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Micro-eddy coagulation mechanism and its application in water purification plants

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ABSTRACT

This paper introduced the new technique of micro-eddy coagulation water treatment, which functioned through micro-eddy cohesion and three-dimensional contact flocculation to take full advantage of the coagulation space, the coagulation energy, and floc activity, thus greatly improving the efficiency of coagulation reaction. Also, the core of the micro-eddy coagulation technique—the structural characteristics and process characteristics of vortex reactors were described, and the key technology regarding the selection of different hole-opening diameters and the control of hole-opening rate was pointed out explicitly. Finally, the modification and operation of this micro-eddy coagulation technique in a water treatment plant in Guangdong Province was described in detail. The operational practice shows that micro-vortex coagulation technique has high coagulation efficiency, fast reaction time, excellent outflow quality, and excellent versatile ability. In addition, this technique can help save the overall project investment, reduce the cost of water production, simplify the construction processes, maintain stable operation environment, and facilitate operation processes, and thus is of pretty high social and economic benefits.

Keywords: Micro-eddy coagulation; Vortex reactors; Vortex clarification; Hole-opening rate

1. Introduction

During water treatment processes, coagulation is one of the most important processes. Meanwhile, it also represents one of the most difficult parts in terms of system management. In general, coagulation includes two processes, agglomeration and flocculation. Timely and accurate dosage control is a key factor that determines coagulation effect. Also, the form of flocculation equipment also has an important impact on coagulation effect. Usually, the flocculation tank is divided into two categories, hydraulic mixing and mechanical stirring [1]. From the perspective of reactors, plug flow reactor type is commonly found in hydraulic mixing tank, whereas continuous flow stirred tank reactor type dominates in mechanical stirring tank. Because mechanical stirring tank has some obvious shortcomings, including low energy utilization efficiency, poor uniformity, and high machinery maintenance costs, hydraulic mixing tank is more commonly used in a variety of forms, such as partition board, flap board, corrugated board, and grid forms. The grid reaction tank is characterized by low loss level, short flocculation time, high collision probability, and hydraulic energy utilization efficiency, and thus has been widely applied in recent years. However, it has been found during the engineering practice that the grid reaction tank also has some obvious shortcomings [2,3]. For example, mud sediments tend to accumulate at the end bottom of the tank, and the mesh is easily congested by floating debris or algal particles. Also, the operation requirement is high whereas the operation life is short. Therefore, an alternative new product, the eddy reactor and associated micro-eddy flocculation technique, was designed to test its feasibility in engineering practice and to replace the grid reaction technique.

2. Materials and methods

2.1. Vortex reactor

2.1.1. Construction features of the vortex reactor

The vortex reactor is the core of micro-eddy flocculation technique. Initially, the vortex reactor was designed to replace the grid reactor and thus to solve the shortcomings of the latter, such as installation inconvenience, congestion tendency, and short life expectancy. Inspired by the idea of filling material applications during the sewage treatment process, the vortex reactor is designed through repeated demonstration, computing, and small-scale test, and the major structure features of the vortex reactor are as follows [4]:

- hollow spherical structure, with its diameter determined by technical requirement, and with both the inner and outer surface dulled;
- surface-opening holes, with corresponding pore size and opening porosity determined by related technology;
- the utilization of acrylonitrile butadiene styrene (ABS) plastic materials, with the bulk density slightly greater than that of water, and with wall thickness determined by the structural strength.

2.1.2. Characteristics of the vortex reactor

The structural characteristics of the vortex reactor include the following:

- Water micro-vortex flow is generated because of continuous changing of flow velocity and flow direction through holes, as well as persistent internal and external wall friction resistance;
- Lacking water flow direction; the vortex reactor can be directly put into the water without clogging wall pores, and it doesn't need to be installed;
- The production of the vortex reactor can be carried out in a large industrial scale. Because its structure is simple, it is easy to produce and transport the produced products, the construction period of renovation project is relatively short, and the produced products could be widely applied;
- The strength of the vortex reactor is good without toxicity, and the reactor is corrosion-resistant, anti-aging, with the usage life over several decades;
- The vortex reactor will rotate but not float on the surface of water stream and will not be easily clogged.

