ISSN: 2414-1895 DOI: 10.6919/ICJE.202109_7(9).0027

Advances in the Treatment of Radioactive Wastewater Containing Heavy Metals by Electroflocculation

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Abstract

With the development of the nuclear industry, the removal of radioactive waste streams is receiving increasing attention. Electroflocculation technology, compared with traditional methods for the removal of radioactive waste streams, has greater advantages. This paper compares the commonly used methods for the treatment of radioactive wastewater and highlights the scientific progress in recent years in the application of electroflocculation technology for the treatment of radioactive wastewater at home and abroad.

Keywords

Nuclear Industry; Electroflocculation; Radioactive Wastewater.

1. Introduction

Since the 21st century, the rapid development of global technology and economy has led to an increasing demand for energy, and traditional fossil energy sources such as coal, oil and natural gas [1] are no longer sufficient to meet human energy needs. At the same time, the burning of fossil fuels has resulted in huge carbon dioxide emissions [2], causing a series of problems such as the greenhouse effect and global warming. For this reason, mankind has turned its attention to low-carbon, environmentally friendly and renewable energy sources. Nuclear energy is a typical representative of new energy sources, making up for the environmental pollution caused by the carbon emissions of fossil energy and the shortcomings of non-renewable fossil energy, which is conducive to the transformation of the energy structure and the achievement of a high level of green development [3].

The development of nuclear energy and power is not without its drawbacks [4, 5]. The operation of nuclear power plants requires nuclear fuel, the treatment of which generates a large amount of radioactive waste water [6], which contains radioactive heavy metals and, if not properly treated, can also cause significant environmental pollution.

2. Conventional methods for the removal of radioactive wastewater

The main methods of treating radioactive wastewater at home and abroad are: chemical precipitation, ion exchange technology, membrane separation, biological methods, etc.

2.1 Chemical precipitation method

Radioactive wastewater contains a certain amount of heavy metals, and when a precipitant is added to the wastewater, a direct chemical reaction occurs between it and the nuclides to be removed from the wastewater, resulting in a precipitate that is insoluble in water and the contaminants are separated and removed.

The advantages of the chemical precipitation method are its low cost and the simplicity of the treatment process, which is mainly suitable for the treatment of low concentration radioactive wastewater with low purification requirements and large volumes. The precipitation method is not

ISSN: 2414-1895 DOI: 10.6919/ICJE.202109_7(9).0027

very selective and has a precipitation effect on many ions, so the purification effect is not particularly good and is often used in combination with other methods to improve the treatment effect. The co-precipitation-microfiltration process (PCM) used by Zhou Li Hai [7] and others then combines the advantages of chemical precipitation and membrane separation methods, and has a good treatment effect on mixed wastewater containing drill and strontium, with an average DF of up to 504 for strontium [8].

2.2 Ion exchange technology

From the beginnings of the development of the nuclear industry, the application of ion exchange technology in water and wastewater treatment has developed rapidly. Recent research has been devoted to the development of new ion exchangers, although this can present some difficulties in terms of industrial application as well as improved performance. The choice of ion exchanger is strongly influenced by the chemical composition of the wastewater [9]. Most of the elements in radioactive wastewater are present in ionic form and can be removed relatively easily by ion exchange methods.

2.3 Membrane separation technology

Membrane separation technology, as an emerging water treatment technology, is increasingly used in the treatment of radioactive wastewater. Membrane separation technology is a method of solid-liquid separation of radioactive liquid mixtures by means of selective permeability membranes between two phases, under the action of mass transfer driving forces such as pressure difference, temperature difference, potential difference and concentration difference. It has many advantages compared to conventional treatment technologies: low energy consumption due to room temperature operation; low footprint and simple operation; wide adaptability and the ability to treat various forms of contamination in wastewater. The membrane separation method has good effluent quality and stable operation when treating low discharge wastewater, but is constrained by factors such as cost and contamination of the membrane.

