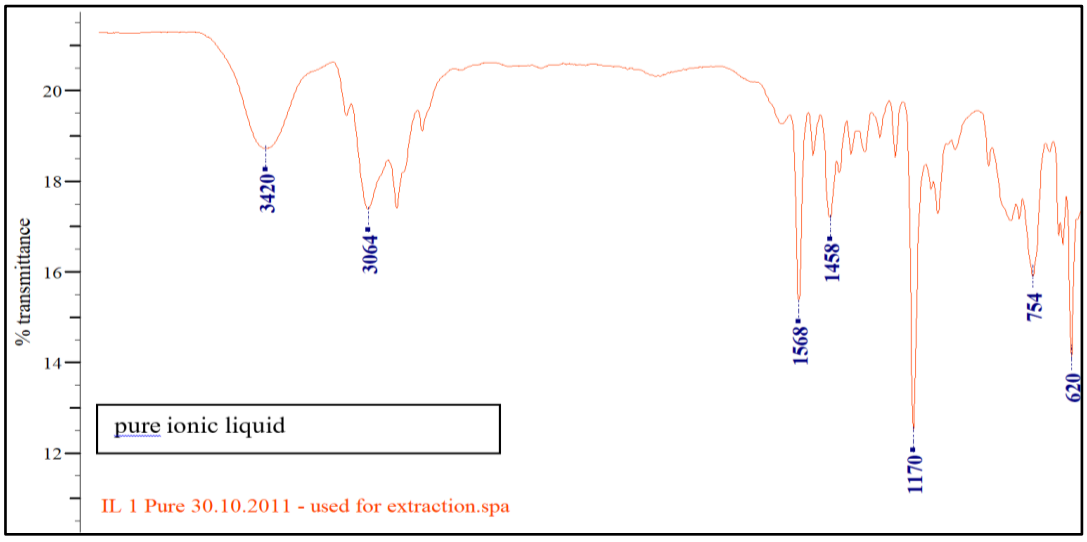
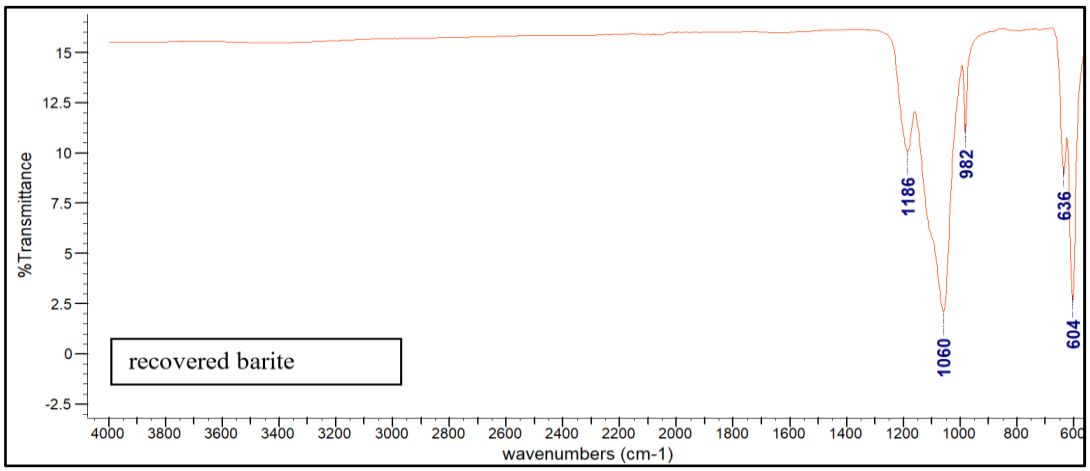
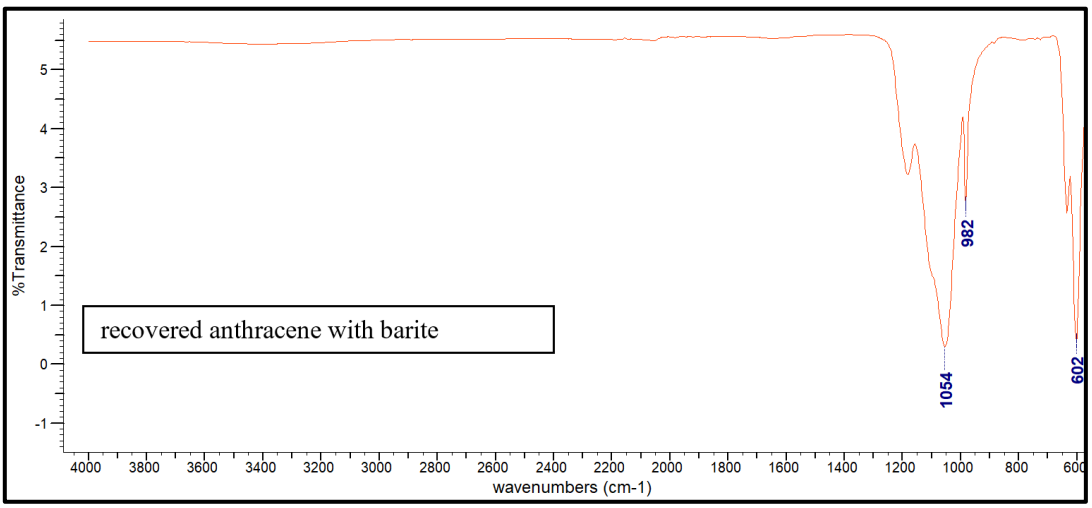


