Water Treatment Industry Solutions

- Waste water treatment
- Water purification plant
- Intermediate water reuse
- Municipal pump station
Waste water treatment plant

1. Treatment process procedures

A typical municipal waste water treatment process includes mechanical treatment, biological and chemical treatment, sludge treatment, and other procedures, as shown in Fig. 1. The system consisted by mechanical treatment and biological & chemical treatment belongs to secondary treatment system, whose BOD5 and SS removal rate can reach 90% - 98%. If the treatment results are between those of primary and secondary treatment, they are usually referred as enhanced primary treatment, primary semi-treatment, or incomplete secondary treatment. There are mainly two categories of them, high-load biological treatment and chemical treatment, with a BOD5 removal rate as 45% - 75%. The secondary treatment system with function of biological nitrogen and phosphorus removal is usually referred as advanced secondary treatment. To remove specific materials, the treatment system following after secondary treatment belongs to tertiary treatment, such as chemical phosphorous removal, flocculation filtration, and activated carbon absorption.

**Mechanical treatment section**

The mechanical (primary) treatment section includes bar screen, waste water lifting pump room, grit tank, and primary sedimentation tank, and other structures, for the purposes of coarse particles and suspended solids. The treatment principle is to achieve solid-liquid separation through physical method, separating pollutants from waste water. This treatment method has been widely used for waste water treatment. Mechanical (primary) treatment is an essential procedure for all waste water treatment processes (through some technique processes omit the setting of primary sedimentation). Typically, the BOD5 and SS removal rates of municipal waste water primary treatment are 25% and 50%, respectively.

**Biological and chemical treatment section**

This section is the core of the entire waste water treatment process, so the waste water treatment processes referred in this brochure is specifically focusing on this section, such as oxidation ditch.
method, SBR method, and A/O method. The biological and chemical treatment of waste water is secondary treatment to remove suspended solids and soluble biodegradable organic matter as main purposes. Currently, most municipal waste water treatment plants use activated sludge to do that. The principle of biological & chemical treatment is to complete decomposition of organic matter and synthesis of organisms through biological role, especially the role of micro-organisms, turning organic pollutant into harmless gaseous products (CO$_2$), liquid products (water), and organic-rich solid products (also known as microbial community or bio-sludge). The excess bio-sludge in the sedimentation tank goes through solid-liquid separation by sedimentation, and is removed from purified water.

### Sludge treatment section
The sludge generated from the biological & chemical treatment firstly arrives at sludge pump room. Some sludge is sent back to the biological & chemical treatment section. Other sludge quickly enters into the sludge concentration tank through sludge pump. After concentrated in the sludge concentration tank for a certain period of time, the supernatant flows back to the collecting tank at the waste water lifting pump room. The concentrated sludge comes to the sludge conditioning tank, lifting to sludge dewatering room through the sludge pump. After dehydrated in the sludge dewatering room, the sludge is made into mud-cake and sent out.

### 2. Common waste water treatment methods
At present, the common waste water treatment methods include A$_2$/O, oxidation ditch, SBR, CASS, CAST, AB, biological contact oxidation (BCO), biological aerated filter (BAF), biofilm, etc.

#### A$_2$/O method
A$_2$/O biological nitrogen and phosphorus removal process has combined conventional activated sludge process, biological nitrification and denitrification process, and biological phosphorus removal process. Its flow chart is shown in Figure 2. The biological tank is divided into anaerobic, anoxic, and aerobic section through the layout of the aeration device, the propeller (anaerobic and anoxic section), and recirculation channel, respectively. In this process, BOD5, SS, and existing nitrogen and phosphorus in various forms will be removed in turn. The bacteria living in the activated sludge of the A$_2$/O biological nitrogen and phosphorus removal system primarily consist of nitrifying bacteria, denitrifying bacteria, and phosphate accumulating bacteria. In the aerobic section, the nitrifying bacteria transform inflow ammonia nitrogen and ammonia ammonified by organic nitrogen into nitrate through biological nitrification. In the anoxic section, the denitrifying bacteria will transform the internal circulated nitrate into nitrogen gas, releasing into atmosphere, through biological denitrification. The purpose of nitrogen removal is achieved by this way. In the anaerobic section, the phosphate accumulating bacteria release phosphorus, and absorb easily degradable organic matter like lower fatty acids. In the aerobic section, phosphate accumulating bacteria will absorb excess phosphorus, and phosphorus will be removed through the discharge of the residual sludge. The above three types of bacteria all play a
role in removal of BOD5, which is mainly fulfilled by the denitrifying bacteria.

Oxidation-reduction potential (ORP) and dissolved oxygen (DO) as the main control parameters, the treatment is regulated on aeration system, internal returning system, external returning system, and residual sludge disposal system, achieving a good efficiency on nitrogen and phosphorus removal, effective reduction of BOD5 in waste water. Meanwhile, it also maximizes energy saving, ensuring the highly efficient and stable operating of the whole system.