2.4 Biological methods

In recent years, biosorption has gradually become a hot spot for research. Biological treatment methods mainly include phytoremediation [10] and microbial methods, such as the use of biological bacteria moss fresh as adsorbents to adsorb radioactive waste liquids. Biosorption is the use of certain organisms [11] (algae, fungi, bacteria and yeast, etc.) which themselves have a special affinity for radionuclides to achieve the removal of radioactive substances from radioactive waste streams. Biosorption is highly efficient in decontamination, requires less investment and does not produce secondary contaminants, which facilitates the recycling of nuclides. However, biosorption is also a relatively complex process, influenced by factors such as the type of adsorbent, the type of nuclide and the surrounding environment [12].

3. Electroflocculation

3.1 Electric flocculation technology

Electroflocculation is an electrochemical-based water purification method that uses an electric current to dissolve anodes to produce cations (commonly Al^{3+} and Fe^{3+} etc.) to achieve the separation and removal of solids and dissolved pollutants from wastewater [13,14].

The electroflocculation process is a coupling of electrochemical reactions, mass transfer and air floatation. Under the action of an applied electric field, the soluble anode produces metal cations, while the cathode electrolyses water to produce OH^{-}, which combine with each other in the native solution to produce metal hydroxides and polyhydroxylated complexes, resulting in hydroxide flocs. One part of the floc sinks to the bottom after adsorption of organic matter in the wastewater, while the other part adsorbs on the H^2 bubbles produced by the cathode and rises to the surface under the action of air flotation. The whole process of electroflocculation can be understood as a result of electrolytic flocculation, electrolytic air flotation and electrolytic redox.

The metal cations generated by the loss of electrons in the soluble anode plates form hydrated ions with water molecules on the electrode surface, which in turn form mononuclear and polynuclear hydrolysates, resulting in flocs with -OH on the surface. The flocs then adsorb and polymerise and precipitate the hard-to-degrade organic matter through netting, adsorption bridging and electrical neutralisation, completing the whole process of electrolytic flocculation. At the same time, the H^+ in the water body gets electrons on the cathode plate and generates a large amount of H^2. The pollutant flocs in the water body attach to these small bubbles and rise to the surface of the solution through air floatation, which in synergy with electrolytic flocculation results in a good separation of the solid-liquid components of the solution and improves the removal rate of organic matter. Electrolytic redox involves the redox of the pollutant itself and the redox effect of the oxidant and reduced [H] produced in the water, but the production of oxidant and [H] in this process is very small, so in practice electrolytic redox is much less effective than flocculation and air flotation in removing pollutants [15].

3.2 Advantages of electroflocculation electrolysis of wastewater

In recent years, electroflocculation has entered the arena as a relatively new wastewater treatment technology. Electric flocculation plays an increasingly important role in wastewater treatment and is widely used in the treatment of various wastewaters, which has certain advantages using electric flocculation [16].

The equipment required for the operation of electroflocculation technology is simple, easy to operate, convenient to operate and manage, and also has the advantages of small size of process equipment, small footprint, low operating costs, etc. These unique advantages make the electroflocculation method has been widely used at home and abroad [17].

Electric flocculation is playing an increasingly important role in wastewater treatment and is widely used in various wastewater treatments, such as the treatment of dairy wastewater, lead and zinc smelting wastewater and suspended organic colloids [18, 19].

4. Application of electroflocculation technology in the treatment of heavy metal wastewater

Today, after more than 100 years of development, electroflocculation technology is used in almost every field of water treatment. Gao Chen of Donghua University of Technology [20] used electroflocculation technology in the process conditions of liquid phase pH = 6.0, tank voltage 3.0 V, electrolyte concentration 2.0%, the initial concentration of 10.0 mg/L of chromium-containing wastewater, after 12.0 min electroflocculation reaction, the effluent chromium concentration of 0.018 mg/L, the removal efficiency of 99.98%, to meet the drinking water Cr (VI) emission The effluent had a chromium concentration of 0.018mg/L and a removal efficiency of 99.98%, meeting the Cr(VI) emission limit for drinking water.

