以鋁鹽混凝劑處理二氧化矽顆粒廢水─鋁型態分佈及轉化特性的影響

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摘 要

聚氯化鋁混凝劑為目前廣泛使用於水及廢水處理中的水化學藥劑，其具有處理效果佳、用藥量及污泥量少、不易消耗水體鹼度及較不受溫度的影響等優點，有逐漸取代傳統硫酸鋁及氯化鋁混凝劑的趨勢。由於聚氯化鋁為經由預水解而製備的無機高分子混凝劑，容易因製備條件的異動而導致有效混凝作用基 (Al_{13})的含量變動極大。因此，目前混凝科學的研究領域為致力於開發各種具有低耗能、穩定、快速及能夠量產的製備技術，並且著力於純化後之聚合鋁物種 (Al_{13})的混凝機制探討。期望能藉由各種提純的技術將 Al_{13} 自聚氯化鋁中分離、濃縮並純化，探討 Al_{13} 純度達 90 %以上之 PACl-Al_{13} 混凝劑於混凝過程中的表現，並逐步釐清單核鋁物種、聚合鋁物種及膠體鋁物種各自的混凝作用特性。

本研究利用四種不同鋁型態分佈及轉化特性的聚氯化鋁，針對二氧化矽顆粒廢水進行混凝沉澱實驗的評估。首先著眼於混凝劑的鋁型態特性分析，隨後探討操作 pH 值及加藥量對處理效果的影響，最後則是綜合分析各個混凝劑於處理後的水質參數、顆粒聚集動力學及污泥的特性，搭配混凝劑的基本鋁型態特性進行各個混凝劑處理二氧化矽顆粒廢水的混凝機制推論。

研究結果顯示，隨著混凝劑預水解程度的提升，聚合鋁物種 (Al_{13})對溶液的穩定性越高，且較不受溶液 pH 值變化及熟化時間延長而發生進一步的轉化，相對所表現出的混凝效果亦隨著鹽基比的增加而成效越好。低鹽基比的 Alum 及 $PACl_{14}$ 適用於中性偏酸性的 pH 範圍；高鹽基比的 $PACl_{21}$ 及 PACl-Al_{13} 則適用於鹼性範圍。對於帶有極負界達電位的二氧化矽顆粒而言，四種混凝劑皆表現出以吸附-電性中和為最適用的混凝機制，然而於適當的操作條件下，Alum 及 $PACl_{14}$ 可利用沉澱掃除為混凝機制，而 $PACl_{21}$ 則可利用 Electrostatic patch effect 為輔助的混凝機制，PACl-Al_{13} 則可能具有 Electrostatic patch effect 或架橋作用的混凝機制。

關鍵字：二氧化矽顆粒、混凝劑、聚氯化鋁、聚十三鋁、光纖膠羽偵測儀

Treatment of Wastewater Containing Silica Particles with Aluminum Coagulants – Effects of Al Speciation and Transformation

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Abstract

Polyaluninum chloride (PACl) has been widely used in water and wastewater treatments, substituting alum and $AlCl_3$. It is superior to other coagulants in its good performance including the low dosage demand and low sludge volume, less alkalinity consumption and independency of temperature. PACl is produced by prehydrolyzation of $AlCl_3$ and the content of Al_{13} varies with the condition of manufacturing. Many manufacturing processes and purification methods of PACl have been developed by researchers. They have concentrated on production of PACl with stable and high Al_{13} content at low energy cost. The high Al_{13}- containing PACl has been used in the study of coagulation to clear the individual role of monomeric Al, polymeric Al and colloidal Al during coagulation process. This study assessed the coagulation and sedimentation of silica particles by using four PACls with different aluminum speciation and transformation characteristics. The effect of pH on coagulants speciation and the coagulation efficiencies were investigated. The quality of the treated water, particle aggregation dynamics and sludge characteristics were evaluated to investigate the coagulation mechanisms of individual Al species on silica particles.

Experimental results proved that the Al_{13} tridecamer produced in high degree of neutralization (γ value) was more stable in the solution and less transformable with the variation of solution pH and aging time. The coagulation performance of each PACls was also improved with the increase in degree of neutralization. Alum and $PACl_{14}$, both with low γ value, performed best in neutral and acidic pH ranges, while $PACl_{21}$ and PACl-Al_{13} worked most efficiently in alkali pH. The coagulation by four coagulants demonstrated that adsorption and charge neutralization were the most effective coagulation mechanism in treating silica particles of extremely negative zeta potential. However, under certain circumstances, sweep flocculation could occur in the coagulation of Alum and $PACl_{14}$. On the other hand, the coagulation of $PACl_{21}$ could be supplemented by electrostatic patch effect (EPE), while that of PACl-Al_{13} might be effected by the combination of EPE and inter-particle bridging.

Key words：Silica particle, Coagulant, Polyaluminum chloride, Al_{13}, Photometric dispersion analyzer