**Oxidation ditch method**

Oxidation ditch is also known as oxidation channel, because its structure was named after a closed loop ditch. It is a variant of the activated sludge. Because waste water and activated sludge are continuously cycling in aeration channels, some people call it a “cyclic aeration tank” or “endless aeration tank”. The oxidation ditch has long hydraulic retention time, and its organic load is low, belonging to extended aeration system in nature.

Oxidation ditch uses a continuous loop reactor (CLR) as bio-reactor. Liquid mixture undergoes continuous cycles inside a closed aeration channel of the CLR. The oxidation ditch often is used under conditions of extended aeration. Utilizing directional controlled aeration and agitation devices, the ditch transfer horizontal speed to the mass inside the CLR, making the stirred liquid circulate in the closed loop channel.

The oxidation ditch generally consists of ditch, aeration equipment, water inlet and outlet devices, diversion and mixing equipment. The 2D shape of the ditch is usually circular, but it can be rectangular, L-shaped, round, or other shapes. The cross-section shape of the ditch is mostly rectangular and trapezoidal. The treatment process is schematically shown in Fig. 3.
Oxidation ditch method features a long hydraulic retention time, low organic loading, and long sludge life. Compared to conventional activated sludge process, the designers can omit the conditioning tank, primary sedimentation tank, sludge digestion tank, and sometimes the secondary sedimentation tank can also be omitted. The oxidation ditch can guarantee good treatment effect, mainly because it cleverly combines the CLR form and positioning of a particular arrangement of aeration devices. This brings the oxidation ditch with unique hydraulic and operational characteristics.

With the development of the oxidation ditch process, current relatively representative forms of this method in engineering applications are multi-channel alternating oxidation ditch (e.g., three-channel type and five-channel type) and its modified forms, Carrousel oxidation ditch and its modified forms, Orbal oxidation ditch and its modified forms, and integrated oxidation ditch.

**SBR method**

SBR is the abbreviation form of Sequencing Batch Reactor Activated Sludge Process, a type of activated sludge waste water treatment technology using intermitted aeration mode. It has different Chinese translation names. Compared to the traditional waste water treatment, SBR technology uses time-dividing operation mode instead of space-dividing, non-stable biochemical reactions instead of stable ones, and static ideal sedimentation instead of traditional dynamic sedimentation. Its main features are orderly and intermittent operation. The core of SBR technology is SBR reactor, with the integrated functions of homogenization, primary sedimentation, biological degradation, and secondary sedimentation. It needs no sludge returning.
SBR method has the following features:

- Operation process is simple, with basically no need of moving operations. Five procedures, water inlet, aeration, sedimentation, water outlet, and idle phase, can be controlled by PLC. The running program can be reprogrammed according to the variation situation of water quality, making tedious and complex operation into automated operation.

- Resistance to impact of loading: the waste water is slowing dilated when it enters into the tank. The proportion of waste water to the original water inside the tank gradually increases, so it is resistant to the impact of water quality change.

- Good outlet water quality: the water inside the tank settles under the ideal static condition of zero horizontal flow speed. The sedimentation result is good. The dissolved oxygen alternatively changes in the tank. When the sedimentation is pumped out, the dissolved oxygen is approximately equal to zero. This will restrain the growth of filamentous bacteria, with good sludge sedimentation performance.

- Low energy consumption: The concentration gradient of the dissolved oxygen is large because of the alternative change of dissolved oxygen in the tank. The utilization of oxygen is increased. There is no sludge returning system, saving the energy and lowering the operation cost.

- SBR can achieve continuous water inlet. When the waste water volume is small, one tank is enough for the operation. Automatic control valve can be saved for the
distribution on the waste water flow change with the time. Also, only one decanter is needed. This makes a much simpler tank structure.

**CAST method**

Cyclic Activated Sludge Technology (CAST) is a cyclic activated sludge method. CAST system has an intermittent reactor, where activated sludge process constantly repeats aeration and non-aeration phase alternatively. The biological reaction processes and mud separation process are carried out in one tank. The flow chart is shown in Fig. 5.

CAST process is a “water filling and drainage” activated sludge method. The waste water undergoes cyclic treatment according to a certain time period. CAST technology modified from SBR method. Its each cycle is comprised of the following stages: inflatable/aeration, filling water/sediment, draining water, and idle section. Those four stages form a loop and repeating cycle. At the beginning, water-filling makes the minimum water level to rise. After a certain period of time of aeration and mixing, aeration stage is ended so that activated sludge will flocculate and settle in a static environment. After completion of the sedimentation stage, supernatant is discharged by a movable draining weir. When the water level decreases to the preset minimum level, the entire process will repeat from the start.

