Experimental Research on Wastewater Reuse Technology of Industrial Circulating Cooling Water System

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Abstract. By means of decrease of hardness, neutralization and desalination union technology, the drained wastewater of industrial circulating cooling water system can be treated. The purified water quality (total hardness and calcium ion components) is greatly better than fresh water, and completely can be reused as make-up water for circulating cooling water system. The experimental results show that the ratio of wastewater reuse reached more than eighty percent, saving a large amount of fresh water, reduce waste water discharge, water saving and emissions reduction effect is obvious, and the production cost greatly reduced.

Introduction

The widespread use of water treatment agents provide strong technical support for the circulating reuse of industrial cooling water, so as to make the industrial water-saving became a reality. In recent years, water treatment agents have been greatly developed and improved, but the existing chemical agents still have some limits for water quality conditions, or the concentrated by evaporation is impossible on indefinitely. When concentration ratio of circulating cooling water system is 3.5, there are still 28% water is drained in order to maintain the normal operation of the circulating water system. The drained circulating water can not be used again as supplementary water without water treatment, becouse of high hardness and high amount of bacteria and algae[1,2].

To meet the recycling water quality requirements, the wastewater should be treated by means of circulating cooling water wastewater reuse technology[3], and fall hard, neutralization, desalination and so on a series of processes. According to water quality characteristics of circulating water system from a chemical fiber enterprise in our province, to provide effective way for solving the problem of sewage wastewater reuse, we adopted the above methods, and sought the best experiment conditions[4].

Experiment Instrument and Methods

Reagents and Experimental Instruments

The reagents and experimental instruments used are as follows: NaOH (industrial grade), H_2SO_4 (industrial grade), fungicide (industrial grade), electronic balance (CP225D), precise pH instrument (pHS-3C), digit display conductivity instrument (DDS-11A), atomic absorption spectrophotometer (AA2610).

Water Quality Analysis

In this experiment, the raw water samples and wastewater samples used are taken from circulating cooling water system of a steel company blast furnace workshop is shown in Table 1.

Table 1 Water quality of raw water samples and wastewater

Items	Total hardness (mg/L)	Ca^{2+} (mg/L)	SO_4^{2-} (mg/L)	Cl- (mg/L)	Total alkaloids (mg/L)	Conductivity (μs/cm)	Heterotrophic bacteria (cfu/mL)	pH
Raw water	420.4	356.7	124.2	41.3	100.2	987.4	102	7.32
Waste water	1204.4	1034.9	372.6	124.5	293.7	1473	106	8.47

Experiment Methods

According to the actual situation, a circulating cooling water waste water reuse test apparatus was assembled, the process flow diagram is shown in Fig.1.

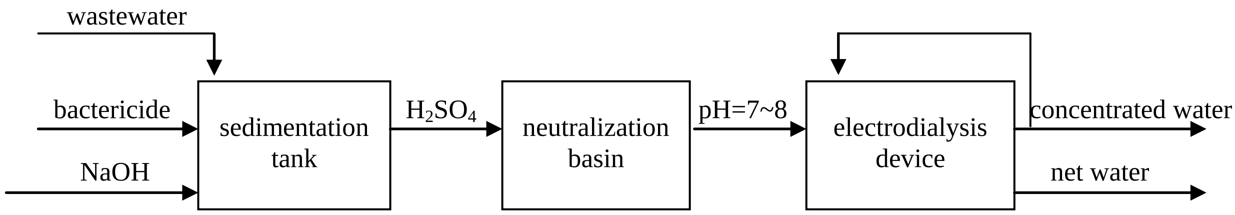

Fig.1 The process flow diagram of wastewater reuse test apparatus

Total hardness and concentration of Ca^{2+} are based on GB/T 15452-2009, concentration of Cl^-, SO_4^{2-}, total alkali and heterotrophic bacteria are based on GB/T 15453-2008, GB/T 6911-2007, GB/T 15451-2006, and GB/T 14643-2009, electrical conductivity and pH were measured using instrument[5].

Results and Discussion

Down Hard Experiment

The circulating cooling wastewater was treated of sterilization firstly, and NaOH was added. The total hardness, conductivity, concentration of Ca^{2+}, the change of heterotrophic bacteria were tested under various pH. The results are shown in Table 2.

