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Design of Centralized Water Quality and Water Supply System in Hospital

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Abstract: *Water is the source of life, and the quality of water is closely related to people's life and health. In recent years, with the development of society and the increase of the population, the number of diseases in our country is also increasing every year. In the context of a huge sick population base, medical water consumption is also increasing. At the same time, it also puts forward higher requirements for water quality and production management. Because of its unique advantages in resource utilization, the medical central water purification system is rapidly replacing the traditional status of separate water supply to each department of the hospital. Its water production method is to use a set of equipment to perform advanced treatment of raw water, so that it can meet the standard that can be directly used by various departments of the hospital, and then use the pipe network to supply each department separately, so as to achieve centralized water production and quality water supply. The design of the system saves water and electricity, and produces high economic benefits, and has gradually become the first choice for green hospitals. This design refers to various process design standards, consults a large number of books and information on the Internet, understands and compares various processes in the field, and finally completes this design task.*

Keywords: *Medical pure water; Quality water supply; Process design*

1. Introduction

In recent years, with the continuous enhancement of my country's comprehensive national strength and the continuous improvement of people's living standards, people pay more and more attention to their health and medical security. My country is a large country with a population of more than 1.3 billion, and the annual number of sick people is very large [1]. While people's demand for medical security is rapidly increasing, they also put forward higher requirements for the medical level of hospitals in all aspects. At the same time, economic development has also led to the reform of the medical system. In the process of development, hospitals have gradually strengthened measures to reduce the cost of medical activities, which not only improves economic benefits, but also further improves social benefits [2].

The central centralized water production and quality water supply system of the hospital generally uses a set of water production equipment to perform advanced treatment on tap water to make it meet the water quality standard that can be directly used by each department, and then use the pipe network to supply each department for use.

The medical central water purification system has already established a relatively complete hospital pure water use system and water standards for different departments in some developed countries and areas with more advanced hospital management. Since then, driven by its unique advantages, more and more countries have begun to establish medical central water purification systems [3]. The medical central water purification system is gradually adopted by various hospitals because of its strong economic benefits. It not only improves the management level of the hospital, but also maximizes the use of resources, energy saving and emission reduction. Compared with the traditional water production equipment, the medical central water purification system is controlled by a set of intelligent systems, which requires less daily operation and management personnel, high reliability, good pure water quality, and low operating costs. The advantages of small area and other advantages have gradually become the first choice for new hospital plans [4].

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2. Analysis of medical water quality

2.1. Design water quality

The requirements for pure water in hospitals are divided into cleaning water, flushing water, direct drinking water and hemodialysis water. Section, endoscope, DSA, disinfection supply room, preparation room, office, medical staff office, logistics department, etc. The water treated by the engineering design shall meet the relevant water standards, as detailed in the table below.

Table 1: Cleaning water management specification (WS310.1-2016)

Indicator name	Standard value
Residual steam	≤10 mg/L
SiO_2	≤1 mg/L
Iron	≤0.2 mg/L
Lead	≤0.005 mg/L
Trace heavy metals except iron, cadmium	≤0.1 mg/L
Chloride	≤2 mg/L
P_2O_5	≤0.5 mg/L
Conductivity (at 20℃)	≤5 us/cm
PH	5-7.5
Color	Colorless, Clean, No precipitation
Hardness (alkaline earth)	≤0.02 mmol/L
Microorganisms	≤10cfu/100mL

Table 2: Standard of flushing water

Project	Standard value(mg/L)
Iron	≤0.30
Mn	≤0.05
Cu	≤1.0
Zn	≤1.0
Anionic ingredient detergent	≤0.3
Fluoride	≤1.0
Arsenic	≤0.04
Sn	≤0.01
Hg	≤0.002
Cr	≤0.005
Cd	≤0.01
Pb	≤0.05
TDS	≤500

Table 3: Water for Hemodialysis and Related Treatment (YY0572-2015)

Pollutants	Maximum allowable concentration (mg/L)
Pollutants	0.01
Aluminum	0.1
Total chlorine	0.1
Cu	0.2
Fluoride	0.005
Lead	2
Nitrate nitrogen	100
Sulfate	0.1

Table 4: The maximum allowable amount of trace elements in the dialysis water clock.