![Fig.5 Flow chart of oxidation ditch method](image)

CAST tank is divided into three zones, namely, selection zone, oxygen-deficient zone, and primary aeration zone. In the selection zone, the dissolved organic matter in waste water is rapidly removed through enzyme reaction mechanism. The volume of this zone can be constant or variant for operation. For multi-tank systems, the inlet and distributing tank can also be used as
select zone. The nitrate of the returned sludge is denitrified in the selection zone. The most basic function of this zone is to prevent the development of sludge swelling. In the oxygen deficient zone, there is small amount of aeration, to regulate aeration zone for phosphorus removal with no oxygen. The primary aeration zone mainly undergoes degradation of organic compounds and nitrification process, also engages in nitrification - denitrification process.

**CASS method**

Cyclic Activated Sludge System (CASS) is a type of cyclic activated sludge technology (CAST). Its main principle is to divide sequencing batch reactor (SBR) into two parts along the length direction. The front part is pre-reaction zone, and the rear is the primary reaction zone. In the pre-reaction zone, micro-organism rapidly absorbs soluble organic matter in the waste water through the mechanism of rapid enzyme movement. This rapid high-load substrate accumulation process play a role of buffer effect on water quality, water flow, pH value, and toxic materials, effectively preventing sludge from swelling. Followingly in the primary reaction zone, organic matter in the waste water is degraded through a process of low-load substrate degradation. The CASS process can fully release the degradation function of activated sludge. Also it alleviates burden of the secondary sedimentation tank, helping improve the solid-liquid separation efficiency of the tank.

**AB method**

Adsorption biodegradation (AB) is a new type of dual biological treatment process. Compared with the conventional activated sludge, it has high efficiency and stability, with energy saving and low cost advantages. A typical AB process is: waste water – bar screen – grit tank - Section A aeration tank - middle sedimentation tank (sludge is returned to Section A aeration tank) - Section B aeration tank - secondary sedimentation tank (sludge is returned to Section A aeration tank) – water outlet. Breakthrough of the AB technology is mainly in Section A. This section eliminates the need for a primary sedimentation tank. The Section A aeration tank is operating at high-load \[ \geq 2\text{kg BOD}_5/(\text{kgMLSS} \cdot \text{d}) \], short residence time (30 min), low dissolved oxygen (0.5-1 mg/L), and short sludge retention time (0.5-0.7 d). However, the working mechanism study for Section A of is not making big progress. For instance, in the absence of sludge regeneration the system is able to maintain microbial activity and good sludge settling characteristics, which cannot be explained by the traditional microbial oxidation of adsorption mechanisms.

The method has excellent pollutant removal ability, strong load resistant capacity, good nitrogen and phosphorus removal performance, and lower investment and running costs.

- Efficient organic substrate removal
- The system is running stable, with features of small fluctuations in water quality, strong resistance to load impact, and good sludge settling characteristics.
- Efficient nitrogen and phosphorus removal
- Energy saving: Low operation cost and power consumption, with recyclable biogas
energy. The experiment proved that AB method can save operating cost savings 20% ~ 25% more than traditional single section treatment process.

**Biological contact oxidation (BCO) method**

Biological contact oxidation (BCO) method is a type of submerged biofilm process. Waste water is in contact with the biofilm on the filler. Under the effect of the micro-organism on the biofilms, the waste water is purified. Its processing structure is submerged aeration biological filter, also known as biological contact oxidation tank.

![A common rapid filter tank](image)

The biological contact oxidation tank has biofilm-covered fillers submerged in wastewate. During the contact between biofilms and waste water, the organic matter in the water is absorbed by the micro-organisms, oxidized and degraded into new biofilms. The detached biofilms from the filler flow with the water to the secondary sedimentation tank, and are removed. The waste water is purified. In the contact oxidation tank, the oxygen needed by the micro-organisms comes from the water, so air is added into the water to compensate the loss of the dissolved oxygen. The air is coming from the perforated air pipe located at the bottom of the tank. When the air bubbles rise in the water, the oxygen dissolves into the water, and sometime the water returns by this measure.

Compared with activated sludge method, biological contact oxidation has the following features:

- As the specific surface area of the filler is large, the tank has well-oxygenated condition. Bio-solids volume in unit volume of the biological contact oxidation tank is higher than that of activated sludge aeration tank and biological filter. Therefore, the biological contact oxidation tank has a high volumetric loading capacity.
- The biological contact oxidation method does not require sludge returning, and sludge
swelling problem would not exist, facilitating simple operation and management.

- The bio-solids volume is large and the water is completely mixed, so the biological contact oxidation tank has a stronger adaptability to the sudden changes of water quality and quantity.
- When the bio-contact oxidation tank keeps a high organic volumetric loading, the F/M remains at a low level, with a low sludge production.

