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NEW TECHNOLOGY FOR WASTEWATER TREATMENT

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ABSTRACT

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Water pollution has become an increasingly serious threat to human survival and economic development on a global scale. Prevention and control of water pollution, to protect water resources, and adopt the road of sustainable development has become the common goal of mankind. With the development of the global economy and the accelerated progress of industrialization, the discharge of sewage has been increasing gradually.

At present, the biological sewage treatment technology represented by activated sludge is quite mature. It has been widely used in urban and industrial wastewater treatment, and in the prevention and control of water pollution has played an enormous role.

However, due to the rapid increase in wastewater discharge, the traditional process in many ways has been difficult to meet people's continuous improvement of wastewater treatment requirements. Research and development and application of new sewage treatment of new technologies, new technology, and water treatment have become an important issue for workers.

Key words
Catalytic wet air oxidation, Supercritical Water Oxidation Technology, Ozone catalytic oxidation, Electrochemistry, Magnetic separation, Electro - adsorption technology

ABSTRACT

CONTENTS

1 INTRODUCTION

With the rapid development of science and technology, industrial pollution and ecological destruction at an unprecedented rate is revealed, the human life gradually affected. So humans began to realize that the environment should be protected. Saving the planet on which mankind lives, and achieving sustainable development has become a common choice for mankind.

In China, environmental protection has been defined as a basic national policy, from the “fifteen plan” to “thirteen five plan” that the environmental problems are the most important. The state attaches great importance to the treatment of key industrial wastewater and the intensity of water pollution control continues to increase and investment increased year by year. For industrial wastewater, it is important to select the appropriate wastewater treatment program that it is important to minimize the water pollution load.

In recent years, environmental science research units, universities, engineering design units do large quantity work and many wastewater treatment facilities have been successfully built in various industrial enterprises across the country, which is for the control and enhance the quality of China’s water environment and make tremendous contributions. But because of the large variety of industries, products and production processes are complex and changeable, and the types of waste water pollutants are varied. Thus there are still many problems in the wastewater treatment needs to be resolved, especially small and medium enterprises are more complex and there are many problems for this type of wastewater treatment process research and design should be given more attention.

This paper is mainly for industrial wastewater treatment of new technologies for a simple analysis research. This’s paper is mainly divided into three parts, the first part briefly introduces the city sewage. The second part introduces industrial wastewater, which is divided into industrial wastewater sources, classification, water quality characteristics and contaminants in water. The third part introduces the new technologies of sewage treatment, respectively, there were introduced the catalytic wet air oxidation technology, supercritical water oxidation technology, catalytic ozone oxidation technology, electrochemical method, magnetic separation technology and electric adsorption technology.

Due to the limitation of the length of the article and the limited time, in this paper, it is impossible to introduce large quantity of new and very detailed information on the new technology, which is difficult

to manage industrial wastewater. While briefly introduces its principle, characteristics, classification and its application. Article strive to be easy to understand, to solve practical problems, so that the new technology described in the promotion and application and in the industrial wastewater treatment to sufficient exert to the role for the water treatment industry to contribute.

2 MUNICIPAL WASTEWATER

Urban wastewater is mainly derived from the urban residents' life, industrial enterprises in the production process of the production of waste water as well as urban precipitation and some of the contaminated surface water in three areas. Wastewater is in the daily life of urban residents. Those are including residents of the family, hotels, institutions, schools, shopping malls and other facilities due to the daily activities of residents of sewage discharge, such as vegetables, cooking, showering, and flushing. This kind of sewage water quality is characterized by often contain high organic matter, such as starch, protein, grease, as well as nitrogen and phosphorus and other inorganic substances, in addition, municipal wastewater also contains pathogenic microorganisms and more suspended solids.(Tao &Yu 2005.)

The industrial enterprises in the production process of wastewater generate from the production process, including wastewater, circulating cooling water, washing wastewater and integrated wastewater. As the production industry is different, the resulting wastewater quality is not the same. About this type of water, the total discharge of wastewater is large, also high levels of pollutants more difficult to deal with, and then great harm to the environment. Some of the effluent quality indicators are far from the national emission standards. Due to the cyclical nature of production, the amount of wastewater discharged into a day also varies considerably. This kind of waste water is an important part of urban sewage. At present, it has received extensive attention; also there are many examples of the application of sewage treatment works, and achieved satisfactory results. (Tao & Yu 2005.)

Urban precipitation and contaminated surface water in urban waste water has not accounted for a large proportion. This kind of wastewater water quality difference is large, often affected by climate, time, geographical location and the surrounding environment. The treatment of such waste water, ought to be specific water quality of wastewater for the need to choose whether to blend emancipate with other wastewater after treatment. (Tao & Yu 2005.)

3 INDUSTRIAL WASTEWATER

Industrial wastewater refers to the industrial production process of wastewater discharge, including process water, machinery and equipment cooling water, flue gas washing water, equipment and site washing water. Industrial wastewater in addition to indirect cooling water, and then also known as industrial sewage, is the main target of industrial wastewater treatment. (Wang & Ren 2004.)

3.1 Sources of industrial wastewater

Industrial wastewater is different from the domestic sewage, and the meaning is very extensive. Due to the broad variety of industries and that means of each industry is composed of a variety of processes, the resulting nature of the wastewater is completely different, and the composition is also very complex. According to the harm caused by wastewater for environmental pollution is different, which can be divided into solid pollutants, organic pollutants, oil pollutants, toxic pollutants, biological contaminants, acid-base pollutants, aerobic pollutants, nutritional pollutants, sensory pollutants and thermal pollution. Although some of the pollution indicators are the same as to municipal sewage, but its concentration or numerical value is often very different from urban sewage. For example, some industrial wastewater COD concentration are as high as thousands or even tens of thousands, while the urban sewage is generally more than a few hundred. The other industrial wastewater biodegradability is generally much worse than urban sewage. Heavy metals and other toxic and harmful substantial concentration is often higher of great quantity than the urban sewage, which have increased the difficulty of dealing with industrial wastewater. (Wang & Ren 2004.)

Some of the pollutants in industrial wastewater can be caused by a variety of reasons. And the contaminant may be a raw material for the production process or an impurity in the raw material for production. And then the production process of by-products and pre-treatment or disposal of waste water were before the project due to transportation, dosing agents and other reasons or other causal factors. In the light of the main harmful substances contained in industrial wastewater, the partition of its sources, see Table 1.(Wang & Ren 2004.)

TABLE1. Major pollutants and sources in industrial wastewater (Wang & Ren 2004.)

No.	Harmful Substance	The main sources of wastewater
1	acid	Chemical, mining, steel, non-ferrous metallurgy, machinery, electroplating industries
2	Alkali	Chemical fiber, caustic soda, paper, printing and dyeing, leather, electroplating industry and oil refineries, etc.
3	Mercury and its compounds	Chlor-alkali, explosives, mercury Pesticides, chemicals, instruments, electroplating, mercury refining industry, etc.
4	Cadmium and its compounds	Metal mining, smelting, electroplating, chemical, metal processing, batteries, etc.
5	Hexavalent chromium and its compounds	Mining, smelting, electroplating, chemical, metal processing, batteries, specialty glass industry, etc.
6	Arsenic and its compounds	Ore processing, pharmaceutical, metallurgical, chemical, paint, pesticides, fertilizers and other industrial
7	phenol	Coking, coal gas, oil refining, synthetic resins, chemicals, dyes, pharmaceuticals and other industries
8	Cyanide	Coking, coal gas, electroplating, metal cleaning, acrylic, acrylonitrile synthesis, refining industry and the gold industry, etc.
9	Lead and its compounds	Smelting, chemicals, pesticides, gasoline explosion, lead paint, enamel industry.
10	oil	Oil refining, machinery, food processing, oil, natural gas processing industry
11	Sulfide	Chemicals, leather, gas, coking, dyeing, oil refining, oil and gas processing industry, etc.
12	Free chlorine	Papermaking, textile bleaching, chemical industry, etc.
13	Organic phosphorus, organic chlorine	Pesticides, chemical industry, etc.
14	Polychlorinated biphenyls (PCBS)	Electricity, plastics, lubricants and other industrial
15	Radioactive substances	Nuclear industry, radioisotope laboratories, hospitals, and other weapons production

3.2 Classification of industrial wastewater

Industrial production enterprises in a variety of production processes of wastewater discharge, collectively refer to as industrial wastewater, including the production of sewage, cooling water and domestic sewage about 3 kinds. In order to distinguish the types of industrial wastewater, and to understand its nature, and then to understand its harm, and to study its treatment measures, in addition usually the classification of wastewater, there are generally three classification methods. (Wang & Ren 2004.)

Industrial wastewater is classified according to industry product processing's object. There are including metallurgical wastewater, papermaking wastewater, coking coal gas wastewater, metal pickling wastewater, textile printing and dyeing wastewater, tannery wastewater, pesticide wastewater, chemical fertilizer wastewater.(Wang & Ren 2004.)

It is classified according to the features of the major pollutants contained in the industrial wastewater. There is mainly containing inorganic pollutants called inorganic wastewater. This is mainly containing organic pollutants called organic wastewater. For example, wastewater from electroplating and mineral processing is inorganic wastewater, and wastewater from food or petroleum processing is organic wastewater. This classification method is relatively simple. It is beneficial to consider the treatment method. For example, the biodegradation of organic wastewater is generally used biological treatment method. And inorganic wastewater is generally treated by physical, chemical and physical-chemical methods. However, in the industrial production process, wastewater often contains both inorganic and organic matter. (Wang & Ren 2004.)

According to the main components of pollutants contains in waste water to classification. It can be divided into acidic wastewater, alkaline wastewater, phenol wastewater, cadmium-containing wastewater, chromium-containing wastewater, zinc-containing wastewater, and mercury-containing wastewater, fluoride wastewater, containing organic phosphorus wastewater, and including radioactive waste water. The advantage of this classification method is to highlight the main pollution components of wastewater, and can be targeted to consider the treatment method or for recycling. (Wang & Ren 2004.)

3.3 Water quality characteristics of industrial wastewater

Due to the rapid development of industry, industrial waste water of water quantity and water quality pollution is tremendous, it is the most significant source of pollution, and it has the following characteristics: a large amount of pollution, and a wide range of pollution, and then emissions of complex industrial production of water, a considerable part of the production of water are carrying raw materials, intermediates, by-products and end products discharged from the plant. Industrial enterprises throughout the country, a wide range of pollution, and many products in use will produce new pollution. For instance, it is the use of chemical fertilizers around the world about 500 million tons, more than 200 million tons of pesticides, bring about vast areas around the world of surface water and groundwater are subject to varying degrees of pollution. Industrial wastewater discharge method is complex, and intermittent emissions, continuous emissions, regular emissions and irregular emissions, and to the prevention and control of pollution have caused tremendous difficulties. (Shui 2012.)

There are many kinds of pollutants in industrial wastewater, and the concentration of large fluctuations due to a wide variety of industrial products, and production processes are also different, hence the discharge of industrial production processes are numerous. Different pollutants are very different nature, and the concentration is also very different.(Shui 2012.)

Pollutants are highly toxic and dangerous. Wastewater contaminated by acid and alkali which is irritating, corrosive, and organic oxygen-containing compounds such as aldehydes, ketones, ethers are reductive, and it can consume dissolved oxygen in water, and the water hypoxia. And it leads to the death of aquatic life. Industrial wastewater contains a lot of nitrogen, phosphorus, potassium and other nutrients, and can promote the growth of algae consumes a large number of dissolved oxygen in water, resulting in eutrophication of water pollution. Suspended matter in industrial wastewater content is high, up to 3000mg / L, 10 times for the domestic wastewater.(Shui 2012.)

After the discharge of pollutants the variation of migration varies greatly and the nature of the various pollutants contained in industrial waste water differ greatly, and some also have strong toxicity, large storage capacity and high stability. Once the emissions, there are changes in the law of migration is very different, and certain sedimentation underwater, a few volatilize into the atmosphere, a little gathering in the body of the organisms, a few disintegrate into other substances, even cause secondary pollution, and make pollutants with tremendous dangerousness. Recovery is difficult once the water body

is contaminated. And even the emission of pollutants is reduced or stopped, and to restore to its original state still takes a long time. (Shui 2012.)

3.4 Pollutants in industrial waste water

There are many kinds of pollutants in wastewater. In the light of the harm caused by the wastewater pollution to the environment is different, and it can be divided into solid pollutants, organic pollutants, oil pollutants, toxic pollutants, biological contaminants, acid-base pollutants, nutritional pollutants, aerobic pollutants, sensory pollutants and thermal pollution etc.(Shui 2012.)

In order to characterize the wastewater quality, numerous water quality indicators have been formulating. There are chemical oxygen consumption, toxic substances, organic substances, suspended matter, the total number of bacteria, pH value, chroma, ammonia nitrogen, phosphorus, and biochemical oxygen consumption. A water quality index may include a comprehensive indicator of the concentration of pollutants, and a pollutant can also bring about the surface features of the concentration of water quality indicators. For instance suspended solids may include organic pollutants, inorganic pollutants, algae and one type of organic pollutants can cause COD, BOD, pH values and other indicators of water quality.(Shui 2012.)

3.4.1 Suspended solids

Contaminants in the wastewater can be divided into soluble components and suspended solids, there was no clear boundaries between the two. After the water sample is filtered, the solids that cannot pass through the filter are called suspended solids. Suspended solids are an important indicator for the determination of sediment-laden river water and some industrial wastewater. Suspended matter will plug the pipeline, and siltation of riverbed. Suspended solids are usually measured by using glass sand core filter, filter paper, filter-membrane as a filter. The international often use of 0.45μm as the filter aperture standard. (Wang & Ren 2004.)

Suspended solids, particle size between 0.1 ~ 1.0μm are called finely dispersed suspended solids; particle size greater than 1μm are referred to as dispersed suspended solids. Suspended solids consist of organic and inorganic matter. It can be divided into volatile suspended solids and non-volatile sus-

pended solids two kinds. The former is also known as burning weight loss, the latter is also known as ash. The suspended solids were burned in the muffle furnace (temperature 600 ℃), the lost weight is called volatile suspended solids. Residual weight is called non-volatile suspended solids. (Wang & Ren 2004.)