2.2. Micro-eddy flocculation process

2.2.1. Micro-eddy flocculation principle

Currently, the mainstream control theory of the flocculation process includes the velocity gradient theory and the vortex theory. According to Kolmogorov's micro-vortex scale theory, during the flocculation process, the order of vortex plays an important role, and its centrifugal inertia effect is the dynamic cause of floc collisions. Also, the vortex of similar size to those particles plays a dominant role in affecting the motion of those particles. The smaller the mainstream spatial scale is, the smaller the vortex scale and the vortex Reynolds number is, and the higher effective energy consumption and utilization is, accompanied by a stronger shearing effect on the alum [5,6]. The vortex reactor is the core of the vortex micro-coagulation process. According to Kolmogorov's local isotropic turbulence theory, in order to enhance the collision efficiency among particles, the microscopic vortex scale of the fluid must be effectively controlled. In engineering practice, the microscopic vortex scale could be controlled by manipulating the aperture ratio and the hole diameter of the vortex reactor in order to ensure a high coagulation reaction efficiency under a variety of conditions. Based on many years of theoretical and practical studies, our research group has developed three types of vortex reactors to deal with different treatment water quality as shown in Figs. 1, 2, and 3.

The main principle of the flocculation reaction realized by the vortex reactor is based on two aspects, micro-eddy cohesion and three-dimensional contact flocculation. Fig. 4 is a schematic view of the coagulation process [7,8].

2.2.1.1. Micro-eddy cohesion It can be known from coagulation dynamics that the power which promotes the particle collisions in the water body is derived from the fluid

Fig. 1. HJTM1 type.

Fig. 2. HJTM2 type.

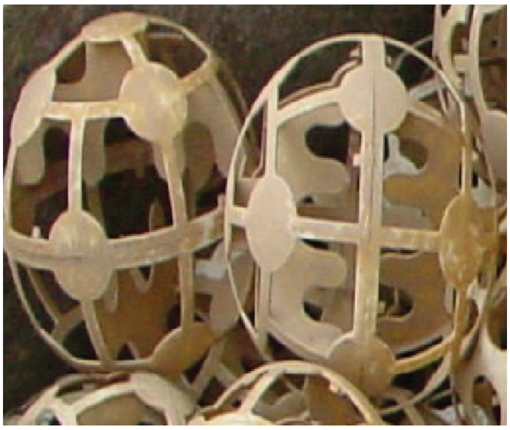

Fig. 3. HJTM3 type.

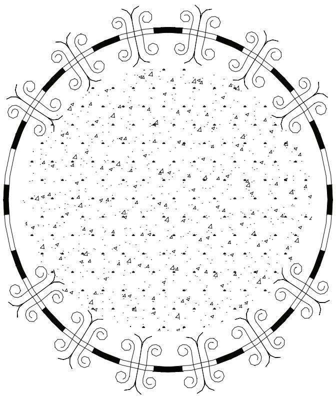

Fig. 4. Coagulation process.

motion. When water flows through many wall holes of the vortex reactor, some small vortexes and many tiny vortexes are formed simultaneously. According to Kolmogorov's local isotropic turbulence theory, vortexes of a variety of sizes coexist in the turbulence. Large vortexes then pass energy to small vortexes, which then further transport the energy to vortexes with smaller sizes. Large vortexes tend to cause particles to move as a whole without causing collisions among particles, whereas tiny vortexes are not able to promote particle collisions. Only vortexes of similar size to nearby particles could cause collisions among particles. The degree of turbulence could be controlled through choosing vortex reactors with different surface-opening hole diameters and opening rates. Also, a combination of vortex reactors with different surface-opening hole diameters could promote the formation of vortexes of similar size to nearby particles as much as possible, which is the key technique to achieving excellent coagulation effect of the vortex reactor. A large number of micro-vortex flows could effectively promote the diffusion and collision processes of particles in the water body. On one hand, colloids from coagulant hydrolysis could diffuse rapidly and collide completely with other colloids in the water body so that colloids from the water body could be destabilized rapidly. On the other hand, the large flow rate difference results in the relative movement of particles. Meanwhile, the centrifugal inertial force is generated by the rotary action of the eddy current, which then causes the radial movement of particles along the vortex direction. As a result, destabilized colloids in the water body are more likely to collide with one another in the presence of micro-vortex actions, and corresponding condensation efficiency is also dramatically enhanced. The flow rate could be gradually reduced by controlling the opening ratio of vortex reactors with different layers along water flow direction. As a result, energy transferring process among vortexes of different sizes could also be reduced. Meanwhile, many smaller vortexes are generated, and the viscous effect of water gradually becomes larger, resulting in the loss of energy. With the extension of residence time, water flow energy is gradually reduced, accompanied by an increase in alum size, associated condensed level, and the anti-shear capacity, all of which facilitate the subsequent sinking process in the sedimentation tank.