**Biological aerated filter (BAF)**

Biological Aerated Filter (BAF) technology is developed as an aerobic waste water treatment process, introducing the idea of drinking water filtering treatment, based on biological contact oxidation process. Its noteworthy feature is the combination of biological oxidation and filter on the basis of primary strengthening. The rear part of the filter tank has no sedimentation zone. The cyclic operation of the system depends on back-flushing regeneration.

- Pre-treatment system: it includes bar screen, waste water lifting pump, aerated grit tank, and primary sedimentation tank. After the waste water is treated, it flows to BAF relying on natural water level difference.
- Multi-level biological aerated filter: each level of biological aerated filter contact with different qualities of waste water for biological carriers. The formed composition of microbial community varies at every level, suitable for the growth of the microbial flora corresponding to the waste water flowing to the level.
- Post-treatment system: efficient gas floatation substitutes for the traditional secondary sedimentation tank. The sludge is directly discharged into the sludge storage tank. After digestion, the sludge enters into the vortex spiral belt filter press or centrifuge for processing, turned into mud-cake for sending out or used for agricultural fertilizer.

**Biofilm method**

Biofilm process uses water distributor, allowing waste water flow uniformly through filtration material, biological rotating wheel, or biofilm on filler surface. The biofilms have a large surface area, containing a large number of micro-organisms, capable of absorbing, oxidizing, and degrading organic matter in the water. During the degradation of organic matter, the micro-organisms on the biofilms rapidly grow, multiply, and age. The old biofilms detach from the surface and flow with discharged water. By this way, the waste water is purified. Biofilm method has several process types, such as, aerated biological filter, biological rotating wheel, and contact oxidation.
3. Automatic control instrument system

3.1 Overview

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Hollysys LK Series Programmable Logic Controller (PLC) based automatic control systems can be applied to waste water treatment plants, fully meeting the requirements of the waste water oxidation ditch treatment process. This provides a high reliable, low-cost, more optimized control solution.

LK series are the medium and high-end performance control field products, developed from the company’s concluding 10 years of control system design and implementation experience based on thousands of projects in the applied field. The instruction processing speed of CPU module integrated industrial-grade processor (frequency up to 533MHz) can reach up to 13 ns. Compared with the traditional PLC, LK fully programmable controller combines the advantages of DCS and PLC, using high-performance analog processing technology, miniaturization of the structural design, open industry standards, and uniform platform. The products not only have the powerful features and superior performance, but also have higher reliability, greater openness and ease of use.

3.2 Automatic control system design

The entire system consists of one central control room and three on-site PLC control stations. The on-site PLC control station is comprised of programmable logic controller (PLC) systems and measuring instruments. It performs distributed controlling on each procedure of waste water treatment process in the plant. The central control room (CCR) takes integrated control on the entire plant. The communication between CCR and PLC control stations adopts high-speed real-time industrial loop-structured Ethernet, with a speed of 100 Mbps and optical fiber as transmission media. The central control station is located at the central control room of comprehensive building. The three on-site control stations are located at inlet pump room (#1 PLC control station), blower room (#2 PLC control station), and sludge squeezing and dewatering room (#3 PLC control station), respectively. They all adopt LK series PLC from Hollysys.
The whole plant communication network is divided into two levels. The first level is central control/on-site monitoring level, using industrial optical-fiber loop Ethernet between the on-site stations and the central control station. The second level is data transmission level, using common I/O wire connection between the on-site stations and equipment control cabinets.

The control modes of automatic control system for waste water treatment plant are designed as manual control of on-site equipments, remote manual control of automatic control system, and remote automated control of automatic control system. The three modes ranks from higher to lower as on-site manual control, remote manual, and remote automated control.

### 3.3 Process control strategy

**Bar screen control**

Bar screen control adopts two modes, time control and liquid level difference control. Under normal circumstances, the bar screens will operate according to preset time interval and duration. If the liquid level difference before and after bar screen is larger than the setting value, the bar screen machine start continuous operation until the liquid level difference is smaller than the requirement, and it will back to...
normal operation.

The screening transit and squeezing machine operates interlinked with the bar screen machine.

 **Lifting pump room**

The speed and on/off of the pumps are automatically controlled and frequency-adjusted depending on the liquid level of the sump. When the liquid level of the sump reaches the minimum level, the pumps will automatically stop, achieving dry running protection of the pumps. Starting counting and overall running time of each pump are monitored for balance. The initial setting assumes that each pump running time is equal. The running process of the pumps will be monitored by the automatic control system. If any failure occurs to a pump, the system will alarm and automatically start backup pumps.

 **Grit tank and grit-water separator**

The grit transit pump and other electrical equipments, as well as grit-water separator form a system, controlled by the attached control cabinets.