3.4.2 Biochemical oxygen demand BOD

Biochemical oxygen demand or biochemical oxygen consumption represents the organic matter in water and other aerobic pollutants quantity of a comprehensive indicator. Indicating that the organic matter in water is due to microbial biochemical oxidation decomposition, and the total amount of dissolved oxygen in the water consumed when it is rendered inorganized or gasified. This unit is showed in ppm or mg / l. The higher the value the more organic pollutants are in water, and the more serious pollution. In order to make the test data comparable, the general provisions of a time period. During this time, and at a certain temperature with water samples of microorganisms, and determine of dissolved oxygen in water consumption, and generally five days, and known as the five days biochemical needs Oxygen, and it recorded as BOD5. About extended storage time can be measured microbial degradation of organic matter in water required for all the oxygen, called the total biochemical requirements, to BODu named. Biochemical oxygen demand is an environmental monitoring indicator, mainly used to monitor the pollution of organic matter in water. And the larger the value the more organic matter is contained in water, therefore the higher severe pollution. General organic matter can be decomposed by microorganisms, but the microbe decomposition of organic compounds in water is needed to consume oxygen. If the dissolved oxygen in water is not sufficient to supply the needs of microbe, the water body is in a contaminated state. BOD is the indicator of environmental protection. BOD5 of municipal wastewater accounts for about 68% of the total BODu, while the proportion of industrial waste water may be less than 50%. The individual examples are the BOD5 of the landfill leachate about equal to 20% of the BODu, this indicates that the rate of degradation of industrial wastewater is low, and that is the reason for usually requiring a longer residence time. (Wang & Ren 2004.)

3.4.3 Chemical oxygen demand COD

Chemical oxygen demand is the strong acid medium and heating conditions, and the amount of oxidant consumed when oxidizing the water sample with potassium dichromate as the oxidant, expressed as mg / L of oxygen, and the results should be determined include dissolved substances and suspended solids in water samples. Chemical oxygen demand reflects the degree of water pollution by reducing substances. And reducing matter in water is mainly organic matter, which can also be seen as a comprehensive indicator of organic pollution. Therefore, chemical oxygen demand is also one of the indicators of the relative content of organic matter, but can only reflect of which it has oxidized the organic pollution, and it cannot reflect the pyridine, polycyclic aromatic hydrocarbons, dioxin and other relatively stable organic compounds of the pollution circumstances.(Wang & Ren 2004.)

COD has the advantage of more accurate reflected the content of organic matter in wastewater, while the time period is determined , subject to water quality restrictions, however the presence of reducing inorganic waste water such as sodium sulfite, sodium sulfide, ferrous sulfate, can consume potassium dichromate and has showed COD value, resulting in some error. In addition, it cannot be like microbial oxidation of organic matter, from the perspective of the health of water pollution levels. (Wang & Ren 2004.)

3.4.4 Eutrophication

Eutrophication refers to beneath impact of human activities, and the desired biological nitrogen, phosphorus and other nutrients poured into lakes, rivers, bays, and other slow-flow water bodies, causing algae and other plankton multiply rapidly, and dissolved oxygen decline, deterioration of water quality, fish and other biological phenomenon of a large number of deaths. Under natural conditions, the lake might of the transition from oligotrophic state to eutrophication, but this natural process is very slow, and industrial wastewater and domestic sewage containing nutriment anthropogenic emissions caused by eutrophication can appear in a short time. Water eutrophication occurs when phytoplankton blooms, forming blooms (algal blooms in freshwater bodies of a natural ecological phenomenon).Because of the color of the dominant planktonic algae is different, the surface water tends to appear blue, red, and brown, ivory. This phenomenon is called the red tide in the ocean. (Wang & Ren 2004.)

The causes of the problem of eutrophication have different opinions. Most researchers believe that the concentration of nutrients like nitrogen and phosphorus has increased, and it caused algal blooms, among which phosphorus is the key factor. It is affect the growth of algae physical, chemical and bio-

logical factors (such as sunlight, nutrient salts, seasonal changes in water temperature, PH value of water, and the relationship between creature's own) is extremely complex. Therefore, there is difficult to predict the trend of the growth of algae, and it is difficult to fix a representation of eutrophication index. The general index is used: Nitrogen content of more than 0.2 ~ 0.3mg / L, the phosphorus content of greater than 0.01 ~ 0.02mg / L, BOD greater than 10mg / L, the total number of PH value 7-9 in freshwater bacteria per milliliter more than 100,000, the number of algae chlorophyll -a characterization content greater than 10μg / L.(Wang & Ren 2004.)

3.4.5 Heavy metal ion problems

Original meaning of heavy metal refers to the fact that the proportion of the metal is greater than 5 (density greater than 4.5 grams per cubic centimeter of metal), and including gold, silver, copper, iron and lead. Heavy metal pollution and contamination of other organic compounds are different. Many organic compounds by nature have physical, chemical or biological purification, and allowing harmful dropped or removed. The enrichment of heavy metals is difficult to deteriorate in the environment. Since China is currently mining heavy metals, and smelting, and processing came about quite a few heavy metals such as lead, mercury, cadmium, cobalt, into the air, water, soil, and causing serious environmental pollution. For instance, there was followed wastewater discharge of heavy metals, even small concentrations, however also in algae and sediment accumulation, and fish and shellfish are adsorbed external, generating condensed food chain, resulting in pollution. If the metal in the water body has beneficial or harmful depends not only on the type of metal, physical and chemical properties, but also on the concentration of the metal and the presence of valence and forms, although beneficial concentration of metal element exceeds a certain value will be a severe toxicity that make plant poisoning and even death. Metal organic compounds (such as organic mercury, organic lead, organic arsenic, organic tin.) compare the corresponding inorganic metal compounds are much stronger toxicity; and toxicity of soluble metal off than the state of the metal particles to be large; and ratio of hexavalent chromium trivalent chromium toxicity is large.(Wang & Ren 2004.)

Strong interaction of heavy metals can occur in the human body and various enzymes and proteins, making them lose their activity. It may also is enrich in certain organs of the body, and if it exceeds the limits the human body can withstand, the human body come about acute poisoning, and sub-acute poisoning. Chronic poisoning of the human body will cause great harm, such as Minamata disease, oc-

curred in Japan (mercury contamination) and bone pain disease (cadmium pollution, disease, pollution, there is caused by heavy metal contamination).(Wang & Ren 2004.)

Heavy metals are widely distributed in the atmosphere, water, soil, organisms, and the sediment is often the repository and the final destination of heavy metals. When the environment changes, heavy metals form in sediment will occur conversion furthermore release to create pollution. Heavy metals cannot be biodegradable, but hold bioaccumulative and may direct threat to higher organisms, including humans. The scientist pointed out that heavy metals are inconvertible to soil contamination. Contaminated soil treatment has no value, and it can only be avoided by adjust planting varieties. Therefore, the problem of heavy metal pollution in sediment was received increasingly attention. (Wang & Ren 2004.)

3.4.6 PH value

For industrial wastewater was, pH value is both a pollution index, and an indicator of the need to control the purge. PH value represents the pH of the solution, it is equal to the negative logarithm of the hydrogen ion, i.e., (Wang & Ren 2004.)

$$PH = \lg \frac{1}{\left[H^{+}\right]} = -\lg\left[H^{+}\right] \quad (1)$$

Wherein - the hydrogen ion concentration in mol / L meter.

When pH = 7, the waste water is neutral; pH <7, the waste water is acidic. The smaller the value, the stronger the acid; pH> 7 is alkaline waste water. The greater the number, the more stronger alkaline.(Wang & Ren 2004.)

PH value of different types of industrial waste water and the different stages of the process in some industries generate a large difference. Chemical plants, chemical fiber plants, electroplating plants, coal plants, citric acid plants and metal pickling workshops discharge acidic wastewater. Some waste water was containing inorganic acid, some containing an organic acid, sometimes it containing both inorganic and organic acids. Acid-containing wastewater varies hugely, from less than 1% to 10%. Dyeing, metal processing plants, oil refineries, paper mills and other discharge alkaline wastewater. It contains organic base, also contains inorganic bases. Concentrations can be as high as a few percent. In

addition to containing acid or base the wastewater, but also may contain acid salts, basic salts and other inorganic substances and organic substances. These will affect the PH value. (Wang & Ren 2004.)

Furthermore PH value of <7, industrial waste water will corrode steel tube, concrete, and textiles, andburning skin. It can also change the PH value of the surrounding medium. PH> 7 is lesser degree of harm created from industrial wastewater. This kind of uncontrolled discharge of industrial waste water will not only cause pollution, pipeline corrosion, damage crops, harm fishery production, disrupt the normal operation of the biological treatment system, but also is a tremendous waste. In dealing with this type of waste water, the first thing is to consider recycling, followed by the neutralization treatment. (Wang & Ren 2004.)

3.4.7 Toxic contaminants

Toxic pollutants in waste water is mainly refers to inorganic chemical toxins, organic chemical poisons and radioactive substances. Inorganic chemical poisons mainly refer to heavy metals and their compounds. Most heavy metal ions and their compounds are easily adsorbed by particles suspended in the water, and sediments deposited in the bottom of the sedimentary layer, and long-term contamination of water bodies. Certain heavy metals and their compounds in fish and aquatic organisms and crops are tissue deposition, accumulation and cause harm. People are drinking or through the role of the food chain, so that the gathering of heavy metals accumulated in the body poisoned, and even led to death. Organic chemistry toxicology mainly refers to phenol, benzene, nitro compounds, organic pesticides, PCBs, PAHs, and synthetic detergent. These substances have strong toxicity. Such as polychlorinated biphenyls possess a new lipid, is soluble in fats and oils can be carcinogenic, and polycyclic aromatic hydrocarbons are carcinogenic. Radioactive substance mean a substance has a radionuclide. These substances can emit alpha, beta, and gamma rays from their own disintegration. Radioactive substances enter the human body will continue to release radiation, harm the body, and people suffering from anemia, cancer and other diseases. (Wang & Ren 2004.)

Cyanide is a class of compounds containing cyano group (-CN), including simple cyanide, organic cyanides and cyanide complexes. Simple cyanide is a highly toxic substance, toxicity of organic cyanide and cyanide complexes are lower than simple cyanide. Nature has very strong purification effect to cyanide, so exogenous cyanide is not readily accumulate in the environment. Only when accidental discharge or high concentrations of continuous pollution and contamination level is more than the wa-

ter environmental purification capacity, and in order to accumulate in the water environment, and residues, and constituting the potential harm to the human body. Cyanide can enter the body through the digestive tract, respiratory tract and skin pathways. While cyanide is highly toxic to the human body, and it enters the human body which it can inhibit cellular respiration, resulting in the body tissue hypoxia, and form asphyxia. However, cyanide is a non-accumulative poison, and the body has strong detoxification function of cyano-group, so that acute and chronic cyanide poisoning caused by the cyanide pollution is rarely reported. The mainly industrial pollution sources of cyanide are for electroplating, coking, metallurgy, chemical, mining, petrochemical and other industrial waste.(Wang & Ren 2004.)

Fluoride can enter the body through the respiratory tract, digestive tract and skin. If the fluoride content in drinking water exceeds 1.5mg / L, people of its intake exceeds 4 ~ 5mg / L, and accumulated in the body caused chronic poisoning. Chronic fluorosis has mainly the upper respiratory tract inflammation, bone and tooth damage. The main sources are for the metal smelting industry, phosphate fertilizer production, electrolysis, casting, glass processing, rubber, plastics and other industrial waste. (Wang & Ren 2004.)

4 NEW TECHNOLOGIES OF SEWAGE TREATMENT

With the continuous improvement of water treatment technology, a number of new sewage treatment technologies has been applied to practice, and in industrial wastewater treatment has achieved good results for the purpose of the water pollution control industry has made tremendous contributions.

4.1 Catalytic wet air oxidation technology

Catalytic wet air oxidation method is the latest technology of wastewater treatment. Wet catalytic oxidation method is the development direction of wet oxidation method, and foreign country in the catalyst screening, evaluation, recycling, regeneration and other aspects of a mass of research work. A series of industrial scale production equipment has been established (Wang 2003.)

4.1.1 Overview

Catalytic Wet Air Oxidation (called CWAO) method is based on the wet oxidation (called WAO) method developed in the mid-eighties and for the international high concentration of organic wastewater treatment of advanced environmental protection technology. Under the effect of a certain temperature, pressure and catalyst, by air oxidation, the organic matter in sewage and ammonia were oxidized and decomposed into CO2, H2O and N2 and other harmless substances, to achieve the purpose of purification. Catalytic wet air oxidation has high purification efficiency, and simple process, and small size, and there was a wide range of industrial applications. Catalytic wet air oxidation (CWAO) suitable for governance coking, dye, pesticide, printing and dyeing, chemical, leather and other industries with high chemical oxygen demand (COD) or with biochemical method cannot degrade compounds (such as ammonia, polycyclic aromatic hydrocarbons, carcinogenic substances BAP) about industrial organic wastewater. (Wang 2003.)

The catalytic wet oxidation method is developed by the wet air oxidation method, which it is due to the use of oxidation catalyst. In a comparatively wet air oxidation more moderate operating conditions is to achieve higher efficiency, which can greatly reduce the investment and operating costs. There is considered to be a wide range of industrial application prospects of new wastewater treatment technology. (Wang 2003.)

4.1.2 Process principle and process

Catalytic wet air oxidation (CWAO) method is very effective in the treatment of high concentration organic wastewater about has toxic and harmful and difficult to decompose. Adding suitable catalyst to reducing the temperature and pressure of the reaction, improving the ability of oxidation and decomposition, shortening the time, preventing the corrosion of equipment and reduce the cost. Application of catalyst is to speeding up the reaction rate, and the main reason, and one of the reduction of the activation energy of the reaction; and the second change the reaction process. (Wang 2003.)

