Oil Recovery and Heavy Metal Immobilization for Petroleum Sludge Waste Treatment

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Abstract: The treatment of petroleum sludge waste generated from oil and gas industry has received increasing concerns in recent years due to its hazardous nature. It is a complex emulsion of various petroleum hydrocarbons (PHCs), water, solid particles, and metals. Given the stringent environmental regulations, there is a pressing need to develop cost-effective sludge waste treatment methods. In this work, the main methods used for petroleum sludge waste treament were reviewed, and the combined processes based on ultrasonic irradiation, ionic liquid enhanced solvent extraction, and co-pyrolysis were introduced. The oil recovery and metal immobilization effects of the study processes on petroleum sludge were investigated through a series of laboratory experiments arranged by using a Taguchi experimental design method, while the impacts of different factors were evaluated. These include solvent type, solvent to sludge (S/S) ratio, ionic liquid/sludge ratio, extraction duration, ultrasonic irradiation power, ultrasonic treatment duration, pyrolysis temperature, reaction time, and biomass waste addition in the feedstock. The chemical speciation characteristics of heavy metals in sludge after treatment was also examined to evaluate the heavy metal immobilization effects, and the corresponding ecological risk posed by metals was calculated through an index-based approach. The results indicated that petroleum sludge treatment using the proposed combined processes can be completed within a shorter duration under lower solvent/sludge ratio and lower energy consumption conditions. When compared to crude oil, the recovered oil had a higher level of F3 fraction and similar calorific value, indicating its usefulness as a potential energy source and petrochemical feedstock. It was also observed that the co-pyrolysis of sludge waste with other biomass waste led to increased metal immobilization, and significantly reduced the risk index (RI) value of the petroleum waste. In summary, the proposed combined processes through ultrasound, ionic liquid enhanced solvent extraction, and co-pyrolysis could hold great potential to be used for waste management practices within the oil and gas industry.

Keywords: Ultrasonic irradiation, solvent extraction, petroleum sludge, pyrolysis, oil recovery