 **Oxidation ditch**

The operation and speed of the rotating wheels are adjusted by PLC according to measured dissolved oxygen values of ditches. The PLC also controls the operation of the propeller sludge scraper bridge.

 **Returning and residual sludge pump room**

The on/off and running time of the returning sludge pump are controlled by PLC depending on the mixture concentration feedback measured in the biological tank.

 **Substation**

PLC does not control substation, which is controlled by station automatic monitoring and control system through communication in RS485 or other interfaces.

 **Sludge concentration tank**

The mixer of the sludge concentration tank runs continuously, manually on/off controlled from on-site electrical control cabinet or controlled by PLC.

 **Sludge dewatering room**

Sludge dewatering machine and its auxiliary machine are controlled by sludge dewatering machine cabinet. When the sludge dewatering machine is running, sludge pump, chemical adding device, and distributing pump are interlocked to run.

 **Blower room**

Blower control system uses gas signal as master control signal and oxidation ditch dissolved oxygen signal as auxiliary signal. The regulation valve opening is automatically controlled based
on actual loading, for the purpose of control water quality of outlet water. The on/off counting and overall running time is balanced for each blower.

3.4 Instrument system

For a modern waste water treatment plant, the effluent water quality and automation of operation management of the wastewater treatment plant rely on dozens of online real-time monitoring and analysis instruments distributed at various process sections in the plant. The instrument system follows the design principle of “process necessary, measuring compliance, practical and effective, maintenance-free”. The waste water treatment plant instrumentation includes two broad categories, conventional measuring instruments and water analysis instruments.

- **Conventional measuring instruments**: ultrasonic liquid level difference gauge, ultrasonic liquid level gauge, liquid level switches, ultrasonic flowmeter, electromagnetic flowmeter, pressure transmitter, gas flowmeter, etc. The instrument manufactures include Germany E+H, Beijing Ripenss, Beijing Defei Shiji, Shanghai Guanghua, Shanghai Welltech, etc.

- **Water analysis instrument**: pH (with temperature) meter, suspended solid analyzer, mix liquid suspended solid analyzer, dissolved oxygen analyzer, oxidation-reduction potential (ORP) analyzer, mud-water interface meter, residual chlorine meter, chlorine leak alarm system, COD, BOD, etc. In addition, along with the advanced treatment development of waste water treatment plant, nitrate nitrogen, ammonia nitrogen, total phosphorus, TOC, and other analysis instruments are starting to be adopted. The instrument manufactures include Germany E+H, U.S. HACH, etc.
Water purification plant

1. Process of water purification plant

The water purification plant consists of primary pump room, chlorination room, blower room, flocculation and sedimentation tank, filter tank, clean water tank, and secondary pump room. The water source passes through the primary pump room (or water pump room) to the plant. After pre-sterilization, it enters into the flocculation and sedimentation tank. Following flocculation and sedimentation steps, the water comes into filter tank, which is a significant part of the plant, used for filtering suspended solid in the water. During filtration process, the water level in the filter tank shall be adjusted as constant. Also, the filter tank is backwashed (gas washing – water washing – water and gas mixed washing). Finally, the water is sent to clean water tank. After post-sterilization, it is discharged to municipal pipe network through secondary pump room.

2. Automatic control system

2.1 Overview

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![Flow chart of water purification plant process](image)

The water purification plant adopts Hollysys LK series of Programmable Logic Controller (PLC) based automatic control system, to achieve production control, running operation, and management monitoring of the plant. The system not only has reliable hardware, but also has powerful, stable, and user-friendly system software, programming software, and control software, with low cost of running and maintenance and ease of operation.

### 2.2 Automatic control instrument system

In order to ensure of the safe and reliable engineering control process and production continuity of the water purification plant, also to improve the level of automation, Hollysys LK series PLC-based, combination of centralized and distributed automatic control system is mainly for production control, operation, monitoring and management of water purification plant.

The entire system consists of one central monitoring and control station, six on-site control stations (PLC1 – PLC6), and eight PLC branch stations (PLC2-1 – PLC2-8). The central monitoring and control station is comprised of two central monitoring and control computers (backup for each other), servers, large-screen projection system, GPRS DTU, director room computer, engineering room computers, and production division computers. The on-site control stations adopt programmable logic controller (PLC), performing distributed control on the various parts of the process. They are located at chemical adding and chlorination room (PLC1), water purification room (PLC2), eight-grid filter tank (PLC2-1 – PLC 2-8), outlet water pump room (PLC3), sludge dewatering room (PLC4), purified water production workshop (PLC5), heat exchange room (PLC6). Among them, PLC5 and PLC6 will provide a whole set to the process.
The central room monitoring and control computer, director room, engineer room, analysis room, large-screen projection system computers, switches, and hubs or routers constitute a 100 Mbps industrial Ethernet.