There is waste water at high pressure (2 ~ 8MPa) and high temperature (200 ~ 280 ℃), while maintaining the liquid state to pass air, and under the action of the catalyst, the coking wastewater pollutants for complete oxidation and decomposition, and to make it into harmless substance, so that the waste water can be deeply purified. There is such as nitrogen-containing compounds in wastewater ammonia nitrogen, cyanide, thiocyanide, organic oxides by decomposition, the final generation of N_2, CO_2, and SO_4^{2-}. (Wang 2003.)

$$NH_3+3/4O_2=3/2H_2O+1/2N_2 \quad (2)$$

$$NH_4SCN+7/2O_2=N_2+H_2O+H_2SO_4+CO_2 \quad (3)$$

Wastewater phenols, hydrocarbons and the composition of the general constitute the COD after catalytic wet oxidation also generates CO_2 and H_2O and the like. (Wang 2003.)

$$C_6H_5OH+7O_2=6CO_2+3H_20 \quad (4)$$

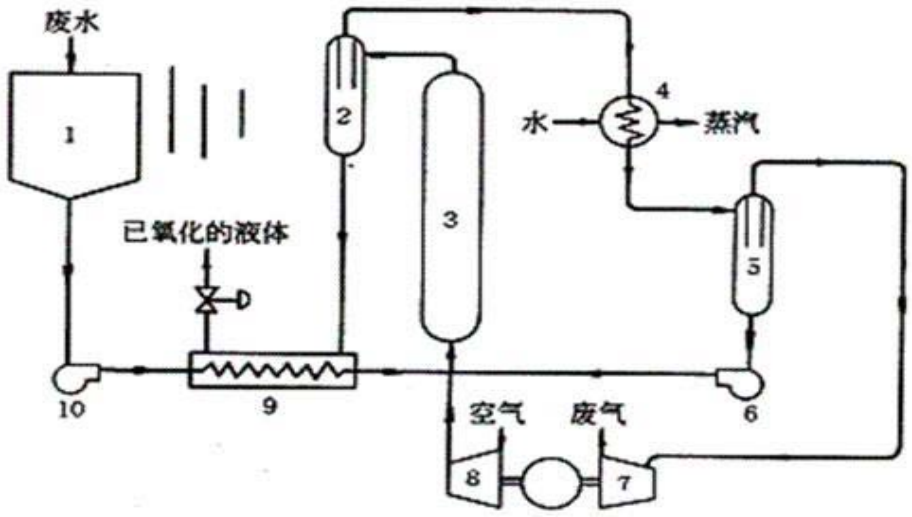


FIGURE1. Principle and Process of Wet Catalytic Oxidation Process (Adapted from Teng Valley Environmental Network. 2011.)

1- storage tank; 2- separator; 3- Jian reactor; 4- reboiler; 5- splitter; 6- circulating pump; 7- turbine; 8- air compressor; 9- heat exchanger ; 1O- high-pressure pump

The process is showing: The waste water is driven into the heat exchanger through a storage tank by a high pressure pump, it exchanging heat with the high temperature oxidation liquid after the reaction, and causes the temperature to rise close to the reaction temperature to enter the reactor. The oxygen required for the reaction is driven from the compressor into the reactor. In the reactor, the organic matter in the wastewater reacts with oxygen and exothermic reaction. The organic matter in waste water is oxidized to carbon dioxide and water, or lower organic acid and other intermediate products at high temperature. After the reaction, the gas-liquid mixture is separated by the separator, and the liquid phase is used to preheat the feed through the heat exchanger, and the heat energy is recovered. High temperature and high pressure exhaust gas are first through the reboiler (such as exhaust-heat recovery boiler) to produce steam or preheat boiler feed water by heat exchanger. The condensed water is separated by the second separator and then pumped into the reactor through the circulating pump. The separated high-pressure tail gas is sent to the turbine to produce mechanical energy or electrical energy. Therefore, this typical industrial catalytic wet oxidation system not only treats the waste water, but also uses the energy step by step, reducing the loss of the effective energy, and maintains and replenishes the energy needed by the catalytic wet oxidation system itself. (Guten environmental protection network. 2011.)

4.1.3 Classification by catalytic wet oxidation

Depending on the state of the catalyst, the catalyst can be divided into two types of homogeneous and heterogeneous catalysts. And wet catalytic oxidation is also divided into homogeneous wet catalytic oxidation and heterogeneous wet catalytic oxidation. Homogeneous wet catalytic oxidation process is by adding a soluble catalyst to the reaction solution, and the molecular or ionic level plays a catalytic role in the reaction process, because the catalyst is miscible in water. The need for follow-up treatment is so that if the practicality of the treatment process is poor, there is more difficult to achieve industrial applications. Catalysts for heterogeneous catalytic wet air oxidation are present in solid state, so that the catalyst is simple and easy to separate from wastewater. Heterogeneous catalysts are of noble metal

series, copper series and rare earth series three categories, among which the catalytic wet air oxidation using precious metals as catalysts has been applied. (Wang 2003.)

4.1.4 Catalytic wet oxidation process advantages

Catalytic wet air oxidation method in the treatment of high concentration organic wastewater has distinct advantages, such as the process does not produce sludge, and only in the interior of the device will having a small amount of cleaning waste liquid, which needs special treatment. The treatment efficiency is high, and the thermal energy can be recovered. The process is simple and small footprint. Through domestic and foreign scientists' research and practice confirmed that catalytic wet air oxidation is an effective method to treat high concentration refractory organic wastewater and sludge. (Wang & Gao & Zhang 2006.)

4.1.5 Application of catalytic wet oxidation

Catalyst and process technology were developed by Dalian Chemistry Research Institute of Chinese Academy of Sciences to build the 30,000 tons / year catalytic wet oxidation of saccharin production wastewater treatment device, in Northern Tianjin Food Co., Ltd. nearly a month's running operation, and a variety of indicators stabilized. For 1 ~ 30000 mg/L CODCr (chemical oxygen demand) of high concentration of refractory saccharin production waste water, the device CODCr removal rate reached 90 ~ 95%, and CODCr emission reductions is equivalently to 3 million tons/year of sewage treatment plant. (Wang & Gao & Zhang 2006.)

Tianjin North Food Co., Ltd., catalytic wet oxidation of saccharin production wastewater treatment system, is currently the largest domestic use of China's independent research and development of catalyst for the treatment of high concentration of difficult degradation organic industrial wastewater device. The device adopts the catalytic wet oxidation technology to treat the saccharin produced wastewater, and has the advantages of small floor area, high removal rate of CODCr, high biodegradability of the effluent. Treating processes can achieve self-heating and evident energy-saving effect in the process. The catalyst and process technology in this device are developed by Dalian Institute of Chemical Physics, Chinese Academy of Sciences, and process design by Dalian Dahua Engineering Design Co., Ltd. promise. The successful operation of the device indicates that Dalian Institute of

Physical Chemical Development of catalytic wet oxidation technology has fully met the international advanced level. The successful application of this technology will play a leading role in the treatment of high concentration and refractory organic industrial wastewater in China. (Wang & Gao & Zhang 2006.)

Saccharin production process in various types of raw materials, and complex technology, so its discharge of wastewater components is complex, and CODCr high, deep color, has a high concentration of refractory organic industrial wastewater, and saccharin production wastewater treatment has been restricting the production scale of such enterprises. In December 2013, Tianjin North Food Co. Ltd. entrusted Dalian Institute of Physical Chemical for saccharin production wastewater to carry out in pilot test furthermore industrial scale. (Wang & Gao & Zhang 2006.)

For the past few years, the rapid development of the national economy has led to the rapid development of petroleum, chemical, pharmaceutical, paper, food and other industries, meanwhile, the wastewater emissions involving high concentrations of difficult biodegradation of organic pollutants and ammonia nitrogen compounds has grown at a more rapid rate. This issue has aroused the community and the government's environmental protection department’s attention. High concentration of industrial organic wastewater is a major pollutant that causes serious pollution of water body, deterioration of ecological environment and threat to human health. It has the characteristics of high contaminant content, high toxicity, scattered discharge points, less water, complicated treatment process, processing equipment investment and operation cost is high and difficult to manage the characteristic. It is difficult to meet the technical and economic requirements of such waste water purification treatment because of the conventional physical and chemical and biological treatment methods, therefore, is becoming a difficult problem waiting to solve at the present stage to develop the difficult degradation and high concentration of organic industrial wastewater treatment technology. (Wang & Gao & Zhang 2006.)

4.1.6 Summary

CWAO is suitable for the treatment of coking, dyes, pesticides, printing and dyeing, petrochemical, leather and other industries containing high chemical oxygen demand (CODCr) or biochemical methods and cannot be degraded compounds (such as ammonia, PAHs, carcinogenic BAP) Industrial organic wastewater. It has high purification efficiency, simple process, and small footprint and other

characteristics. Meanwhile it also has a wide range of industrial application prospects. (Wang & Gao & Zhang 2006.)

But the CWAO method also has some shortcomings, such as the conditions of the harsh process, the capacity requirements for technical staff are relatively high, requiring high temperature and high pressure corrosion resistance, high quality requirements for equipment, high operating costs, and the more serious loss of catalyst. The effectiveness of the catalyst is one of the factors restricting the development of CWAO method. If the CWAO method can be developed rapidly, it is the necessary to strengthen the research on the catalyst, through the choice of catalyst, optimization, catalyst regeneration, and development of efficiency, wide practicability and the stability of the catalyst. (Wang & Gao & Zhang 2006.)

It is for the high concentration of difficult degradation of the waste water is relatively small characteristics, and it should develop a complete set of equipment, and the processing system modular, integrated, and can be assembled into mobile processing equipment, and reduce the duration, and it is easy pilot test, observe the treatment effect . It is improving the level of automation, minimizing human control parameters, improving processing efficiency. (Wang & Gao & Zhang 2006.)

4.2 Supercritical water oxidation technology

Water is the most important solvent in nature, and it has many unique properties in supercritical state. Especially important applications of supercritical water chemical reaction - supercritical water oxidation method refers to the high temperature and high pressure (high temperature: 400 ℃ ~ 650 ℃; high pressure: 2150 × 107Pa) oxidation of water and effective destruction of organic waste technology. It is the most effective technology for dealing with organic waste that has been developed and has been beginning for applying in recent years. (Dai & Huang 2001.)

4.2.1 Overview

Supercritical water oxidation technology is a new oxidation technology that can completely destroy the structure of organic matter. The principle is the use of a special nature of the supercritical water as a medium to the organic matter contained in wastewater with oxygen decomposition into water, carbon dioxide and other simple non-toxic small molecule compounds. In Europe, the United States, Japan

and other developed countries, supercritical water technology has been tremendous developing, and there have been some pilot plant and some commercial installations. China's supercritical water is still in the research stage, there has no engineering applications. (Dai & Huang 2001.)

Supercritical water oxidation technology in the treatment of various waste water and excess sludge has achieved great success. And the shortcomings of the reaction conditions are harsh and strong corrosive to metals, and the time required for the oxidation of compounds with stable chemical properties is also long. In order to accelerate the reaction rate, reduce the reaction time and reduce the reaction temperature, the advantages of supercritical water oxidation technology has further evident. And many researchers are trying to introduce the catalyst into the supercritical water oxidation process. (Dai & Huang 2001.)

4.2.2 Supercritical fluid and supercritical water characteristics

The so-called critical refers to the material of a special fluid state. When put the material lay in the gas-liquid equilibrium is heated up, and the pressure is raised, and the thermal expansion caused by fluid density reduction, moreover pressure increases to make the phase boundary of the gas-liquid two-phase disappears, turn into a homogeneous system, which is the critical point. When the temperature and pressure of the material are higher than the critical temperature and the critical pressure, they are in a supercritical state. The supercritical fluid has a good fluidity similar to that of gas, and it is much larger than the density of the gas, so it has many unique physical and chemical properties. (Liu & Gao 2003.)

Under normal conditions, water is always in steam, liquid water and ice in one of three common state of existence, moreover is a polar solvent, and can dissolve most of the electrolytes, including salts, and the gas and most organic matter is slightly soluble or insoluble, and the density of water practically does not change with pressure. However, if the temperature and pressure of water is raised to the critical point (temperature is 374.3 ℃, pressure is 22.05MPa) or more, it will be in a new fluid-supercritical state different from gaseous state, liquid state and solid state. Regarding the water is called supercritical water. Under supercritical conditions, the properties of water change extremely, and its density, medium constant, viscosity, diffusion coefficient, conductivity and solvation are different from that of ordinary water. In the supercritical state the water has both the nature of gaseous water, but also has the nature of liquid water. (Liu & Gao 2003.)

Supercritical water has a special solubility, and easy to change the density, and lower viscosity, and-lower surface tension and higher diffusion. The density, the dielectric constant, the viscosity, the conductivity, the ionic product, and the solubility of the various substances in the supercritical water can be varied continuously by changing the temperature and pressure. It is with this property, the supercritical water temperature and pressure controlling the reaction environment, coordinating the reaction rate, chemical equilibrium, catalyst selection and activity. The dependence of the solubility of the various substances in the supercritical fluid on temperature and pressure allows the reaction and separation during operation to be combined. Supercritical water is completely miscible with non-polar substances, but also with the air, O2, CO2, N2, are completely miscible, however the inorganic salts, especially in the supercritical water solubility is very low. Table 2 lists the solubility of supercritical water compared with ordinary water. (Liu & Gao 2003.)

TABLE2. Comparison of solubility of supercritical water with common water (Luo 2003.)

solute	Ordinary water	Supercritical water
Inorganic substance	Most easily soluble	Insoluble or slightly soluble
Organic compound	Most of the slightly soluble or insoluble	freely soluble
Gas	Most of the slightly soluble or insoluble	freely soluble

4.2.3 Supercritical water oxidation technology principle

The so-called supercritical fluid substance is a special state. When the temperature and pressure of the fluid in the vapor-liquid equilibrium is increased, the thermal expansion causes the density of the liquid to decrease, and the pressure increases and the phase boundary of the vapor-liquid phase disappears and becomes the homogeneous system, which is the critical point. When the temperature and pressure of the fluid are, respectively, higher than the critical temperature and critical pressure it is called in a critical state. Supercritical fluids have good fluidity of similar gases, but the density is much larger than the gas, so there are many unique physical and chemical properties. (Sun & Liu 2005.)

