Treatment of organic pollutants in high salinity wastewater

new catalysis systems

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Popular science summary

Water quality plays a key role for environmental and human health. In the last decades, with the help of modern water treatment and supply systems, life expectancy of human has increased significantly. However, with the development of economy and industry, massive high salinity wastewater (HSW) from production processes has emerged as new threats, which can pollute water bodies and therefore leads to risk for both human and environment. The high concentrations of organic matter in HSW can be directly toxic or indirectly negatively influential to environment and human's life quality. Organic matter often needs to be degraded before discharge.

Degradation is to decompose organic matters to inorganic CO_2, H_2O, NH_4^+, etc. Therefore, the risk by organic matters can be avoided. There are already several physical, chemical and biological degradation methods for this purpose. However, they are either highly energy and material costly or less efficient when dealing with HSW. Hence, the new electrochemical catalysis (EC) and photo-electro catalysis (PEC) have been developed to address these issues. Degradation requires chemical reactions occurring on the organic matters which decomposed their constructions. In chemical treatment, for instance, the added chemical oxidant agents are responsible for this work. In bio-treatment, on the other hand, organic matters are slowly digested by well-adopted microorganisms. EC and PEC utilize electric and photo power to transfer the ions and compounds in HSW to oxidant agents which can do the degradation work. Therefore, they show faster degradation than bio-treatment and cause less media consumption compared to chemical treatment.

In both EC and PEC, electrodes (anode or cathode) are the key catalyst to produce agents for degradation under electro and photo power. However, to achieve ideal performance, expensive noble metals and graphene with high catalysis activity are always needed as electrodes materials. Meanwhile, all effective reactions and degradation rely on the current circulating between anode and cathode. But in traditional EC and PEC systems, only single anode or cathode side is employed for degradation work, which ignores the possible synergistic work between the two electrodes and wastes the current passing the other side. Moreover, as new methods, the degradation performance should be further developed in both EC and PEC before future applications. This leaves us the space for further development and research.

This study aims to develop new EC and PEC systems with duo working electrodes (anode and cathode) and economic electrode materials for the organic matter degradation in HSW, with new systems named EC-D and PEC-D. The possible degradation routes for duo working electrodes were developed. Under EC, on anode, oxidation reaction occurred, resulting in the production of active chlorine. In cathode, a novel air-diffusion cathode was employed to diffuse O_2 into water and transfer it to H_2O_2 in reduction reaction. Both active chlorine and H_2O_2 can

act as agents for degradation; They can be also transferred into stronger free radicals by photo radiation under PEC to enhance the performance. Methyl orange (MO) and Norfloxacin (NOR) and real HSW were selected as targeted pollutants. The electrode materials included economic SnO_2-Sb, carbon black and activated carbon with low price and high catalysis activity.

The result showed higher degradation efficiency of the new EC-D and PEC-D systems compared to single-working-electrode EC and PEC systems (EC-S and PEC-S), respectively, due to the synergistic work of anode and cathode in new systems. In EC-D, the degradation agents from both sides were produced as expected, which lifted the degradation efficiency and lowered the energy cost in the MO degradation in HSW. However, EC methods were unable to degrade refractory organic matters such as NOR. This was because neither active chlorine nor H_2O_2 contributed enough reaction activity. In degradation processes, the activity can be understood as a power for decomposing organic matters. Higher activity means faster reaction and more thorough destruction of the organic matters. The degradation efficiency was enhanced significantly by a PEC processes. With combined electrochemical and photo power, more active free radicals were produced from active chlorine and H_2O_2. The highest degradation performance was obtained in the PEC-D, since the free radicals were produced on both anode and cathode sides. The performances were in the order of PEC-D>PEC-S>single photo catalysis>EC. In general, this can be explained as the utilization of synergistic work between anode and cathode as well as between photo and electro in PEC-D. Therefore, the improvement was conducted in two dimensions and resulted in a significant lift of the performance.

By modelling, the anode and cathode were both proven to contribute significantly in degradation, with anode as prior. To further improve the performance, anode was formatted by a new urea precipitations method, resulting in larger surface area and higher photo and electro catalysis activity. These features created more reaction space on anode surface and faster reaction rate. Subsequently, high degradation performance was obtained.

Overall, the efficient and economic new EC and PEC systems were successfully developed and investigated in this work. They showed great potential for organic matter degradation in HSW. This is one step towards the future application of EC/PEC methods. However, the drawbacks such as the dependency to electric power and solar radiation, the limited electric and photo power utilization ratio as well as the difficult design of large-scale plants still retain as big challenges. This leaves us the space for future study.