The central control room (operation station, engineer station) is connected to branch stations (PLC) using optical-fiber looped industrial Ethernet. The control stations are larger than or equal to 40, with a communication speed at 100 Mbps. The communication between two optical-fiber link modules uses multi-mode fiber, with the maximum length of 3000 meters. The communication between the inlet pump station and central control room monitoring and control computer use GPRS communication network for data transmission. The monitoring and control system of substation is provided by 10 KV electrical equipments. Through MODBUS protocol, the substation monitoring and control system is connected to the automatic control system.

2.3 Process control strategy

- **Primary pump room**

The status and data signals of pump motor, electronic butterfly valve, and on-site instruments are collected and control signals are sent to these equipments. The motor running frequency and electronic butterfly valve opening are automatically adjusted by pre-installed PID regulation programs.
 Chemical adding and chlorination room
The status and data signals of on-site equipments and instruments are collected and control signals are sent to these equipments and instruments. The operations of chemical adding and chlorination equipments are automatically controlled by automatic control programs.

 Sedimentation tank
The mud removal is automatically operated according to mud removal cycle. The cycle time and mud removal time of mud value can be modified at operation station.

 Filter tank
Filter is an important part of the water, used to filter water and suspended solids in the filtration process. During filtration process, it needs to achieve the filter constant water level adjustment, filter backwash (air washing – water washing - gas-water mixed washing), and other functions.

 Constant level adjustment during filtration process in filter tank
The filter outlet water valve opening is adjusted according to the water level setting value, to keep constant level of the filter tank.

 Filter backwash control
The backwash of the filter tank is controlled by a common PLC. When the backwash condition is reached, the filter submits backwash request. The PLC forms a backwash request queue according to filter priorities.

The control condition of filter backwash is setting time and filter water level.

 Secondary pump room
The main implemented functions are status and data signal acquisition of on-site equipments and instruments. Based on actual water usage conditions, the pump motor running frequency is automatically adjusted by pre-installed PID regulation programs to achieve the purpose of constant pressure water supply.
Intermediate water reuse

There are two forms of living waste water treatments. The first is surrounded by municipal waste water treatment plant pipe network. The living waste water flows into municipal waste water pipe network, and treated by the municipal waste water treatment plant. The second is to construct on-site living waste water treatment facilities for the living waste water unable to flow into the municipal pipe network. After treatment, the water reaches standard and is discharged, or it may be further treated to achieve the purpose of intermediate water reuse. Here we mainly discuss the latter one.

Using living waste water as water source, after appropriate treatment, the water can be used for miscellaneous purpose. Its quality parameters are between drinking water and drainage, being called intermediate water. The corresponding technology is called intermediate water technology. For lack of fresh water resources, and serious municipal water supply shortage areas, the adoption of intermediate water technology not only saves water resources, but also makes waste water harmless. It is a significant way to prevent water pollution. Our country shall strongly promote this new technology and process at present and for a long time in the future.

1. Intermediate water sources

The intermediate water sources include cooling water, shower, lavatory, kitchen, toilet, and waste water treatment plant secondary sedimentation tank outlet. Usually, industrial waste water is not taken as intermediate water source. It is inhibited to use infectious disease hospital, tuberculosis hospital, and radioactive waste water as the water source. For residential building, it is considered as using other waste water except for toilet waste water as the water source. For large-scale public buildings, hotels, commercial and residential buildings, the cooling water, show drainage, and lavatory drainage can be used as the water source. For the public canteens and restaurants, the drainage water quality undergoes severe pollution, hard to be treated, not acceptable for the source. The drainage of large laundry rooms contains a variety of detergents. Whether it is used for the source shall be proved by the experiments.

2. Intermediate water treatment process

To treat waste water into intermediate water quality standard, there are generally three stages:

- Pre-treatment: This stage will focus on two processing units, bar screen and regulation tank. The main purpose is to remove the solid impurities in waste water and homogenize water quality.
- Main treatment: This stage is critical to the treatment process. The main role is to remove dissolved organic matter in waste water.
- Post-treatment: The stage is mainly on sterilization. This advanced treatment ensures
that the outlet water reaches the intermediate water standard.

The current adopted methods can be divided into three categories:

- **Bio-treatment method**: this method uses microorganism adsorption in water, to achieve oxidation and decomposition of organic matter in waste water, including aerobic and anaerobic microbial treatment. Aerobic treatment is more common.

- **Physical chemical treatment method**: The combination of coagulation and sedimentation (flotation) technology and activated carbon is used as basic mode. Compared with the conventional secondary treatment, water quality is improved, but with higher operating costs.

- **Film processing**: this method uses ultrafiltration (microfiltration) or reverse osmosis membrane treatment. Its advantage is that SS removal rate is high, and its covering area is reduced largely as compared with conventional secondary treatment. But the practical application of this technology still exists some controversy.