Gao Xiaolian [21] used double iron electrodes sinusoidal AC flocculation of Cr(VI) in wastewater, containing 20 mg/dm^3, pH=4 in Cr(VI) simulated wastewater solution, applied 4V, 50Hz sinusoidal AC, the removal rate of Cr(VI) from hexavalent chromium could reach more than 99% effect when electric flocculation was applied for 25 min.

Huang ChienHung [22] investigated the effect of chloride ions on the electrocoagulation of industrial wastewater containing copper and nickel. In EC (electrocoagulation) systems, chloride ions facilitate the avoidance of passivation of aluminium anodes. Chloride ions as an electrolyte promote the release of Al ions, which leads to a current efficiency of more than 100% in the EC system. For PCB plant wastewater, the EC system can effectively remove Cu^{2+} and Ni^{2+} (Cu and Ni concentrations in the treated wastewater are less than 1.0 mg/L within three minutes). When the initial pH is around 2.5, the pH of PCB wastewater can be stably maintained at around 9.0 in the EC system.

Liu Xing [23, 24] from South China University of Technology (SCUT) investigated the effect of F^- and Cd^{2+} removal using a modified parallel monopole electroflocculation connection. The results showed that when the initial mass concentrations of F^- and Cd^{2+} were 5 mg/L and 0.5 mg/L, respectively, the optimized working conditions were: initial pH=11, current density 9.8 mA/cm2, mass concentration of NaCl 0.75 g/L, plate spacing 0.5 cm and electrolysis time 55 min. The mass concentrations of F^- and Cd^{2+} in the effluent were 0.54 mg/L and 5 μg/L respectively, which were in accordance with the requirements of GB 5749-2006. Fourier transform infrared spectrometry and X-ray diffraction analysis showed that the F^- and Cd^{2+} were mainly removed by adsorption and precipitation.

Li Yu'e [25], School of Environmental Science and Engineering, Kunming University of Technology, formed an Al-Al EC/PMS system by adding potassium peroxymonosulfate salt (KHSO5, PMS) to aluminum-based electroflocculation to treat pit wastewater containing Mn, Zn and Fe from an open pit coal mine in Yunnan. The results showed that the Al-Al EC/PMS system was more effective. -The reaction was carried out by adding 6 mmol/L PMS for 45 min to achieve the discharge standard of Class I A of the Discharge Standard for Pollutants from Urban Wastewater Treatment Stations (GB 18918).

Gao Xu from Dong Hua University of Technology [26, 27] studied the treatment of uranium-containing wastewater by electroflocculation. The main influencing factors of EDTA chelation-electroflocculation treatment of uranium-containing wastewater were the initial pH, current density, EDTA dosing amount and initial uranium concentration. Under the optimized conditions of pH 6.0, current density of 1.0 m A/cm2, n(EDTA):n(UO22+) of 3:1 and reaction time of 24 min, the initial uranium concentration of 3.693 mg/L could be removed by 98.75% and the residual uranium concentration of 0.046 mg/L, which could meet the requirements of GB 23727 -The residual uranium concentration was 0.046 mg/L, which could meet the environmental acceptance value of uranium content (<0.05 mg/L) in the discharge effluent of the 2009 "Regulations on Radiation Protection and Environmental Protection in Uranium Mining and Metallurgy".

5. Conclusion

In this paper, we briefly introduce the conventional methods for radioactive wastewater and compare the advantages of electroflocculation in the treatment of wastewater. The treatment of radioactive wastewater containing heavy metals by electroflocculation technology at home and abroad in recent years is highlighted. In summary, the advantages of electroflocculation in the treatment of wastewater are enormous, but at the same time there are some problems that need further research.

Acknowledgments

Natural Science Foundation

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