The critical point of water temperature is 374.3 ℃, pressure 22.05MPa, if the water temperature and pressure rise above the critical point, that is, supercritical water, its density, viscosity, conductivity,

dielectric constant and other basic properties are very different from ordinary water, showing a similar nature of non-polar organic compounds. Therefore, supercritical water and non-polar substances (such as hydrocarbons) and other organic matter completely miscible, and inorganic compounds, especially salts, and the ionization constant and solubility in supercritical water is very low. At the same time, the supercritical water can be completely dissolved by air, oxygen, nitrogen, carbon dioxide and other gases. (Sun & Liu 2005.)

Since supercritical water is an excellent solvent for organic matter and oxygen, the oxidation of organic matter can be carried out in the oxygen-rich homogeneous phase, and the reaction does not present a limitation due to the need for interphase transfer. At the same time, the high reaction temperature of 400 ~ 600 ℃ also makes the reaction rate increase, which can achieve the destruction of organic matter in a few seconds. (Sun & Liu 2005.)The oxidation of organic matter in supercritical water can be simply expressed as:

Acid +Na0H__ Inorganic substance

Supercritical water oxidation reaction completely is organic carbon into CO2. It is hydrogen into H20. The halogen atom is converted to a halide ion. Sulfur and phosphorus are, respectively, into sulfate and phosphate. Nitrogen is converted to nitrate and nitrite ions or nitrogen. Moreover supercritical water oxidation reaction is to a certain extent and simple combustion process similar, and in the oxidation process releasing a large amount of heat.(Sun & Liu 2005.)

In order to further accelerate the reaction rate, it reducing the reaction time and reducing the reaction temperature, so that the supercritical water oxidation technology can take sufficient exert to its own advantages. The research on treatment of wastewater by catalytic supercritical water oxidation technology is increasing daily. (Sun & Liu 2005.)

With the continuous development of modern industry, various types of toxic substances continue to enter the environment, so that toxic and harmful substances will severely affect the environment. If the use of conventional primitive water treatment methods, it is including physical chemistry or biological processing methods cannot meet the processing requirements. Therefore, the advanced oxidation technology in China by a number of large-scale water treatment factory receives great importance, but also need to study better water treatment methods, so that it can relate to various fields. (Sun & Liu 2005.)

4.2.4 Supercritical water oxidation technology advantages

It is high efficiency and complete treatment. Moreover organic matter in the appropriate temperature, pressure and a certain retention time, which it is, can be completely oxidized into carbon dioxide, water, nitrogen and salts and other non-toxic small molecule compounds. It is toxic substances removal rate of 99.99%. It is in line with the whole closed processing requirements. Because of the SCWO is a homogeneous reaction under high temperature and high pressure. The reaction rate which it is fast and the residence time is short (less than 1min), so the reactor has simple structure and small volume. (Sun & Liu 2005.)

It is wide range of application. It can be applied to a variety of toxic substances and waste water treatment. It is not form the secondary pollution. Product cleaning which it does not require further treatment. Moreover inorganic salts which it can be separated from the water, the treated wastewater can be completely recycled. When it is the organic content of more than 2%, it can rely on the reaction process of self-oxidation heat release to maintain the required reaction temperature. It is no additional heat supply. If it is the concentration is higher, more heat of oxidation is released. This part of the heat can be recycled. (Sun & Liu 2005.)

4.2.5 Shortcomings of supercritical water oxidation technology

Although the supercritical water oxidation method has many advantages, but its operating conditions of high temperature and pressure of the equipment material is definitely propose strict requirements. On the other hand, although that has studied the nature of supercritical water and the solubility of the substance therein and the kinetics of supercritical water chemistry reaction and mechanisms, but these are far from satisfactory in terms of the knowledge and data necessary for the development, design and control of supercritical water oxidation processes. In the practical engineering design, in addition to considering the reaction kinetics of the system characteristics, that also pay attention to some engineering factors, such as corrosion, salt precipitation, the use of catalysts, heat transfer. (Sun & Liu 2005.)

Corrosion in the supercritical water oxidation environment than under normal conditions more easily leads to metal corrosion. High concentrations of dissolved oxygen, high temperature and pressure conditions, extreme pH values and certain types of inorganic ions can accelerate corrosion. Corrosion will have two problems, first, after the reaction of the effluent contains some metal ions (such as chromi-

um), will affect the quality of treatment. Second, excessive corrosion will affect the normal work of the pressure system. The corrosion behavior of 13 kinds of alloys was studied at 300 ~ 500 ℃, pH value 2 ~ 9, chloride concentration 400mg / L. The results show that pH has little effect on corrosion in a given temperature range. In the subcritical state of 300 ℃, the dielectric constant of water and the solubility of inorganic salts are large, mainly in electrochemical corrosion. When the temperature rose above 400 ℃, the dielectric constant of water and salt solubility decreased rapidly, at this time to the main chemical corrosion. (Sun & Liu 2005.)

It is salt precipitation in the supercritical water oxidation, often in the feed by adding alkali neutralization process generated acid and salt, due to supercritical conditions, the solubility of inorganic matter is very small, and there will be a salt precipitation in the process. The viscosity of certain salts is high and may cause clogging of the reactor or line. Optimization of the reactor form and appropriate mode of operation may be partially improved. Pretreatment may be required for some high salinity systems. (Sun & Liu 2005.)

Make use of catalysts in the study of supercritical water oxidation of some substances is mainly to increase the conversion of complex organic compounds, to shorten the reaction time or to lower the required reaction temperature. The vast majority of the available catalysts are used in the study of wet air oxidation and subcritical water oxidation processes. Compared to homogeneous and heterogeneous catalysts, heterogeneous catalytic effect is better. (Sun & Liu 2005.)

Since the nature of water varies greatly around the critical point, the heat transfer problem near the critical point must also be considered in the supercritical water oxidation process. When the temperature is below the critical point but near the critical point, the kinematic viscosity of water is very low, the natural convection increases when the temperature rises, and the thermal conductivity increases rapidly. However, when the temperature exceeds the critical point have a little, the heat transfer coefficient decreased sharply, which may be due to decreased fluid density and the main body fluids and fluid at the pipe wall of the physical properties of the differences caused. (Sun & Liu 2005.)

Although there are still some problems to be solved in supercritical water oxidation technology, due to its outstanding advantages, it is taken seriously in dealing with hazardous waste day by day. It is a new processing technology with broad development and application prospect. (Sun & Liu 2005.)

4.2.6 Supercritical water oxidation technology application

At present, the domestic supercritical water oxidation technology is still in the research and development stage, the real application to the actual project is still rarely, and that has done better is the new Austrian group, and the new Austrian group from 2008 to start the supercritical water oxidation technology research and development. In the pilot test, the company independently developed 4 sets of supercritical reaction units of different sizes, carried out more than 400 tests, accumulated more than 6000 hours of operation time, obtained the sludge, drug residues, residue, waste emulsion, waste organic solvents and other pollutants to deal with a large number of basic data. (New Austrian Environmental Protection Technology Co., Ltd. core technology 2015.)

It is through six years of research and development tests, using the new Austrian own technology to build the 6t / d supercritical water oxidation pilot plant to achieve continuous and stable operation. At the same time completed the 100-ton-class technology package development, formed more than 80 items with independent intellectual property rights of technology patents, the number of PCT patents reached 7, covering all aspects of process, equipment, control, pretreatment, post-treatment and corrosion-resistant materials. And it is established a relatively complete patent system. (New Austrian Environmental Protection Technology Co., Ltd. core technology 2015.)

It is Langfang super-critical sludge treatment project by the New Austrian Environmental Protection Technology Co., Ltd. to invest in the construction, there is the first independent design and construction of industrial supercritical water oxidation device, processing capacity of 240 tons / day. The project is located in the heart of Langhe Industrial Park, Langfang, covering an area of 1.45 hectares. May 14, 2015, the project feed intake trial run successfully, and in the same month to complete a 72-hour continuous assessment run. (New Austrian Environmental Protection Technology Co., Ltd. core technology 2015.)

The project uses the new Austrian group independent research and development of supercritical water oxidation treatment technology, and can completely decompose the organic matter in the sludge, and kill harmful bacteria, stabilize the heavy metal components, and to achieve the sludge reduction, and harmless treatment and resource utilization. A fundamental solution is to the municipal sludge on soil and groundwater pollution. Compared with the traditional sludge treatment, the supercritical water oxidation treatment technology has prominent advantages in treatment effect, and the environmental

and social benefits are evident. (New Austrian Environmental Protection Technology Co., Ltd. core technology 2015.)

PICTURE2. Hebei Langfang Supercritical Sludge Treatment Project (photo: New Austrian Environmental Protection Technology Co., Ltd. 2015)

Supercritical water oxidation sludge treatment process has the characteristics of short process and high efficiency. The sludge to be treated is first diluted in the pulp mill. The sludge was formulated as a 90% water slurry. After pretreatment filter out the larger particles and then transported to the gasification workshop. The gasification plant concentrates on the main equipment of the supercritical water oxidation sludge treatment process. Mud in the gasification workshop is first through the high-pressure slurry pump into the heat exchanger. It enters the supercritical reactor with sufficient heat transfer from the high temperature material after the reaction. It is subjected to supercritical oxidation with high pressure oxygen injected into the reactor at the same time. After the reaction of high temperature products by heat transfer cooling through the separation system to achieve solid - liquid - gas three - phase separation, the resulting CO2, N2 directly emptying. The water is used in the pulp section, and the inert ash after pressure filtration is used to produce unburned bricks. The project uses advanced Distributed Control System (DCS), Safety Instrumented System (SIS) and Flammable and Toxic Gas Detection Alarm System to monitor the entire production process. It provides a guarantee for the safe, smooth

and efficient operation of the system. (New Austrian Environmental Protection Technology Co., Ltd. core technology 2015.)

4.2.7 Summary

Supercritical water oxidation technology in the treatment of various waste water and excess sludge has achieved great success. Harsh reaction conditions and strong corrosion of metal is the key factor restricting the development of supercritical water oxidation technology. The time required for the oxidation of compounds with stable chemical properties is also long. In order to accelerate the reaction rate, reduce the reaction time and reduce the reaction temperature, the advantages of supercritical water oxidation technology is more obvious, many researchers are trying to introduce the catalyst into the supercritical water oxidation process. Although there are still some problems to be solved in supercritical water oxidation technology, due to its outstanding advantages, it is received increasingly attention in dealing with hazardous waste. It is a new processing technology with broad development and application prospects.

4.3 Catalytic ozone oxidation technology

Catalytic ozone technology is based on ozone advanced oxidation technology, and it will be the strong oxidizing of ozone and catalyst adsorption, and catalytic properties combined, and it can more effectively solve the problem of incomplete degradation of organic matter. The heterogeneous catalytic ozonation process uses a solid catalyst to accelerate the oxidation of the liquid phase (or gas phase) under normal pressure. The catalyst is present in a solid state. It is easy to separate from water, and is less secondary pollution, and it simplifies the treatment process and is increasingly causing people's extensive attentions. (Zhong & Zhan 2000.)

4.3.1 Principles

Catalytic ozone is the use of ozone generated under the action of the catalyst. OH oxidative decomposition of organic pollutants in water, due to, OH strong oxidizing power, and oxidation reaction without selectivity, rapid oxidation and decomposition of the vast majority of organic compounds (including some high stability, and difficult degradation of organic matter). Catalytic ozone research is divid-

ed into two categories: Homogeneous catalytic ozonation of the metal (ions) in the solution, and solid metal, metal oxides or a metal supported on a carrier or heterogeneous catalytic ozonation of metal oxides. (Zhong & Zhan 2000.)

4.3.2 Homogeneous catalytic ozonation

The chemical properties of ozone in aqueous solution are complex. Ozone molecules produce hydroxyl free radicals through chain reaction mechanism and hydroxyl radicals react with ozone molecules to produce a superoxide anion (O^{2-}) and a peroxide hydroxyl radical (HO^{2-}). After the two groups is in the reaction. This includes the initiation of chain reaction mechanisms, and the introduction of organic substance into such systems can cause any of the following two reactions: Before the chain reaction, ozone molecules have been directly with the reaction. Through the electron transfer is way to produce ozone anion radical (O^{3-}). (Cooper, C. & Burch, B. 1999.)

Then the protonation reaction in water system, ozone anion radical decomposition of hydroxyl radicals, and organic functional groups react. Such as C=C,C≡C, aromatic compounds, heterocyclic compounds, carbocyclic compounds, =N-N, C≡N, C-N, C-Si, -OH, -SH, -NH_2, -CHO, -N=N-. (Cooper, C. & Burch, B. 1999.)

However considering that hydroxyl radicals are not stable and have very reactive reactivity, which must be through the auxiliary way in place a large number of continuous production, such as the addition of H_2O_2 or Fenton reagent or UV irradiation to the target substrate to produce an effective role. The oxidative degradation of H_2O_2 / O_3 is a highly efficient degradation process. This advanced oxidation technology is widely used in drinking water. The reason is that only hydrogen peroxide is added to the ozone reactor. (Graham, M. 1997.)