Pollutants	Maximum allowable concentration (mg/L)
Antimony	0.006
Arsenic	0.005
Barium	0.100
Beryllium	0.0004
Cadmium	0.001
Chromium	0.014
Hg	0.0002
Selenium	0.090
Silver	0.005
Thallium	0.002

2.2. Design water volume

$Q_d = Nq_d$ =10000×2.0=20000 (L/d)

In the formula: Q_d---- The maximum daily direct drinking water volume of the system (L/d):

N----Number of people drinking water (person);

q_d---- Maximum daily direct drinking water quota [L/ (d. person)].

$Q_j = \frac{1.2Q_d}{T_2} = \frac{1.2\times20000}{8}$=3000 (L/h)

In the formula: Q_j---- System water production (L/h);

T2---- Maximum daily design water purification cumulative working time, take 8h

2.3. Total water volume

Table 5: Design total water volume

Name	Water purification process	Design water purification volume (L/h)
Drinking water, flushing water	first stage reverse osmosis	13000
cleaning water	Secondary reverse osmosis	2000
test water	Secondary reverse osmosis + EDI	1000
Hemodialysis water	Secondary reverse osmosis (individual set)	2000

3. Design points of medical centralized water quality and water supply

3.1. Design content and basis of medical centralized water quality water supply

3.1.1. Design content

The design of this project is divided into medical complex building (14 floors), administration building (12 floors), IMC building (9 floors), infection building (2 floors), pathology department, pharmacy department, blood transfusion department, laboratory department, reproductive center, blood Through the center and other departments, the centralized water supply system design is carried out for different departments.

3.1.2. Design basis

(1) "Hospital Disinfection Supply Center" WS 310.1-2016 & WS310.2-2016

(2) "Technical Specifications for Cleaning and Disinfection of Flexible Endoscopes" WS507-2016

(3) "Analytical Laboratory Water Specifications and Test Methods" GB/T 6682-2008

(4) "Pharmacopoeia of the People's Republic of China" 2015 Edition

(5) GMP drug production quality management standard

(6) "American Standard for Reagent Grade Water"

(7) "American Flushing Water Standard"

(8) "Sanitation Standard for Drinking Water" GB5749-2006

(9) "Water Quality Standard for Drinking Water" CJ94-2005

(10) "Electrical Safety Standards for Medical Equipment" GB9706-2007

(11) Other latest relevant laws and regulations issued by the state and local governments.

3.2. Design principles of medical centralized water quality and water supply

The design quality shall be designed according to the excellent engineering grade. Adopt new technology and new equipment to achieve advanced technology, mature technology and simple process,

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so that the project occupies less land, has good treatment effect and low operating cost;

Fully consider the actual situation of the project, select the appropriate process, and optimize the layout of equipment and pipelines during construction to reduce land occupation, simplify construction and achieve the lowest cost;

During the design and construction process and after it is put into operation, follow the relevant national and local policies and regulations to avoid secondary pollution and ensure that the water quality meets the standard;

The pure water system is fully automatic design, with automatic water production, automatic flushing, automatic shutdown and automatic protection functions when the water is full.

3.3. Design principle of medical centralized water quality and water supply

3.3.1. Preprocessing system

The pretreatment system mainly includes raw water tank, mechanical filter (quartz sand filter), activated carbon filter, security filter, etc. The raw water is pressurized by the raw water pump to pass through the multi-media filter and the carbon filter respectively to remove the large particles of mud sand, rust and colloid in the raw water and absorb the residual chlorine in the raw water, so that the SDI pollution index of the pretreated water is less than 5. Chlorine is less than 0.1mg/L, which can reduce the burden on the RO membrane and prevent the RO membrane from being irreversibly damaged due to oxidation [5].

The original water tank is made of imported high-quality 304 stainless steel, polished inside and outside, and the water tank is equipped with a water inlet float switch and a low-level water level controller. The water source is municipal tap water in the hospital. The raw water tank can not only store water, but also effectively eliminate the "water hammer" effect of the tap water pipeline on the raw water pump.