### 3. Automatic control system

#### 3.1 Overview

The Ministry of Construction issued "Municipal intermediate water facilities administration temporary measures" defined intermediate water as: part of living high-quality miscellaneous drainage treated and purified to achieve "Living miscellaneous quality index" (CJ25.1-89), and it can be reused within a certain range, but not for drinking. The intermediate water is actually recycled water, with the water quality between drinking water and drainage water, therefore called "intermediate water". Although we cannot drink the water, it can be used in some less water quality of demanding occasions. Water reuse objects are divided into municipal miscellaneous water, living miscellaneous water, and industrial users.

Water reuse system adopts Hollysys **LK Series PLC-based automatic control system**. Based on full usage of existing resources, through rational system structure and powerful control functions, the system makes that all devices have been better controlled, with stable and reliable operation, recycling of water in a safe and effective way.

#### 3.2 System design

The intermediate water reuse automatic control system consists of one central control room and three on-site PLC control stations, and high-speed safe industrial Ethernet data communication network. The central control room is comprised of two industrial control computers and projection display system. It monitors and controls on-site PLC control stations via optical-fiber as transmission media industrial Ethernet networks. The three on-site control stations are rapid filter tank control station (PLC1 station), aeration biological filter tank station (PLC2), and inlet pump room station (PLC3). The above on-site control stations are in charge of monitoring and
controlling on the related processing equipments and instruments within the structure, and sending the required information to the central control room located at office and management building.

![Diagram of water reuse automatic control system](image)

The system uses principles of distributed control and centralized management. It is comprised of three layers, central control room management, on-site PLC controlled management, and on-site equipments and instruments. The on-site stations of the control system are configured from Hollysys LK Series PLC and color touch screens. The central computers are connected to the PLC stations using optical-fiber media industrial Ethernet. Remote I/O stations of on-site PLC Station adopt PROFIBUS-DP industrial fieldbus connection.

### 3.3 Process control

Intermediate water reuse process main flow: the outlet water from waste water treatment plant secondary sedimentation tank is lifted to aeration biological filter tank through lifting pump room for biological and chemical treatment. The treated water is added chemicals and chlorinated, then flows into flocculation tank and inclined pipe sedimentation tank. Passing clean water tank, the clarified water is sent users via pump room. The muddy water generated in the process flows into reverse osmosis.
tank for treatment after continuous microfiltration in the cyclic tanks. The treated water enters into clean water tank and to users. The settling sludge is sent to concentration tank of the secondary treatment plant through sludge discharging pumps.

**Aeration biological tank**
- Filtration and backwash process control of the filter tank
- Monitoring dissolved oxygen in waste water, controlling aeration level through the measurement of dissolved oxygen, and controlling backwash on/off according to the filtration materials upper and lower pressure difference in the tank

**Flocculation tank and inclined pipe sedimentation tank**
- Controlling operations of eight mixers in the flocculation tank
- Controlling mud scraper operation in the sedimentation tank

**Lifting pump room**
- Controlling submersible pump on/off duration and counting
- Monitoring submersible pump manual/auto, operation, failure signals, and water level signal

**Outlet pump room**
- Control over centrifugal pump and electronic control valve in the outlet pump room
- Centrifugal pump manual/auto, operation, and failure signals
- Electronic control valve manual/auto, fully open, fully closed, and failure signals
- Outlet pipe pressure
- Monitoring residual chlorine value, turbidity value, pH value, and temperature

**CMF-RO workshop**
- Monitoring inlet water residual chlorine value in CMF-RO workshop

**Rapid filter tank**
- Control over backwash pump and backwash blower
- Control over chlorination tank filtration process and backwash process

### 3.4 System functions
- Process data acquisition, equipment operational status, automatic regulation of production data, controlling of equipment operation.
Display entire process flow chart, sectional process flow chart, power supply system diagram, process parameters, electrical equipment operational status, etc., on the color monitor (TFT).

From the collected data, the system can automatically build database, store process parameters, electrical equipment status, alarm data, and failure data. It can also generate trend curve for process parameters. The management operators can analyze and research the process curve to further improve process operational procedures, increasing production efficiency.

According to production management requirement, print out yearly, monthly, daily, and duty operation table, alarm table, failure table, and process flow chart (color copy). Real-time alarm printing and failure printing.

Communicating with on-site control systems via industrial Ethernet, the computer system can diagnose a variety of failures online.
Municipal pump station

1. Overview

In order to reduce operating costs and enhance enterprises’ modern and information level, Hollysys LK series PLC based municipal water supply scheduling pump station monitoring and control system consists of three parts, FacView monitoring and control configuration software, high-speed data communication network (VPN), and PLC system. The concept of the system structure is developed based on an open and modular structure, to enable the system with flexible and easy programming and configuration operations.