The total reaction of ozone with hydrogen peroxide is shown below:

$$H_2O_2 + 2O_2 \rightarrow 2OH^- + 3O_2 \quad (5)$$

$$H_2O_2 \rightarrow 2OH^- \quad (6)$$

The mechanism of free radical chain reaction, and this process can be supplemented by ultraviolet radiation and greatly improve the yield of hydroxyl radicals. Zhong Li and others are in the study of such reactions that the reaction process is free radicals or direct oxidation of ozone oxidation reaction control, depending on the PH value of the solution and the initial molar concentration ratio of hydrogen peroxide and ozone. At higher initial molar concentration ratios of hydrogen peroxide to ozone, or under alkaline conditions, the degradation process of organic compounds is controlled by free radical reaction, and the reaction rate is significantly accelerated. It was found that the reaction order related to ozone, and hydrogen peroxide and pollutants were respectively first order. However, the effect of the optimum concentration ratio on the degradation of contaminants is controversial. Ma Jun and other studies have shown that hydrogen peroxide and ozone molar concentration ratio of between 0.5 to 1.4, and augment the dosage of H_2O_2 in a certain range of concentration will help to improve the removal rate of organic matter, but it does not specify the optimal value. (Legube, B. & Karpel, N. & Leitner, V. 1999.)

Harbin Institute of Technology is for the catalyst research relatively thorough. Ordinary ozone catalytic oxidation catalyst only accelerates the reaction rate of ozone and organic matter. It is mainly with ozone as oxidant, and did not change the total oxidation capacity. The Harbin Institute of Technology research and development of ozone catalyst mechanism is the rapid decomposition of ozone, that is, in a short time to produce large quantity stronger than the ozone oxidation ability of hydroxyl radicals. And it can make organic matter in a short time to change its spatial structure, and oxidation the same amount organic matter of ozone consumption is lower than the former. The catalyst processing through the control of additives, carriers, temperature, functional materials and other physical and chemical factors, completely solve the catalyst poisoning and failure problems. The key is to make the catalyst in the course of the same as the biofilm constantly peeling off, and always maintain its surface activity, so as to maintain its catalytic efficiency, until depleted.(Zhong & Zhan 2000.)

The cost of commonly used catalyst remains high, the reason is the use of high temperature and high pressure petroleum and petrochemical catalyst processing and use of mechanisms, not considering the sewage at room temperature and pressure characteristics, resulting in high cost, and easy poisoning inactivation, and the effect is poor. Harbin Institute of Technology generation of the catalyst used in the main material is different from the petrochemical catalyst, and catalytic purpose is not to speed up the reaction rate of ozone, but the catalytic decomposition of ozone, to produce hydroxyl radicals, its function requirements and the traditional catalyst is different, and single function, and therefore the cost is low, and for the conventional catalyst cost 1/2. Harbin Institute of Technology’s ozone catalytic

oxidation technology has been successfully applied to oilfield wastewater, port area of oil and sewage treatment, the use of good results.(Zhong & Zhan 2000.)

4.3.3 Summary

It is as one of the advanced oxidation technology of ozone catalytic oxidation technology, because of its high processing efficiency, high speed, thorough, no secondary pollution, can be continuous operation, there were no need of pressurized and heating and many other advantages, has broad prospects for development. The development of ozone catalytic oxidation technology is mainly depended on the research and development of the catalyst, and it is important to select the appropriate catalyst for the different wastewater.

4.4 Electrochemical method

Currently, there are many researches on the treatment of industrial wastewater in the world. The electrochemical method has the advantages of small area, flexible operation and small amount of pollutants. It can not only deal with inorganic pollutants, but also can deal with organic pollutants, and even some cannot be biodegradable toxic organic matter and some of the heavy metal containing sewage can be used to deal with this method. Coupled with wind power, nuclear power and other emerging power generation technology to promote the development and application of the cost of electricity to reduce, making the electrochemical method in the treatment of wastewater has a greater advantage.(Qu 2007.)

4.4.1 Overview

At present, there are many researches on industrial wastewater treatment in the world. Electrochemical process equipment is small in area, flexible in operation and small in discharge. It can not only deal with inorganic pollutants, but also organic pollutants, even some cannot be biodegradable toxic organic matter and some heavy metal-containing wastewater can be used this method for processing. Coupled with wind power, nuclear power and other emerging power technology to vigorously develop and promote the application resulting in lower power costs, making the electrochemical method in the treatment of wastewater has a greater advantage. (Qu 2007.)

4.4.2 Classification of electrochemical methods

Fundamental of electrochemical water treatment technology is the direct electrochemical reaction or indirect electrochemical transformation of the contaminants on the electrodes, that is, direct and indirect electrolysis. Direct electrolysis means that the contaminants are directly oxidized or reduced on the electrodes to be removed from the wastewater. Direct electrolysis can be divided into anode and cathode processes. Anodic process is the oxidation of pollutants in the anode surface and converted into less toxic substances or biodegradable substances, and even organic matter inorganic, so as to achieve the purpose of cutting, removal of pollutants. Cathodic process is the reduction of pollutants in the cathode surface and be removed. It is mainly used for the reductive dehalogenation of halogenated hydrocarbons and the recovery of heavy metals. (Qu 2007.)

Indirect electrolysis refers to the use of electrochemical generated redox substances as a reactant or catalyst, so that pollutants into less toxic substances. Indirect electrolysis is divided into reversible and irreversible processes. That is reversible process (electrochemical oxidation of the medium) means that the redox species can be electrochemically regenerated and recycled during electrolysis. Irreversible process is the use of irreversible electrochemical reaction of the material, such as with strong oxidizing chlorate, hypochlorite, H_2O_2 and O_3 and other organic matter oxidation process. (Qu 2007.)

In addition, according to the specific use of methods can be divided into: electrocoagulation of electric floatation, and electrodeposition, and electrochemical oxidation, and photo electrochemical oxidation, and electro dialysis and electrochemical membrane separation. (Owen 2005.)

Electrocoagulation electric floatation under the action of the external voltage, the soluble anode (iron or aluminum) is oxidized to produce a large amount of cations and then forms the colloid to coagulate the dirt in the waste water. At the same time, the large amount of hydrogen produced on the cathode forms the micro bubble and the floating particles stick together, and the method is called electrocoagulation electrical float. In the electrocoagulation, iron and aluminum are often used as anode materials. (Owen 2005.)

Electrodeposition method using the electrolyte solution of the different metal components of the potential difference, so that the free state or bound state of the dissolved metal precipitation in the cathode. Appropriate electrical potential is the key to electrodeposition. No matter what state the metal is in, it can be determined the potential of high and low by the Nernst equation according to the size of the ionic activity in the solution, and the solution composition, temperature, over potential and electrode material also affect the electrodeposition process. (Owen 2005.)

Electrochemical oxidation is divided into two kinds, which are direct oxidation and indirect oxidation, which belong to the anodic process. Direct oxidation is the direct conversion of pollutants into harmless substances by anodic oxidation. Indirect oxidation is by the anode reaction produced intermediate material with strong oxidation or an intermediate reaction occurring outside the anode reaction, which causes the oxidation of the pollutant to be treated, and finally converted to a harmless substance. For the direct oxidation of the anode, the concentration of the reactant is too low, which leads to the electrochemistry surface reaction is restricted by the mass transfer process; for indirect oxidation, there is no such restriction. In the process of direct or indirect oxidation, it is generally accompanied by precipitation of H_2 or O_2 side effects, but through the selection of electrode materials and electric potential control can be suppressed by the side effects. (Tang & Dai 2006.)

Photoelectric chemical oxidation is the semiconductor material absorbs the energy of visible light and ultraviolet light, produced "electron-hole" pairs, and stores excess energy, enabling the semiconductor particles to overcome the thermodynamic reaction of the barrier, as a catalyst used to carry out some catalytic reaction. (Tang & Dai 2006.)

Electrodialysis relies on the unique function of selectively passing through the membrane under the action of an electric field, so that ions from one solution into another solution, and to the separation of ionized contaminants and concentration. Electrodialysis treatment of metal ions cannot directly recover the solid metal, but can be concentrated salt solution, and the effluent water quality has been significantly improved. It is currently the most studied single-membrane electrodialysis. (Tang & Dai 2006.)

It is electrochemical membrane separation using the potential difference between the membranes on both sides of the separation process. Commonly used in the separation of gaseous pollutants. There are many kinds of electrochemical process for wastewater treatment, among which microelectrolysis, electrocatalysis and electrodialysis are the most widely used.(Tang & Dai 2006.)

4.4.3 Micro electrolysis Technology

Micro-electrolysis technology is an ideal process for the treatment of high concentration organic wastewater; the process for high salt, refractory, high color wastewater treatment can not only significantly reduce the COD and color, but also greatly improving the biodegradability of wastewater. (Alan 1965.)

Micro-electrolysis is also known as the internal electrolysis method, iron reduction method, iron-carbon method, zero-iron method. The principle of wastewater treatment is use iron carbon component in the iron filings constitute of micro primary battery positive and negative electrode, and to fill the waste water for the electrolyte solution, and oxidation - reduction reaction, and the formation of the original battery. The new electrode products with high activity, with organic pollutants in the wastewater redox reaction occurs, so that its structure and morphology is changed, completion from unwieldiness to easy handle, from color to colorless change. Reduction action is an iron inner electrolysis wastewater treatment process, which it is following reaction. (Alan 1965.)

Cathode（Fe）:$Fe-2e \rightarrow Fe^{2+}$ $E0（Fe^{2+}/Fe）=-0.44V$ (7)

Cathode（C）: (8)

This is the reaction equation that occurs under acidic conditions

$2H^{+}+2e \rightarrow H_2 \uparrow$ $E0（H^{+}/H_2）=0.0V$ (9)

This is a reaction equation that occurs under alkaline or neutral conditions.

$O_2+2H_2O+4e \rightarrow 4OH^{-}$ $E0（O_2/OH^{-}）=+0.4V$ (10)

The product produced by the electrode reaction has high chemical reduction activity. In the partial acidity waste water, the new ecological H produced by the electrode reaction can react with the organic matter and inorganic matter components in the wastewater to cause the redox reaction, which can destroy the chromophoric group in the waste water and even break the polymer chain, so as to achieve the purpose of decolorization. At the same time, iron is an active metal, under acidic conditions it can be certain nitro compounds reduced to biodegradable amino compounds, improving the BOD_5 / COD ratio, that is, enhanced biodegradability. The reaction is as follows: (Alan 1965.)

$$R—NO_2+2Fe+4H^+ \rightarrow R—NH_2+2H_2O+2Fe^{2+} \quad (11)$$

Electrolysis of iron ions generated, and ferrous ions by hydrolysis, and polymerization and the formation of ferric hydroxide, and ferrous hydroxide polymer, and colloidal form, and with precipitation, and flocculation and adsorption, moreover flocculation with pollutants produce precipitation, can remove organic matter in water. That at the same time under the action of the electric field around the primary battery, wastewater charged colloidal particles and impurities by electrostatic attraction and surface energy of the role of set, cohesion, but also can make the wastewater be purified. In short, iron-carbon internal electrolysis wastewater treatment is the result of flocculation, adsorption, bridging, sweeping, electrodeposition, electrochemical reduction and other comprehensive effects. (Alan 1965.)

The reaction rate is fast, and it is the general industrial waste water only needs a few minutes to several hours. It is the role of a wide range of organic pollutants. For instance, it is containing azo, and carbon double bond, and nitro, and halogen substituent structure of difficult degradation organic compounds. The operating cost is very low. That is only consumes a small amount of zero-valent iron (the most ideal and readily available and inexpensive metal processing waste iron shavings). It is long life, and easy operation and maintenance. That is micro-electrolysis tower as long as the regular addition of iron filings can be, not to replace the inert electrode, and corrosion electrode added twice a year to add. It has good coagulation effect, and COD removal rate is high. The method can be used as a separate treatment method, but also can be used as biological pretreatment process. In addition to the biochemical nature of wastewater is improved, and it is conducive to the performance of activated sludge sedimentation and biofilm formation. The method can achieve the effect of chemical precipitation phosphorus removal, but also by reducing the removal of heavy metals. (Alan 1965.)

There are dyes, printing and dyeing wastewater, and coking wastewater, and petrochemical wastewater, and wastewater in decolorization at the same time, the treatment of water BOD / COD value increased significantly. There are oil wastewater, and leather wastewater, and papermaking wastewater, and wood processing wastewater, and then the BOD / COD value of the waste water after the treatment is remarkably improved. There are electroplating wastewater and printing wastewater and mining wastewater and other heavy metals containing wastewater, which it can be removed from the waste water of heavy metals. There is organic phosphorus agricultural wastewater and organic chlorine agricultural wastewater, that they are extremely improve the above-mentioned wastewater biodegradability, and phosphorus removal, in addition to sulfide. (Alan 1965.)

4.4.4 Electrocatalytic technology

The so-called electrocatalysis referred to the electric field and exists in the electrode surface or solution phase modifier can promote or inhibit the occurrence of the electron transfer reaction on the electrode, and the electrode surface or solution phase of the modification itself does not occurred change of a class of chemical effects. The electrocatalytic reaction rate is not only determined by the activity of the catalyst, but also with the electric field and the nature of the electrolyte. Because the electric field strength is very high, and it is joined the electrochemical reaction of molecules or ions have a significant activity role, in the activation of the reaction required to greatly reduce the energy, so most of the electrochemical reaction can be much lower than the usual chemical reaction temperature carry out. In the electrocatalytic reaction, due to the role of electrode catalyst electrode reaction has occurred, moreover that chemical energy can be directly converted into electrical energy and the final output current. (Jing & Zhang 2010.)

A common feature of the electrocatalytic reaction is that the reaction process consists of two or more consecutive steps, and a chemisorption intermediate is formed on the electrode surface. Much of the molecules are produced by the ions or make the molecular degradation of the important electrode reactions belong to this type of reaction. The ion or molecule generates a chemisorption intermediate on the surface of the electrode by an electron transfer step, followed by adsorption of the intermediate substance to produce a stable molecule via a heterogeneous chemical step or an electrochemical desorption step. For instance, that it is the acid precipitation in the hydrogen reaction. (Abruna, H. 1999.)