The raw water pump group uses stainless steel horizontal centrifugal pump, its function is to provide filtration pressure and sufficient water flow for the multi-media mechanical filter, activated carbon filter, softener and subsequent reverse osmosis membrane filtration device. The start and stop of the raw water pump group are controlled by the liquid level of the raw water tank, as well as the operation status of the multi-media mechanical filter, activated carbon filter, softening filter and reverse osmosis membrane device; when the raw water tank is in a state of water shortage, the original The water pump group and the subsequent filtration system are protected by water shortage shutdown, and the water shortage shutdown protection will not be cancelled until the liquid level of the original water tank reaches the medium level [6]; when the multi-media mechanical filter, activated carbon filter, and water softener are among. When one of the filters is in the backwash state, the raw water pump will start, and will not stop until the filter returns to the running standby state;

The operation of the mechanical filter can be divided into two relatively independent and simultaneous processes, raw water filtration and filter material backwashing. The two are done in different positions of the same filter, and the power depends on the lifting of the pump. When the mechanical filter affects its normal work due to the retention of excess impurities, it can be cleaned by backwashing [7]. The use of reverse water inflow can loosen the sand filter layer in the filter, so that the retentate adhering to the surface of the filter material can be peeled off and taken away by the backflushing water flow, which is beneficial to remove the sediment, suspended solids, etc. The material is hardened, so that it can fully restore the interception ability, so as to achieve the purpose of cleaning.

The activated carbon filter mainly uses the activated carbon organic flocs with high carbon content, large molecular weight and large specific surface area to physically adsorb impurities in the water in van der Waals force to meet the water quality requirements. When the water flows through the pores of the activated carbon, various suspended particles, The organic matter is adsorbed in the pores of the activated carbon; at the same time, the chlorine (hypochlorous acid) adsorbed on the surface of the activated carbon undergoes a chemical reaction on the surface of the carbon and is reduced to chloride ions, thereby effectively removing the chlorine and ensuring that the residual chlorine in the effluent is less than 0.1 ppm, which meets the operating conditions of the reverse osmosis membrane. When the activated carbon reaches the saturated adsorption capacity and completely fails, the activated carbon should be regenerated or replaced to meet the engineering requirements.

Security filter (also known as precision filter), the shell of the cylinder is made of SUS304 stainless

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steel, and the PP melt-blown filter element is used as the filter element inside. The body can also choose a quick-loading type, which is convenient and quick to replace the filter element and clean. The equipment is widely used in pharmaceutical, chemical, food, beverage, water treatment, brewing, petroleum, printing and dyeing, environmental protection and other industries. It is an ideal equipment for various liquid filtration, clarification and purification treatment.

3.3.2. Primary reverse osmosis system

The primary reverse osmosis mainly includes a primary high-pressure pump, RO reverse osmosis membrane and a reverse osmosis cleaning and disinfection device. The pretreated water is pressurized by a high-pressure pump and enters the primary reverse osmosis membrane. More than 99% of impurities such as small particle suspended solids, most ions and organic substances, bacteria and viruses are filtered out, concentrated water is discharged, and pure water is stored to no Bacterial pure water tank. The system uses 304 stainless steel vertical multi-stage centrifugal pump, which has the characteristics of power saving, energy saving, low noise, anti-pollution and long service life.

As an important component of deep filtration, the reverse osmosis membrane will inevitably remain on the surface of colloids, microorganisms, impurity particles and insoluble salts in the process of use. Therefore, in order to restore the good water permeability of reverse osmosis. As well as good desalination performance, to extend the life of reverse osmosis as much as possible, it is necessary to carry out regular chemical cleaning for reverse osmosis preparations [8].

3.3.3. Two-stage reverse osmosis system

The secondary reverse osmosis system mainly includes a secondary high-pressure pump, a reverse osmosis membrane, and a PH adjustment device. The pure water of the primary reverse osmosis is used as the source water of the secondary reverse osmosis equipment, and is further desalinated by the pressure of the secondary high pressure pump, and the conductivity of the effluent is≤3us/cN.

The secondary high-pressure pump is mainly to pressurize the raw water from the primary reverse osmosis system, so that it can maintain sufficient pressure to pass through the secondary reverse osmosis system to purify the water.

Two-stage reverse osmosis means that water molecules are forced to pass through a reverse osmosis membrane with selective permeation under the action of pressure. According to the different osmotic pressure of various materials, the reverse osmosis method can be separated, extracted, purified and concentrated. It can remove more than 98% of soluble salts and more than 99% of colloids, microorganisms, particles and organic matter in water [9].