Table 2 The results of down hard experiment

pH	9	9.5	10	10.5	11	11.5	12
Total hardness (mg/L)	390.8	224.7	145.1	98.76	40.38	20.74	15.84
Ca^{2+} (mg/L)	336.8	193.2	120.4	76.76	21.5	10.9	9.23
Conductivity (μs/cm)	1514	1607	1713	1842	2009	2204	2514
Heterotrophic bacteria (cfu/mL)	10^2	10^2	10^2	10^2	10^2	10^2	10^2

As show in Table 2, the quantity of heterotrophic bacteria decreased from 10^6 to10^2 when bactericide was added. With the increase of pH, the total hardness and concentration of Ca^{2+} of wastewater decreased, this is because the precipitation of $Ca(OH)_2$ was generated. $Ca(OH)_2$ is poorly soluble chemical substance, solubility product is 3.1×10^{-5}. With the increase of pH, the conductivity and ionic concentration increased, this result in the largeness of precipitation particle and acceleration of precipitation. The increase of pH is helpful to precipitation of Ca^{2+} undoubtedly, but result in processing cost increase and subsequent processing difficulty due to the increase of ionic concentration and the dosage of NaOH. In a comprehensive view, the pH value was controlled between 9.8 ~ 10 during the precipitation separation process. When the the pH value was 9.8 ~ 10, the total removal rate of hard was more than 80%, the effective content of fungicide was 20% and the addition amount was 10 mg/L, the concentration of NaOH solution was 30% and the addition amount was 0.9 g/L.

Neutralization Experiment

In order to the operation of the subsequent process, the value of pH of samples pH=9.5, pH=10.0, and pH=10.5 (in Table 2) was adjusted to 9.5-10.5 by adding 0.15g/L sulfuric acid (10%). The results showed that the conductivity decreased about 20% after neutralization experiment is shown in Table 3.

Table 3 The results of neutralization experiment

Water samples	pH=9.5	pH=10.0	pH=10.5
Conductivity(μs/cm)	1302	1385	1408
Decrease of conductivity (%)	19.0	19.1	23.6

Dynamic experiments

Circulating cooling water discharge wastewater reuse was tested by dyamic experiment, continuous access to water treatment processes was used for a long time to run tests. The feed water was 300 L/h according to the actual situation. The results are shown in Table 4, 5 and 6.

Table 4 The relationship of the amount of water and acid base

Water inflow (L/h)	Sodium hydroxide dosage (10%) (L/h)	Sedimentation tank pH	Acid consumption (5%) (L/h)	Neutralization basin pH
300	2.7	9.78	0.9	7.2

Sodium hydroxide dosage and acid consumption are displayed in Table 4, in order to maintain the pH of sedimentation tank and neutralization basin at 300 L/h feed water.

Table 5 The relationship water yield and water inflow

Water inflow (L/h)	Net water (L/h)	Concentrated water (L/h)	Return concentrated water (L/h)	Discharge concentrated water (L/h)	Power consumption (kW)
300	210	90	60	30	1.2

(Discharge concentrated water was outflow of water at the end of permeability desalting process, return concentrated water was a mixture of concentrated water contained the water was going to and have electroosmosis desalinate.)

Table 6 The water quality status of net water

Net water (L/h)	Total hardness (mg/L)	Ca^{2+} (mg/L)	Conductivity (μs/cm)	Heterotrophic bacteria (cfu/mL)	pH
210	37.5	35.8	620	0	7.2

As shown in Table 5, when the water inflow was 300 L/h, discharge concentrated water was controled at 30 L/h, then the net water was 210 L/h, the recovery rate of circulating water was about 90%. From the water quality status of net water in Table 6, we can know the water quality was excellent, particularly total hardness and the concentration of Ca^{2+} were better than that of raw water, can be used as supplementary cycle water.

Production test

A circulating cooling water wastewater reuse treatment device was produced with 60 t/h processing capacity by using the exsiting circulating cooling water system of this enterprise. The conditions of production operation and water quanlity is shown in Table 7 and 8, respectively.

Table 7 Production operation conditions

Water inflow (t/h)	Net water (t/h)	Discharge concentrated water (t/h)	Power consumption (kW)
60	52	8	45

Table 8 Water quanlity conditions

Water inflow (t/h)	Total hardness (mg/L)	Ca^{2+} (mg/L)	Conductivity (μs/cm)	Heterotrophic bacteria (cfu/mL)	pH
52	36.7	33.2	610	0	7.5

Cost Accounting

The cost was calculated by production test data. Relevant consumption materials are shown in Table 9.

Table 9 The consumption materials and power

Materials	NaOH (30%)	H_2SO_4 (98%)	Fungicide (20%)	Average power consumption
Market price	600 yuan/t	2000 yuan/t	6000 yuan/t	1.00 yuan
Consumption	0.9 kg	0.15 kg	0.01 kg	0.9
Processing cost	$0.9\times10^{-3}\times600+0.15\times10^{-3}\times2000+0.01\times10^{-3}\times6000+0.9\times1.00=1.80$ yuan			

At present, cost of water in enterprise are mostly between 4 ~ 5 yuan/t, so the saved cost of one ton wastewater treatment can be about 2 ~ 3 yuan.

Summary

The sewage wastewater processing of circulating cooling water system by the fall hard, neutralization, and desalination technology is feasible. Purification water quality (total hardness and Ca^{2+} concentration) after traetment ia greatly better than that of the fresh water, completely can be used again as make-up water for circulating cooling water system.

The production test results of enterprise show that reuse rate of sewage waste water can reach 86%, the processing cost is 1.80 yuan/t, water cost saved is about 2 ~ 3 yuan/t, production cost is decreased, and economic and social benefit are remarkable.

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