$H_3O^+ + M + e^- \rightarrow M - H + H_2O$ (Proton discharge) (12)

$M - H + H_3O^+ + e^- \rightarrow H_2 + M + H_2O$ (Electrochemical adsorption) (13)

$2M - H \rightarrow H2 + 2M$ (Surface recombination) (14)

In the formula, M-H represents a chemically adsorbed species of hydrogen on the surface of the electrode. The reactants are first dissociative or associative chemically adsorbed on the electrodes, followed by adsorption of the intermediates or adsorption of the reactants for electron transfer or surface chemical reactions. (Bie , Chen & Wang 2002.)

Such as the electro oxidation of formaldehyde:

$$HCOOH + 2M \rightarrow M-H + M-COOH \quad (15)$$

$$M-H \rightarrow M + H^+ + e^- \quad (16)$$

$$M-COOH \rightarrow M + CO_2 + H^+ + e^- \quad (17)$$

Or

$$HCOOH + M \rightarrow M-CO + H_2O \quad (18)$$

$$H_2O + M \rightarrow M-OH + H^+ + e^- \quad (19)$$

$$M-CO + M-OH \rightarrow CO_2 + H^+ \quad (20)$$

In the formula, M – R (R is –H, –COOH, -CO or -OH, respectively) represents a chemically adsorbed species on the surface of the electrode. Examples of such reactions are the electrocatalysis of organic small molecules such as methanol, the electrooxidation of H_2, and the electrical reduction of O_2 and Cl_2. (Liu, Xiang & Zhang 2006.)

The difference is between electrocatalysis and conventional chemical catalysis and electrochemical reaction. Electrocatalytic reaction and conventional chemical catalytic reaction is essentially different from the reaction time, and the transfer process of electrons at their respective reaction interfaces is fundamentally different. In conventional chemical catalysis, the electron transfer between the reactants and the catalyst is carried out in a defined region. Therefore, during the reaction, electrons cannot be supplied from the external circuit, nor can the electrons be derived from the reaction system or the current can be obtained. In addition, in the conventional chemical catalytic reaction, the electron transfer process cannot be controlled from the outside. In the electrode catalytic reaction of electron transfer process is different, there is pure electron transfer. As a kind of heterogeneous catalyst, the electrode is both a reaction site and an electron supply-reception site, that is, the electrocatalytic reaction has both a catalytic chemical reaction and a dual function of electron transfer. That is in the electrocatalytic reaction process can be used to control the external circuit of the over-voltage, so that the reaction conditions, and the reaction rate is relatively easy to control, and can achieve some violent electrolysis and oxidation - reduction reaction conditions. The electrochemical reaction of the output current can be used as a basis for determining the speed of reaction. In the electrocatalytic reaction, the change of free electric energy before and after the reaction is quite large. In most cases, the direction of the reaction can be pre-estimated by the type of reaction and the reaction conditions. Therefore, for the electrolysis reaction, by changing the electrode potential, the direction of the oxidation reaction and the reduction reaction can be controlled. (Liu, Xiang & Zhang 2006.)

Conventional chemical catalytic reaction is mainly based on the enthalpy change of the reaction for the purpose, while the electrocatalytic reaction is based on the change of free energy for the purpose. Since the change of the free energy corresponds directly to the change of the electrode potential, the change of the free energy can be directly measured according to the change of the electrode potential, thereby judging the extent of the electrocatalytic reaction. (Liu, Xiang & Zhang 2006.)

For electrocatalytic and electrochemical reactions, electrocatalytic reaction is based on the electrochemical reaction, the electrode surface modification of materials and catalytic materials to produce a strong oxidizing active species to improve the ability of degradation of organic matter, while the electrochemical reaction is only a simple electrode reaction. The treatment efficiency is distinctly lower than the electrocatalytic reaction. (Liu, Xiang & Zhang 2006.)

It is multi-dimensional electrocatalysis equipment based on electrochemical technology, and the use of electrolytic catalytic reaction process generated strong oxidized particles (·OH, $\cdot O_2$, H_2O_2.). And the organic pollutants are in the wastewater non-selective rapid chain reaction, and oxidative degradation. Device structure is in the traditional two-dimensional electrolysis electrode filling between the granular working electrodes. Thereby forming a multi-dimensional electrode structure. Its main features is the anode using titanium-based coating electrode (DSA anode), and the plate surface is loaded with a variety of catalytic material coating, and with high efficiency, and long life characteristics. That is in the cathode and anode filled with a variety of catalytic materials attached to the conductive particles and non-conductive particles, the formation of double polarity of the particle electrode to improve the efficiency of liquid-phase mass transfer and current efficiency. Compared with the conventional two-dimensional electrode, the area ratio of the multi-dimensional electrode is greatly increased, and the particle spacing is small, thus the liquid-phase mass transfer efficiency is high, greatly improving the current efficiency, unit time efficiency, sewage treatment efficiency and organic degradation effect, while the low conductivity of wastewater also has good adaptability. This technology is the hotspot of wastewater treatment, and it is the new trend and new technology of high concentration organic wastewater treatment. (Ying 2010.)

Multi-dimensional electrocatalytic equipment features are the multi-dimensional electrode structure, efficient catalytic substances, and mass transfer effect is good, and high organic pollutant removal rate (COD removal rate of 30-90%), and no-selectivity to the treatment of difficult degradation toxic organic matter in the wastewater and degradation to carbon dioxide, water and minerals, and non-

biochemical high-molecular organic compounds can be converted into biochemical treatment of small molecules compounds, and improve B / C ratio. (Ying 2010.)

It is the process of electron transfer only between the electrode and wastewater components, and oxidation reaction depends on the hydroxyl radicals generated by the system itself, and without adding liquid, and no secondary pollution. The influent pollutant concentration is unlimited, and COD concentration can be as high as hundreds of thousands of mg / L, and decolorization, detoxification effect is remarkable, and decolorization rate of 50-80%. And the degradation process of organic pollutants is rapid, and the residence time of waste water is short (30-60min), and the required equipment volume is small. It can be simultaneously efficient removal of the ammonia nitrogen, total phosphorus and color in the wastewater. (Ying 2010.)

The reaction conditions are mild, normal temperature and pressure, the operation is simple and flexible, by changing the voltage and current, and at any time to adjust the reaction conditions, and controllability. It is small footprint, short construction period, and low operating costs, and processing costs province. It is non-dissolution type DSA anode, non-electrode corrosion, passivation problems, with high efficiency, long life characteristics. It is an environment-friendly technology. That is management operation science. As the influent parameters of chemical waste water control difficult characteristics, and optional wireless remote monitoring equipment, and remote monitoring of water parameters, and to provide on-site influent exceeds standard (pH, conductivity) alarm. (Ying 2010.)

4.4.5 Electrodialysis technology

The semi-permeable membrane used in electrodialysis is an ion-exchange membrane. The ion-exchange membrane according to the ion charge properties can be divided into cation exchange membrane (cation membrane) and anion exchange membrane (anion membrane) two types. In an aqueous electrolyte solution, the cationic membrane allows the cation to permeate and block the anion, which allows the anion to permeate and repel the cation, which is the selective permeability of the ion-exchange membrane. In the process of electrodialysis, the ion-exchange membrane does not exchange with the ion in the aqueous solution as in the ion-exchange resin, but selectively permeates the ions with different electrical properties, that is, the ion-exchange membrane does not need to be regenerated. Electrodialysis process electrode and membrane compartment is called the polar chamber, which occurred in the electrochemical reaction with the common electrode reaction is the same. Anode room

oxidation reaction occurs, the anode water is acidic, the anode itself is easy to be corroded. Cathodic indoor reduction reaction occurs, and the cathode water is alkaline, and the cathode is easy to scale.(Wang 2000.)

Electrodialysis is a more mature technology in membrane separation. It has been widely used in brackish water desalination, which is the main method of producing fresh water in some areas of the world. As the newly developed charged film has a higher selectivity, lower membrane resistance, better thermal stability phase chemical stability and higher mechanical strength. Moreover the electrodialysis process is not limited to the application of desalination, but also in the food, pharmaceutical and chemical industry. In addition the electrodialysis process also has many other industrial applications, such as the treatment of industrial wastewater, which mainly involves recovering acids and metals from the waste liquor formed by cleaning the surface of the metal with acid. And that is recovering heavy metal ions from electroplating wastewater. And it is recovering sulfates from synthetic fiber waste water. And it is recovery of sulfites from pulp effluents, and the like. That is for the food industry, such as milk desalination of infant formula, and for chemical industry separation of ionic substances and non-ionic substances. And that is in the clinical treatment of electrodialysis can be used as artificial kidney. (Shi 2000.)

It is automatic control of frequent inverted pole electrodialysis (EDR), operation and management is more convenient. Raw water utilization rate is up to 80%, the general recovery of raw water between 45 and 70%. Electrodialysis is mainly used for primary desalination of water, desalination rate from 45-90%. It is widely used in seawater and brackish water desalination. That is preparation of pure water when the primary desalination and boiler, and power plant water desalination and softening. (Rautenbach 1998.)

In essence, electrodialysis can be said to be a desalination technology, because a variety of different water (including natural water, tap water, and industrial wastewater) in a certain amount of salt, moreover the anions and cations that constitute these salts move in the opposite direction, respectively, under the influence of a DC electric field. If one of the anion and cation exchange membranes is inserted in an electrodialyser, and since the ion-exchange membrane has selective permeation, i.e., the cation-exchange membrane allows only the cation to pass freely, and the anion-exchange membrane allows only anions to pass, thus in the middle compartment of the two membranes, the concentration of salt will be reduced because of the directional migration of ions. While the two compartments are near the

electrode were anion and cation concentration chambers, and finally in the middle of the desalination chamber to achieve the purpose of desalination. (Rautenbach 1998.)

In practice, an electrodialyser is not constituted of a pair of anion and cation exchange membranes (since this is inefficient) but with a hundred pairs, or even hundreds of pairs of exchange membrane, thus greatly improving efficiency.(Rautenbach 1998.)

At present, a wide range of electrodialysis applications, and it is desalinated in water desalination, and seawater concentration salt, refined dairy products, juice deacidification and purification, preparation of chemical products. It can also be used for food, light industry and other industries to take purity water, electronics, pharmaceutical and other industries to take high-purity water pretreatment. Boiler supply water is softening of the primary desalination, and brackish water desalination for drinking water. (Rautenbach 1998.)

Electrodialyser is appropriate for electronic, pharmaceutical, chemical, thermal power, food, beer, beverages, printing and dyeing and coating industries such as feed water treatment. It can also be used for material concentration, purification, separation and other physical and chemical processes. Electrodialysis can also be used for waste water, waste liquid treatment and precious metal recovery, such as from the electroplating waste liquid recovery of nickel. (Rautenbach 1998.)

4.4.6 Summary

Among the several electrochemical methods is for the purification of waste water. Electrodialysis technology has developed into a large-scale chemical unit process, and that in the field of membrane separation occupy an important position, and with a better choice of ion exchange membrane appears. And that is electrodialysis in water treatment, and food, pharmaceutical and chemical applications the prospects will be broader. Micro-electrolysis technology is mainly used for pretreatment of refractory wastewater, and improve biochemical. Only a single micro-electrolysis technology, wastewater is difficult to meet emission standards, but also with the follow-up of other processes for advanced treatment. The research and development of fillers is the key to the development of microelectrolysis technology. The area ratio of electrodes in multi-dimensional electrocatalysis equipment is greatly increased, and the spacing of particles is small. Therefore, the efficiency of liquid-phase mass transfer is greatly improved. The current efficiency was improved greatly, unit time efficiency, sewage treatment

efficiency degradation of organic matter, while low conductivity of wastewater also has good adaptability. This technology is the hotspot of wastewater treatment, and it is the new trend and new technology of high concentration organic wastewater treatment.

In short, electrochemistry is an ancient and young discipline. The development and achievements of electrochemical science have attracted worldwide attention, whether it is basic research or technology applications, from theory to method, there are many major breakthroughs. The development of electrochemical science has promoted the progress of world science and promoted the development of society and economy. It has made great contributions to solving the energy, transportation, material, environmental protection, information and life faced by human society. The future of chemistry is glorious and miraculous. Electrochemical development and breakthrough is difficult to estimate.

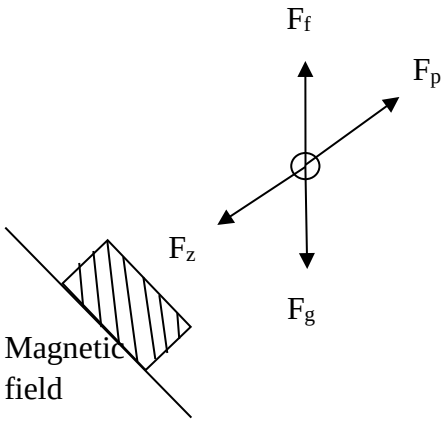
4.5 Magnetic Separation Technology

Magnetic separation technology is a technology for the magnetic field treatment of substances. The application of this technology has penetrated into various fields. The technology is the use of elements or components of the magnetic sensitivity of the difference, with the external magnetic field to the material magnetic field processing, so as to achieve an enhanced separation process of a new technology. (Mei & Wang 2003.)

4.5.1 Principles of Magnetic Separation Technology

There are many kinds of pollutants in the wastewater, and the pollutants with strong magnetic properties, they can be directly separated by high gradient magnetic separation technology. Thus for the magnetic weak pollutants first can be added the magnetic species (Such as iron powder, magnetite, hematite particles.) and coagulant, the magnetic species and pollutants combined, and then remove the use of high gradient magnetic separation technology. The basic principle of the physical role of magnetic separation is through the external magnetic field to produce magnetic, the wastewater with magnetic suspended particles is sucked out, so that with the separation of wastewater to achieve the purpose of removal or recovery. For the sake of convenience of analysis, the tiny magnetic suspended particles in the waste water is regarded as the spherical objects with diameter d, the density is ρ, the

mass is m, from the knowledge of physical mechanics, magnetic particles in the magnetic field force analysis shown in Graph3. (Mei & Wang 2003.)



Graph3.

GRAPH3. The magnetic particles are force analysed in the magnetic field (Mei & Wang 2003.)
Where Fg – for gravity, Ff – for the buoyancy, Fp – for the fluid resistance, Fz – for the magnetic force.