3.3.4. DEI processing system

EDI processing system includes booster pump, precision filter, EDI device. The pure water treated by the two-stage reverse osmosis process is used as raw water, which is pressurized by a booster pump and filtered by a precision filter before entering the EDI device. By combining ion exchange technology and electrodialysis technology, the EDI device utilizes the exchange effect of ion exchange resin on ions in water and the selective permeation effect of anion and cation membranes on anion and cations, and realizes ionization in water under the action of power plants. Directional offset, so as to achieve the purpose of directional desalination. EDI water production has the characteristics of advanced technology and simple operation. It can continuously produce high-quality ultrapure water, and the effluent quality has the best stability.

3.4. Disinfection and sterilization system

The finished products of this water treatment system are medical water and direct drinking water, which are sent to various water points for use through special pipelines. Add a disinfection system to the treatment system. The disinfection system adopts a compound disinfection method, ultraviolet sterilization and ozone sterilization, and continuous disinfection of pipeline circulating water supply.

The ultraviolet sterilizer has the characteristics of no dead angle, good light irradiation conditions, low energy consumption, flexible and convenient installation and disassembly of equipment, and no secondary pollution. The equipment can greatly reduce the operating cost of the equipment. If it is drinking water, the ultraviolet sterilizer is safe and will not have an adverse effect on the human body due to the excess of the agent. Compared with the ozone sterilizer, the ultraviolet sterilizer has the advantages of low energy consumption, no large mixer, and no fishy smell, which not only looks good, but also reduces the operating cost [10].

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The process of ozone sterilization is a biochemical reaction. Ozone has strong oxidizing properties and has four major functions: sterilization, oxidation, decolorization, and deodorization; Ozone sterilization has the characteristics of broad spectrum, high efficiency, environmental protection, convenient operation, economical use, stable performance, and long life; Ozone has obvious inactivation effect on almost all bacteria, viruses, molds, fungi, protozoa and oocysts, and the sterilization time is extremely fast, 300-600 times that of chlorine and 3000 times that of ultraviolet rays; The speed and effect of bacteria are unparalleled. Its high redox potential determines its wide application in oxidation, decolorization and deodorization. Ozone dissolves in water and can almost eliminate all harmful substances in water, such as iron and manganese, chromium, sulfate, phenol, benzene, oxides, etc., can also decompose organic matter and algae.

3.5. Frequency conversion constant pressure water supply

The frequency conversion system adopts advanced frequency conversion speed regulation technology to regulate the speed of the water supply AC motor, and the remote pressure sensor feeds back the dynamic pressure analogous continuous signal (4-20 mA) in the water supply pipe network to the analog input terminal of the frequency converter, as the frequency conversion The feedback quantity of the closed-loop PID control of the inverter controls the change of the output frequency of the inverter to realize the closed-loop constant voltage control. The frequency converter changes the frequency according to the change of (4-20mA), and the frequency change interval is (0-50Hz). The AC motor changes the speed of the water pump with the change of the frequency.

According to the different water consumption, the pressure loss of the water supply network varies with the time period of water consumption. The greater the water consumption, the greater the pressure loss. In order to meet the user's requirements for stable water pressure and achieve the goal of energy saving and consumption reduction, we strictly ensure the constant pressure of the water outlet of the pipe network pump according to the measured value of water output and water pressure through the sensor feedback to the inverter. To realize the automatic adjustment of PID, to periodically change and adjust the speed of the water pump, to achieve uninterrupted water supply to achieve constant pressure requirements [11].

Its advantages are to ensure the stability of water supply on each floor, small fluctuation of water pressure, balanced water flow on each floor, and to keep the water in the system in dynamic operation to ensure the sanitation and safety of the water supply pipeline. The variable frequency water supply pump is made of Grundfos stainless steel multi-stage centrifugal pump, which has the characteristics of power saving, energy saving, low noise, anti-pollution and long service life.

3.6. Water supply pipes

The same-process circulating water supply method is adopted, and the automatic all-weather, no-dead-angle and same-process circulation ensures that the water quality of the pipeline is always fresh and hygienic. The same process system can be divided into the following two situations according to the actual situation: the general pure water system is suitable for multi-layer, in this case, the same process system can be divided into a riser system and a branch pipe system of each layer; For systems with not many layers, if it does not exceed 5 layers, the riser can use a different-pass system, the specific friction resistance of the riser is recommended not to exceed 60Pa/m, and the branch pipes of each layer should use the same-pass system. For some cases where there are not many drinking water devices at the end of the single-layer negative belt, the riser pipes can be used in the same way, and the branch pipes of each layer can be used in different ways.