Figure 1: Recovered ionic liquid from anthracene and barite mixture





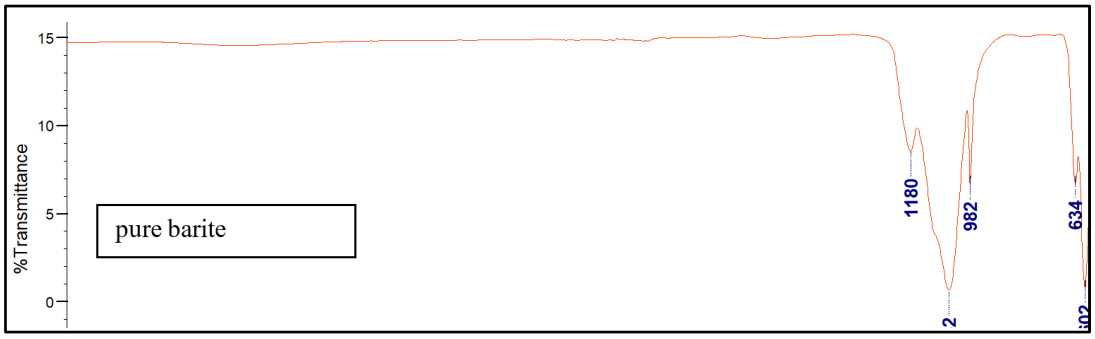


Figure 2: Recovery of Anthracene from Barite and propyIMIMBr Mixture

DISCUSSION

This discussion analyses this method's effectiveness, advantages, and limitations. The technique appears to be effective in achieving its objective of separating barite from anthracene. Stirring the anthracene and barite with propyIMIMBr ionic liquid dissolves barite into the solvent while anthracene remains insoluble. This selective dissolution allows for the isolation of barite from the mixture. The propyIMIMBr ionic liquid exploits the difference in solubility between barite and anthracene, enabling the selective dissolution of barite while leaving anthracene unaffected. This selective solubility simplifies the separation process. Quantitatively transferring the viscous mixture to the membrane filtration apparatus ensures that all components of the mixture are transferred for filtration, thus minimising sample loss and ensuring accurate separation. Membrane filtration facilitates the separation process by allowing the filtration of the viscous mixture. The filter paper retains the insoluble anthracene while allowing the ionic liquid and dissolved barite to pass through. Rinsing the test tube with acetone and pouring it into the Buchner funnel aids in efficiently transferring the remaining mixture, ensuring minimal waste and efficient cleanup. However, drying the anthracene residue on the filter paper may take additional time, especially if residual solvent remains. Proper drying is crucial to ensure accurate measurement and analysis of the isolated anthracene.

RECOMMENDATION

Based on the findings, future research could explore alternative organic solvents to dissolve both barite and anthracene completely, optimising filtration processes to enhance separation efficiency and developing purification techniques to remove impurities. Further investigations into using ethanolamine as a solvent for barite

dissolution are warranted, with attention to mitigating viscosity issues. Additionally, pilot-scale studies could evaluate the feasibility and scalability of the developed separation method for industrial applications, considering factors such as cost-effectiveness and environmental impact. These recommendations aim to refine separation techniques for barite and anthracene, advancing their recovery and expanding their utility across various industries and research domains.

CONCLUSION

The presented method demonstrates a practical approach for the selective separation of barite from anthracene. While it offers advantages such as selective solubility and quantitative transfer, it also has limitations on solvent usage. Researchers should consider this factor when choosing this method for their separation needs and evaluate its applicability based on specific experimental conditions and industrial needs during material recovery.

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