Through the above magnetic particles is force analysis. The main factors that affect the magnetic field capturing magnetic particles are magnetic field force, the magnetic susceptibility of suspended particles, particle size of suspended particles, water velocity and contact area. Magnetic separation technology used in wastewater treatment of three methods: direct magnetic separation method, indirect magnetic separation method and microbial magnetic separation method. The use of magnetic technology to deal with wastewater pollution mainly the use of cohesion and the addition of pollutants, cohesion refers to a ferromagnetic or paramagnetic pollutants in the magnetic field, due to the role of magnetic force cohesion into the surface diameter increase of the particles then removed. and addition refers to the addition of magnetic seeds by means of enhanced the magnetic properties of weak paramagnetic or non-magnetic pollutants and easy to use magnetic separation method to remove. And it is or by means of additional microorganisms to adsorb the paramagnetic ions in wastewater, and then use the magnetic separation method to remove the ion state Paramagnetic contaminants. Zheng Bisheng and others on the basic theory of magnetic separation technology were studied. (Hei 2013.)

Magnetic species preparation method is the first Fe_2O_3 magnetic powder silane treatment, That is, with γ-aminopropyl triethoxysilane as coupling agent, its V group first hydrolyzed into silanol, and then silanol dehydration and Fe_2O_3 Fe atoms in the coupling Fe_2O_3, the surface is wrapped with a layer of monolayer of the silane coupling agent, and then activated with glutaraldehyde, which has a special adsorption function of the species. The aldehyde groups on the surface of the magnetic species are

bound together by colloids, suspensions, proteins, fats, phosphates and the like in covalent bonds. When high gradient magnetic separation is performed, the magnetic particles with the impurity particles can be captured in the filter, so as to achieve the purpose of separation. By changing the pH value of the solution system, the separation effect can be enhanced. (Hei 2013.)

4.5.2 Classification of magnetic separation technology

Magnetic separation technology is a kind of technology that separates different magnetic materials by the effect of magnetic field force. All macroscopic objects, in a certain extent, are magnetic, but according to their characteristics in the role of external magnetic field, can be divided into three categories: ferromagnetic materials, paramagnetic substances and anti-magnetic substances. The ferromagnetic material is a kind of magnetic species which it usually can be used. The magnetic difference of various materials is the basis of magnetic separation technology. Magnetic separation method according to device principle can be divided into magnetic agglomeration separation, magnetic disk separation and high gradient magnetic separation method. According to generating magnetic field's method which it is can be divided into permanent magnetic separation and electromagnetic separation (including superconducting electromagnetic separation). According to the working mode, the method can be divided into continuous magnetic separation and discontinuous magnetic separation. According to the particle removal method that is can be divided into magnetic coagulation sedimentation separation and magnetic adsorption separation. (Pan 2012.)

4.5.3 Advantages of Magnetic Separation Technology

That is the technology to deal with wastewater speed fast, and processing capacity is large. Moreover that is not affected by the natural temperature. The other separation method are hard to remove very fine suspended solids and low concentration of wastewater has a strong ability to separate. Especially the filtration rate of high gradient magnetic filter separator is 10~30 times of treatment with the conventional high-speed filter, equivalent to 100 times of sedimentation tank. (Pan 2012.)

Magnetic separation equipment is small, simple structure, and easy maintenance, and low cost, and then less land. Such as high-gradient magnetic separation equipment and it is easy to automate. That is the work highly reliable, and moderate maintenance. Thus it is in an area of small and ordinary fast

filter, and for example, magnetic filter covers an area of only 1/6, civil construction is also very small. That is greatly shorten the construction period. Therefore, the magnetic filter is particularly suitable for small and medium-sized water plants and land resources are relatively tight in the town. (Pan 2012.)

The use of high gradient magnetic filtration can remove those drug-resistant and highly toxic pathogenic microorganisms, bacteria and some difficult to degradation of organic matter. That is the magnetic field forces can cause pathogenic microorganisms, bacteria and other cells within the water and enzyme passivation or inactivation, thus they are killed by magnetic filter to achieve the purpose of removal, and does not produce harmful by-products. Compared with the use of chlorine or chlorine preparation disinfection, the magnetic separation technology does not produce waste water. Organic compounds react with chlorine to produce trihalomethanes (THMs) and other halogenated hydrocarbon compounds, which are causative agents for a variety of diseases. (Pan 2012.)

The operating cost is relatively low. that is for small and medium-sized water plants, and the use of magnetic filter processing device (filter part) and the traditional process (filter chamber part) compared to increased operating costs (run-time by adding iron powder considerations, and the recovery rate of 80%) is 0.49 yuan / m3 (test equipment according to a separate custom, cost much higher than the mass production). However the magnetic filter on organic matter in water the removal effect is much higher than the traditional process, and can remove the algae, the effluent quality is better than the sand filter effluent. (Pan 2012.)

4.5.4 Application of Magnetic Separation Technology

A new technology, a new device research and development success, will bring a large number of applied research. That is at the same time, people in the separation and purification of equipment, and how to improve the separation efficiency of equipment, and also carried out a large number of research work. For water treatment works, because the magnetic separation technology is only a physical property of the solid-liquid separation means, in practical application, many occasions must be supplemented by other related technologies, thus it can play a very good effect. Below, that is in the light of the characteristics of magnetic separation technology, and according to the application process division, magnetic separation technology in the application of water treatment for a first volume. (Deng & Dong 2011.)

Whether the development of high-gradient magnetic filter or a variety of disk-type magnetic separator, in water treatment, their preferred application areas are steel wastewater treatment. Iron and steel hot rolling / or continuous casting wastewater, and cold rolling emulsions, that the pollutants are more than 98% of the strong magnetic material. And in addition to containing some oil and a small amount of non-magnetic material, and very suitable for magnetic separation purification. The process is simple and small footprint, and good treatment effect. (Deng & Dong 2011.)

That is the use of magnetic separation technology to treat sewage, the condition is that the particles in the sewage have had a certain magnetism. For non-magnetic or weakly magnetic contaminant wastewater, generally by adding magnetic species and then use flocculation technology to non-magnetic substances and magnetic species combined together. And then use magnetic separation technology alone or flocculation and sedimentation combined with high gradient magnetic separation technology to separation and purification of wastewater. Such technology is known as "Magnetic Species Coagulation Magnetic Separation" or "Magnetic Loading Magnetic Separation" technology. (Deng & Dong 2011.)

Magnetic seed inoculation technology in the field of mineral magnetic separation has been embedded research, for the separation of different magnetic minerals, scientific and technical staff to synthesize a large number of optional magnetic carriers. In the field of wastewater treatment, the magnetic species is not selective requirements, generally require only: has a relatively strong magnetic; easy recycling and reuse. (Deng & Dong 2011.)

Most of the pollutants in urban sewage is non-magnetic, in which the magnetic species and the appropriate coagulant, and then through the high gradient magnetic separator, to remove suspended solids in the sewage, color, turbidity, phosphoric acid salt, bacteria. Researchers at the Massachusetts Institute of Technology have added Fe_3O_4 and aluminum sulfate to municipal wastewater, a high gradient magnetic separation treatment was carried out, and a good effect was obtained. However, this technology is not substantially different from the coagulation sedimentation, but is the use of magnetic separation to replace the settlement of gravity separation, the removal of ammonia nitrogen is low. In order to better deal with the COD, BOD, ammonia nitrogen, phosphorus and other pollutants in the sewage, only the magnetic separation technology and the existing biological treatment technology combined. It is possible to achieve better results. (Deng & Dong 2011.)

4.5.5 Summary

In the water treatment project, the magnetic separation technology on its essence, is only a physical property of solid-liquid separation means. The progress of magnetic separation equipment has led to the related application research. The combination of magnetic separation technology and other technologies has expanded its application field in water treatment engineering. (Deng & Dong 2011.)

Although the magnetic separation technology in the treatment of rich-magnetic contaminants, large amount of sewage, compared with the traditional process has obvious advantages. But magnetic separation technology also has some technical difficulties and limitations. First the remanence of the medium makes the magnetic separation equipment in the system backwash, however it is difficult to wash the magnetic particles which are absorbed by the magnetic medium, and thus affect the working efficiency of the next period. Secondly in order to improve the magnetic field gradient, that is must be chosen by high magnetic saturation of the magnetic media, and the selection of magnetic media has some technical difficulties, and increase the cost of running. (Deng & Dong 2011.)

Although the magnetic separation technology is a simple and feasible and efficient treatment of water treatment technology, because of the technical difficulty and limitations is to be further study to overcome. Therefore, in practical applications is affecting its wide application. (Deng & Dong 2011.)

Compared with conventional methods such as sedimentation and filtration, magnetic separation has many advantages, such as large processing capacity, high efficiency, low energy consumption and simple and compact equipment. It has been successfully applied to blast furnace gas washing water, steel-making dust purification wastewater, steel rolling waste water and sintering wastewater purification, but also in other industrial waste water, urban sewage and land water purification is also promising. (Deng & Dong 2011.)

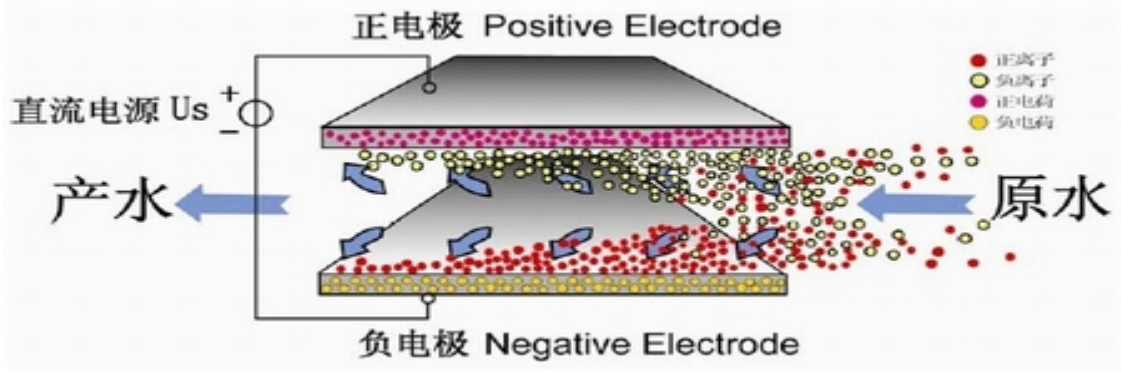
4.6 Electro - Adsorption Technology

Most of the salts in water treatment exist in the form of ions (positively or negatively charged). The basic idea of electro-adsorption desalination technology is to form an electrostatic field by applying an applied voltage to force the ions to move toward the electrode with the opposite charge. Thus the ions

is in the electric double-layer enrichment, greatly reduce the concentration of the solution body, in order to achieve the aqueous solution desalination. (Li 2008.)

4.6.1 Principles

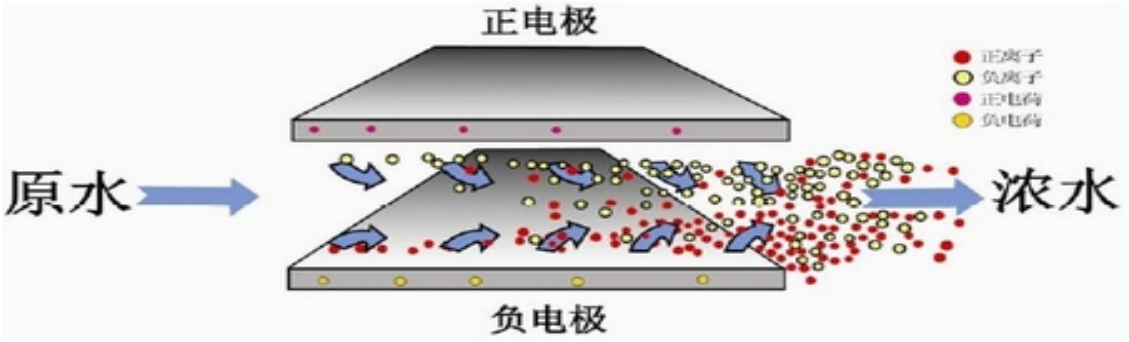
Electro-adsorption principle is shown in Graph4, the raw water from one end into the space separated by the two electrode plates, from the other end outflow. Raw water is flowing between the anion and the anode under the action of the electric field, the ions in the water migrate to the oppositely charged electrode, and are adsorbed and stored in the electric double layer by the electrode. With the increase of electrode adsorption ions, the ion concentration enrichment in the electrode surface, the final separation from water is achieved by purifying / desalinating the product water. (Li 2008.)



GRAPH4. Schematic Diagram of Working Process (Han 2010.)

In the process of electro-adsorption, the storage / release of the electric charge is realized by the adsorption / desorption of ions rather than by the chemical reaction, so that it can be rapidly charged and discharged, and only the ion adsorption / desorption occurs at the time of charging and discharging, The electrode structure does not change, so the number of charge and discharge in principle there is no limit. (Li 2008.)

When the raw water contained a certain amount of salt passes through an electroabsorption module consisting of a highly functional electrode material, and the ions are stored in the electric double layer on the surface of the electrode under the action of a direct current electric field until the electrode reaches saturation. At this point, the direct current power supply is removed and the positive and negative electrodes are short-circuited. As the direct current electric field disappears, the ions stored in the electric double layer are returned to the channel, with the water discharge, the electrode is also from this regeneration. (Li 2008.)



GRAPH5. Schematic Diagram of Regeneration Process (Han 2010.)

As the electric adsorption process, the use of electric field force will be the role of the anions and cations were adsorbed to different electrode surface to form double electric layer, which makes the same pole surface insoluble salt ion concentration product is much lower, that can effectively prevent insoluble salt fouling phenomenon. Second, the electric adsorption between the plates of water runoff and the plate was tangential direction, is not conducive to the precipitation of insoluble salt crystals in the growth of the plate. Electro-adsorption can be concentrated in the water insoluble salt under the state of saturation operation. In addition, in the electric adsorption module, and then due to the process of electro-adsorption of cation and anion adsorption imbalance resulting in more hydrogen ion content of the water, and by way of inverted pole, and slightly acidic water will also have a trace of fouling phenomenon and scale body dissolved out. The effect of electro - adsorption module is good or bad mainly depends on the adsorption performance of the electrode. (Li 2008.)