3.7. Design of drinking water terminal

At each drinking point in the hospital, according to the number of people who use water and the requirements of usage habits, a wall-mounted pipeline machine can be placed in the medical staff office to provide hot and cold drinking water, and a vertical pipeline machine with double ultraviolet sterilization and adjustable water temperature can be placed in the public area, to ensure the safety of drinking water for patients and medical staff.

In the high-end self-care area ward, a 304 stainless steel direct drinking faucet can be installed beside the small kitchen sink of each household, which can not only satisfy daily drinking water, but also provide high-quality cooking water. Adopting the circulating water supply method of upward and downward feeding in the same way, the main water supply riser is laid in the water pipe well, the openings pass through the floors, and the inner branches of the floors are hidden along the ceiling and walls. In the stage of in-depth design and construction, it is necessary to cooperate closely with other majors to determine the location and elevation of the pipeline, which can be appropriately adjusted according to the actual situation on site [12].

In this design, two sets of primary reverse osmosis units (the supply of pure water is 10.0m^3/h) two sets of secondary reverse osmosis units (the supply of pure water is 1.0m^3/h) are selected according to the quality and quantity requirements of medical pure water. Two sets of EDI devices (pure water supply is 0.5m^3/h) can see the process flow chart for the water treatment system flow. The water treated by this design process can meet the national treatment standard, and see the following table for details.

Table 6: Memorial Hospital of Sun Yat-sen University Test report

Water quality index		Total number of colonies	Total coliform count	Heat-resistant coliform count	As	Hg	Pb
July 28, 2021	South Campus	not detected	not detected	not detected	<0.00009	<0.00007	<0.00007
	Headquarters	not detected	not detected	not detected	<0.00009	<0.00007	<0.00007

Table 7: Xingtan Hospital Affiliated to Shunde Hospital of Southern Hospital University

Water quality index		Total number of colonies	Total coliform count	pH	Oxygen content (mg/L)	Nitrate nitrogen (mg/L)
August 10, 2021	Direct drinking water 1	not detected	3	6.94	0.29	<0.10
	Direct drinking water 2	not detected	not detected	7.51	0.24	<0.10

Table 8: The First People's Hospital of Shunde District, Foshan City

Water quality index	Total coliform count	As	Cd	Cr^{6+}	Pb	Hg	Trichloromethane	Formaldehyde	pH	Smell and taste	Nitrite
November 26, 2019	not detected	<0.00009	<0.00006	<0.004	<0.00007	<0.00007	<0.0002	<0.05	6.27	No peculiar smell	<0.001

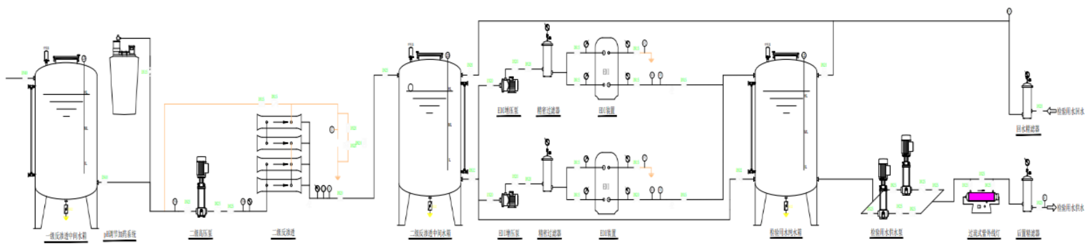

Figure 1: Process flow chart

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4. Conclusion

This design is designed for a hospital's medical central water purification system, using reverse osmosis treatment process and EDI treatment process as the main process, to achieve the required effluent quality requirements, and achieve the purpose of cost saving and good treatment effect, in line with the current situation Green Hospital Green Hospital Development Requirements. It has great advantages in energy saving and emission reduction, which brings greater economic benefits to hospitals and conforms to the normative standards for medical water design in my country; the design of centralized water quality and water supply in hospitals can realize a network visualization management platform, reflecting the modern green hospital. The quality and image are high, and the economic benefit is high; the central centralized water production equipment is relatively concentrated, which greatly reduces the power consumption of the pure water preparation unit. Compared with the pure water supplied by the independent water machines in each department, the central centralized water production equipment will reduce the operating cost by more than half if the same department is supplied with water.

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