According to operational requirement of the municipal water supply pump station monitoring and control system, as well as the full consideration of the requirement of high reliability, availability, convenience, maintainability, and scalability of the system, the entire system can achieve real-time, accuracy, integrity, and uniformity on control operation, data acquisition, and information.

2. Monitoring and control system design

2.1 Overall system architecture

This project adopts international advanced control technology, Virtual Private Network (VPN) being built between each pump station and central monitoring and control center. The communication network sends real-time data signal and video signal acquisition of the automatic system of each pump station to the central control center that can remote control the pump stations in real-time. The entire system is divided into computer monitoring and control layer, PLC control layer, and on-site instrument layer, and communication network.

![Schematic diagram of automatic control system](image-url)
Central monitoring and control center (upper-level monitoring and control layer)
The central control center is located in the system central control room. It is the core part of the entire pump station automatic control system, responsible for managing the whole system database and production process scheduling. The on-site control stations send data information to the monitoring and control computer. The system can automatically complete data storage, display, analysis, alarm, and sharing. Also, the central control center and system sub-control center take control of on-site pump station at the same time, and backup for each other.

PLC control station (on-site control layer)
The system has control station at each pump station, responsible for automatic monitoring and control over operation of each on-site pump station. The PLC control station includes control cabinet, LK serious PLC controller, various I/O modules, operation touch screen, and video monitoring device.

On-site instrument layer
On-site instrument layer locates at the bottom of the system, being the data source for the system. It includes various instruments for on-site data acquisition, responsible for data acquisition, display, alarm, and sending to PLC control station and central monitoring and control center.

Data sharing and safety
The system communication network is the key part to achieve unity, stability, safety, and integrity of the system, as well as the basis of the system functions. For this application, our company adopts Virtual Private Network (VPN) to form a virtual local area network (LAN) connecting each pump station and monitoring and control center. The pump station using this network can achieve data sending/receiving and monitoring and control image transmission.

2.2 Pump station control strategy
The pump station has several submersible pumps, with work/variable frequency switching control. The pump control devices are equipped with three modes, manual, automatic, and central, for the purpose of on-site manual control, PLC system automatic control, and remote control from central control room. All the starting devices of the pumps are equipped with over-voltage and overload protection, enable safe and stable operation of the pumps.

Pump operation control
- Pump units is operating alternatively, to make sure that each pump running time is approximately the same, and no single pump running for a long time.
- Control modes: manual, automatic, and remote
Variable frequency constant water level control strategy
Control during maintenance of frequency transformer cabinet

**Pump special control**
When the system detects one of these that the water level is lower the minimum limit or the pump is overheated, overloaded, over-voltage, phase lack, or frequency transformer failure, it will mandatorily start or stop the pump.

**Bar screen machine control**
The operation of bar screen machine is controlled by PLC setting time. That is, a time cycle is set inside the PLC (time cycle can be set using touch screen or remotely). According to this time cycle, bar screen machine clear the screening periodically.

**Electronic valve control**
Under any control modes, the electronic value must be controlled to open, close, and stop.

**On/off control**
The machine can be turned on/off according to the water level of the water collecting basin, to control waste water flow. It can be manually, touch-screen controlled, or remotely controlled by the central control room to open, close, and stop the electronic valve. Also, the electronic valves can be remotely controlled under automatic control mode.

**Communication failure control**
When the PLC system is disconnected from the communication with the central monitoring and control system, the PLC system automatically converts to on-site automatic control, ensuring that the pump control system is normally operating under unmanned condition.

### 2.3 System functions

**Pump station control system**
- Communication and control
- Monitoring and alarming
- Event handling
- Customization

**Database system**
- Data storage
- Data processing

**Specific functional modules**
- Print and tabulating module
- Data inquiry module
- Data chart and plotting module

**Pump station database maintenance function**
In the maintenance interface, users can add, delete, and modify data. When pump station
number increases, user can easily add the new pump stations to the database.

- User management function
- Image system

**Information sharing**

The running information of the monitoring and control system, pump station data management system, and image system can be provided to various functional divisions of the plant, managers and decision-makers, and other different authorization levels of department or personnel via Intranet network.

**Management Assisting**

The pump station data management system can provide historical data recordings to managers, enabling them to make dynamic analysis on the local pump station operation status. This also provide basis for decision makings.

### 3. Features and advantages

- A solution integrated from on-site data, off-site data, and disaster recovery can guarantee data consistency in the maximum degree.
- Support two modes of disaster recovery, homogeneous and heterogeneous structure.
- The disaster recovery level increases in turn, the latter being based on the former
- It can be implemented step by step. The later investment protects earlier one.
- It can support manual/automatic disaster recover solution. User can freely select as needed.