4.6.2 Technical characteristics

Electro-adsorption technology has many advantages, first of all, low energy consumption of electro-adsorption technology. Electro-adsorption technology is for water desalination, the main energy consumption in the migration of ions, and in the electrode and no obvious chemical reaction. Compared with distillation, reverse osmosis and other desalination technology, electro-adsorption technology is selective to separate and extraction of ions from the water, rather than the water molecules from the raw water to be separated out, without high temperature or high pressure, therefore the energy consumption is relatively low. In addition, since the electrodes are energized as a charging capacitor. That the applied electric energy is stored in the electric double layer capacitor, if necessary, a portion of the

stored energy can be recovered when the electrode is regenerated. That is means the electric energy stored on the module which is absorbed by the saturation is then added to another regeneration module, the so-called "swing" power supply. This can greatly save energy. (Sun & Zhu 2002.)

Secondly, the electro-adsorption technology has a high water rate, for the regeneration of the flushing water can be reused, and then under normal circumstances get water rate can reach more than 75%. For instance, that is using the appropriate combination of technology, and then even up to 90%. Meanwhile electro-adsorption is an environmentally friendly technology. Electrode regeneration only needs to release the stored energy, without any chemical agents for regeneration. That is compared with the ion exchange technology, reducing concentrated acid, concentrated alkali transport, storage and operation of the trouble, and not to the outside world discharge of acid and alkali neutralization solution. Compared with reverse osmosis, without adding reductants, and dispersants, and scale inhibitor and other chemicals, moreover the concentrated water emitted from the raw water, and then the system itself does not produce new emissions, thus avoiding the secondary pollution problems. In addition, the anti-pollution performance is strong, and is show a certain ability to remove COD. (Sun & Zhu 2002.)

As the electro-adsorption technology does not use membrane-type components, only the use of special inert materials for the electrode. Therefore the requirement for pretreatment of raw water is not high and even though that in the pre-processing on some of the problems are not easy to cause irreparable damage to the system. Electro-adsorption desalination device using channel-type structure (channel width mm-level), therefore it is not easy to plug, and then lower requirements for particulate pollutants. That the electro-adsorption technology is the use of electric field effect will be anion and cation was removed. And therefore, the anions and cations are located in different places. That will not combine with each other to produce scale body. And that a small amount of oil, iron, manganese, chlorine, organic matter, pH value, and so little impact on the system. That on all kinds of water quality of raw water has good adaptability. However, there is also no need for special maintenance of the core components during downtime. That is the system uses computer control, and a high degree of automation. Which is the use of carbon-based electrode material, in theory, that is can be long-term electrical adsorption module service. (Sun & Zhu 2002.)

The system of raw water pretreatment requirements of the index is not high, and iron, manganese, chlorine and other ions, PH value and organic matter on the system have little influence, therefore desalination technology adaptability is strong. There is also no need for special maintenance of the core

components during shutdown, and easy maintenance. Even in the pretreatment out some of the problems can also be processed to restore, that is not easy to cause irreparable damage to the system. The system uses computer control, high degree of automation, thus that simple and easy to master the operating procedures. (Sun & Zhu 2002.)

4.6.3 Application areas

Because the electric adsorption desalination technology has the characteristics of reliable operation, stable effluent, low energy consumption, convenient operation, low requirement for water quality, high water production rate and low running cost. Therefore that in industrial waste (waste) water recycling can be involved in many areas. For instance, papermaking, textile, printing and dyeing, electricity, chemical industry, metallurgy and other field that need great amount of water purification as a process water and nuclear industrial wastewater treatment. (Zhao 2008.)

4.6.4 Technical advantages

The EST module uses the highly effective functional material as the electrode. The electrode material not only has good demineralization effect, but it also has the characteristics of high chemical stability, acid resistance, alkali resistance, corrosion resistance and oxidation resistance. This makes the electric adsorption desalination device is provided with water quality constraints of small, anti-pollution, reliable equipment, and then stable operation.(Zhao 2008.)

This kind of high-efficient functional material belongs to the inert porous inorganic material, which has large specific surface area and a certain amount of primary active oxidizing group in the electric adsorption operation. It has certain eliminate efficiency on the organic matter in the raw water and enlarges the raw water quality restriction range. After proper pretreatment, the raw water can enter the EST module. Even if some problems are found in the pretreatment, such as organic pollution, which contains a small amount of oil pollution, that also will not cause the great harm to the electro absorption material. A relatively high salt removal rate can be ensured. Therefore, in this case, that is able to half a year or even a year after the long-term operation, the use of pickling or alkaline washing of the electrode material cleaning recovery. During downtime, there is no special maintenance of the core components, and that maintenance is easy.(Zhao 2008.)

The electro-adsorption desalination unit adopts the micro-channel design (the width of the channel is millimeter). The water flow is in the macroscopic channel, so a small amount of suspended matter and organic matter will not blocking the equipment. The pre-treatment requirements are relatively low, and can greatly improve the water rate, under normal circumstances up to 75% or more. Then if there is a particular requirement, that is part of the concentrated water by the recycling reuse process, thus the system water rate can reach 85%. (Zhao 2008.)

Electro-adsorption desalination technology development is based on the hydraulics, electrochemistry, mechanics, and electronic control theory. The system uses modular design, and that each link in the central control computer under the centralized control of the formation of the entire system. All of the implementing agencies, and the testing instruments by the computer in accordance with the set procedures to achieve the operation. That is normal operation without human intervention. (Zhao 2008.)

As the electric adsorption desalination technology utilizes the electric double layer capacitor electrostatic adsorption principle. That is the process of operation without adding inhibitor, and scale inhibitor, reducing agent and like special agents. Then that the concentrated water discharged from the system comes from the raw water. And therefore the system does not produce new pollutants. This not only saves the running cost, but also avoids the secondary pollution. (Zhao 2008.)

In addition, compared with other technologies, that is electro-adsorption technology belongs to atmospheric pressure operation, and it is improve energy consumption a little. And then that the main energy consumption is in the ion migration, furthermore through the control voltage so that the electrode surface did not occur polarization phenomenon. While the work of the stored electric energy that a part can be recovered at the time of regeneration. Therefore the overall energy consumption is low. (Zhao 2008.)

Electro-adsorption desalination technology on the requirements of the water quality is not high. In addition the desalination rate can be controlled to vary within the range of 60% to 90% in accordance with the voltage regulation. Therefore, this has expanded the application field of electro adsorption technology. Electro-adsorption can be widely used in drinking water, wastewater, sewage treatment, including metallurgy, chemical, electronics, power, pharmaceutical, textile, paper and other industrial fields. For those heavy pollution does not require complete desalination of the situation, thus the electric adsorption is a good choice.

4.6.5 Summary

As the electro-adsorption desalination technology has low water quality requirements, reliable operation, low energy consumption, easy operation, high water production rate and low comprehensive running cost. It is suitable for further popularization and application in municipal and industrial wastewater desalination fields, especially in chemical, petrochemical, metallurgy, electric power, papermaking and other high-water-consuming industries, as well as nuclear industrial wastewater treatment has a great potential. Brackish water desalination and seawater desalination is going to be the next more attractive application area of EST technology.

5 CONCLUSIONS

Water is the source of life, and that is also one of the most important resources on Earth. Water shortage and water environment pollution has become a prominent global problem in the 21st century. The issue of water must be given high priority. It is an important way to solve the problem of water environment pollution and rational utilization of water resources by correctly mastering and rationally using existing water treatment technology and researching new water treatment technology. As processing workers, and those have more responsibility to face the problem, and actively explore and correctly grasp the future development trend of water treatment technology.

For the industrial wastewater with complex pollutants, that the key is to control the wastewater by developing new technology which is mature, stable, and simple in operation and low in energy consumption. Countries around the world have wastewater treatment for industrial and commercial environmental protection areas and sewage low-power consumption, and zero emissions targets, and that has been competing to explore the path of efficient technology.

REFERENCES

Abruna D H（ed）.Electrochemiscal Interfaces-Modern Techniques for In-Situ Characterization,NewYork:VCH，1991 20：13-22.

Burch, B. & Cooper, C.1999. Investigation of Catalytic Ozonation for The Oxidation of Habcarbons in Drinking Water Prepanation[J]. Wat Res. 33(18):3695-3700.

B.Legube,N.Karpel & Vel Leitner. 1999. Catalytic Ozonation:Apromising Advanced Oxidation Technology for Water Treatment[J]. Catalysis Today ,1999,53:61-72.

Bie, Chen & Wang 2002. Electrocatalytic Oxidation Technology for Treating Refractory Organic Wastewater. Zhejiang University of Technology. 12: 8-9.

Chen & Zhan 2008. The Bottleneck Problem of Industrialization of Supercritical Water Oxidation Technology and Its Solution. Dalian Chemical Industry Design. 2: 4-14.

China Encyclopedia Network. Hei Guoxiang. Characteristics of Magnetic Separation Technology. 2013. Available:http://www.chinabaike.com/m/c/1608981.html.Accessed 12 October 2016.

Charles, S. & Owen. 2005. High Gradient Magnetic Separation of Erythrocytes.

Dai & Huang 2001. Supercritical Water Oxidation Water Treatment Technology Progress. Wuhan Chemical Environmental Protection Press. 8: 5-9.

Dai & Tang 2006. Water Treatment Engineer Handbook. Chemical Industry Press. 277: 12-23.

Deng & Dong 2011.Engineering Practice of Magnetic Separation Technology. China Water Supply and Drainage. 27: 83-86.

Guten Environmental Protection Network. 2011.03. Wet Catalytic Oxidation Treatment Principle and Process. Available: http://www.goootech.com/news/detail-10136505.html. Modified 3 March 2011. Accessed 9 October 2016.

Gao, Wang & Zhang 2006 (5). Catalytic Wet Oxidation Method and Its Application in Wastewater Treatment. Henan Science and Technology. 5: 8-16.

Gao & Liu 2003. New Technology of Wastewater Treatment - Supercritical Water Oxidation Process. Dalian Environmental Treatment. 2: 1-9.

Han 2010. Electric Adsorption Desalination Technology Development and Application. Industrial Water Treatment. 30 (2): 20-23.

Jing & Zhang 2010. Research Progress of Electrocatalytic Oxidation Technology [J]. Chemical Engineering and Equipment. (8): 140-142.

Liu & Sun 2005. Development Status and Prospect of Supercritical Water Oxidation Technology. Beijing Chemical Industry Environmental Protection Press. 3: 1-13.

Liu, Xiang & Zhang 2006. Study on Electrocatalytic Oxidation and Degradation Kinetics of Dye Wastewater [J]. Environmental Science and Technology. 29 (7): 23-25.

Li 2008. Advances in Electric Adsorption Desalination Technology and Its Application. Water Resources Protection. 24 (4): 63-66.

MaJ,Graham N JD. 1997. Prelim Inary Investigation of Manganese-Catalysed Ozonnation for The Destruction of Atrazine[J].O zone:Sci.Eng.,1997 19(3):227-240.

M.J.Alan 1965. Organic Electrolysis Process [M]. Beijing: China Industry Press. 220: 15-22.

Mei & Wang 2003. Research Progress of Magnetic Separation Technology in Wastewater Treatment in China. Sichuan Environment. 23: 22-28.

New Austrian Environmental Protection Technology Co., Ltd. 2015.03. Hebei Langfang Supercritical Sludge Treatment Project Available: http://www.envirotech.enn.cn/. Modified 17 March 2015. Accessed 2 November 2016.

Pan 2012. Magnetic Separation Principle of Technology Application. Beijing Science and Technology Press. 5-7: 11-19.

Qu 2007. Water Treatment Electrochemical Principles and Technology. Beijing Science Press. 156: 8-15.

Ren & Wang 2004. Industrial Wastewater Treatment Engineering Design and Example. Industrial Wastewater Source and Characteristics. Beijing Chemical Industry Press. 1-15: 5-33.

Rautenbach, R. 1998. Membrane Processes - Components and Devices Design Fundamentals. Chemical Industry Press. 274-289: 25-30.

Shui 2012. Industrial Wastewater Treatment Technology. Beijing Science Press. 5: 12-17.

Shi 2001. Membrane Technical Manual. Membrane selection. Beijing, Chemical Industry Press. 33-34: 9-22.

Sun & Zhu 2002. Principle and Composition of Electro-Adsorption Water Treatment Technology (EST). Industrial Water and Wastewater. 33 (4): 18-22.

Tao & Yu 2005. Urban Sewage Treatment Technology and Engineering Examples. Beijing Chemical Industry Press. 2: 8-11.

Wang 2003. High Concentration Organic Wastewater Treatment Technology and Engineering Application. Catalytic Wet Oxidation Method. Beijing Metallurgical Industry Press. 302: 12-15.

Wang 2003. High Concentration Organic Wastewater Treatment Technology and Engineering Application. Catalytic Wet Oxidation Method. Beijing Metallurgical Industry Press. 303: 14-24.

Wang 2000. Foundation of Membrane Separation Technology. Beijing Chemical Industry Press. 20-23: 2-12.

Ying 2010. Research Progress of Electrocatalytic Oxidation Technology [J]. Chemical Engineering Equipment. (8): 140-142: 22-29.

Zhong & Zhan 2000. Application of Advanced Oxidation Technology in Wastewater Treatment [J]. Shanghai Environmental Science. 19 (12): 568-571.

Zhang 2000. Waste Disposal Technology Manual. Wastewater Rolls. Beijing Chemical Industry Press. 465-466: 12-19.

Zhao 2008. Application and Research Progress of Electro-Adsorption Technology in Salt Water Desalination. Industrial Water Treatment. 28 (3): 5-8.