2.2.1.2. Three-dimensional contact flocculation When a large number of vortex reactors are installed in the coagulation reaction zone, because the flow velocity within vortex reactors is relatively small, a large number of larger-sized flocs (alum) are accumulated in the vortex reactors or suspended in the water body. The suspended flocs (or, more commonly called as sludge) could absorb the destabilized colloids, and this flocculation adsorption function is also known as contact flocculation phenomenon. Compared with traditional contact flocculation clarifier, the vortex reactor has higher work efficiency. First, there is only one layer of suspended flocs in the traditional clarifier, whereas the new technology allows water to flow vertically through the vortex reactor so that each vortex reactor has its own suspended flocs, the total volume becomes larger, and three-dimensional contact flocculation is generated. Second, the growth quality of flocs is better within the internal part of the vortex reactor, and flocs of larger size would be broken into smaller flocs with good flocculation capacity (flocs of larger size would cause a reduction of total surface area, and thus leads to an increase of absorption ability). Also, under the influence of micro-eddy process, low-density flocs would be broken down and re-flocculate to form flocs with higher density, and to facilitate sediment separation process.

In addition, the vortex reactor also plays other important roles, such as preventing short water flow, promoting uniform flow distribution, and increasing water flow velocity gradient. In sum, the design of vortex reactor fully takes into account various hydraulic intrinsic elements that might affect the coagulation effect, and the optimum hydraulic conditions for coagulation are created so that the optimal effect of coagulation process could be realized.

2.2.2. Characteristics of micro-eddy coagulation process

2.2.2.1. High coagulation efficiency Vortex micro-flocculation process creates highly efficient agglomeration and flocculation hydraulic conditions, and corresponding coagulation efficiency is much superior to the conventional coagulation process or the grid coagulation process. The reaction time of vortex micro-flocculation process could be shortened to 5–8 min, which also indicates that water production could be increased with small footprint and low investment compared with conventional processes.

2.2.2.2. Excellent water outflow quality With the same amount of coagulant dosage, the quality of flocs produced by micro-vortex coagulation technique is much better than that produced by traditional techniques; therefore, the settling capacity of the former is better that that of the later.

2.2.2.3. Adaptation ability of water quality and quantity Micro-eddy current coagulation is useful for the treatment of polluted water with high turbidity. The micro-eddy current could facilitate rapid diffusion process of coagulants, making them less susceptible to many impurities colloids in the water body with very high turbidity. Even if coagulants are wrapped to form flocs, these flocs are easy to be broken down to regain the flocculation capacity under the influence of micro-vortex function [9,10].

Micro-vortex coagulation process is also useful for the treatment of polluted water with low turbidity. Even if the number of collides in the water body is limited and the collision efficiency is reduced, suspended flocs could be effectively maintained in the internal part of the vortex reactor, and three-dimensional contact flocculation can efficiently remove colloids from water body.

Low temperature is also unfavorable for the coagulation process of the micro-vortex reactors. As long as the appropriate coagulant is selected to overcome coagulant hydrolysis difficulties, and the micro-vortex cohesion and the three-dimensional contact flocculation is with high efficiency, water treatment under low-temperature conditions is no longer difficult.

Micro-eddy flocculation technique has a strong adaptability to the changes of water volume, which is because the hydraulic conditions of the coagulation process mainly depend on the formation of eddy currents rather than the macro velocity of the water flow. In contrast, the formation conditions of the coagulation process mainly depend on the changes of water flow velocity (i.e., the opening ratio of the vortex reactor). In addition, a large number of active flocs are accumulated in the micro-eddy coagulation zone, and they provide a buffering function of the changes of water quality and quantity. Also, these flocs would not be deposited, compacted, or discharged when water availability in the tank is limited, which makes the micro-eddy flocculation tank able to work intermittently.

2.2.2.4. Simple implementation Micro-eddy flocculation technique is suitable for either constructed new water plant or modified traditional water plant, and it has no special requirements for the tank size or the convergence process, such as mixing and precipitation. The modification of the traditional water plant is simple, as long as the old reaction tank is removed, the existing facilities are appropriately segregated, and vortex reactor brackets are installed. When these conditions are met, the reactor could be put into use directly.

2.2.2.5. Stable operation and low-dosage consumption Micro-eddy flocculation technique no longer experiences difficulties that exist in the traditional technique regarding sludge clearage process within the clarifier tank. Flocs within the internal part of the vortex reactor are kept for a long term, and floc sludge outside the vortex reaction zone could be got rid of completely. Therefore, sludge clearage process could be simplified and the entire operation process could be more stable.

Coagulants are diffused effectively due to micro-eddy current, which greatly increases coagulant utilization rate. Meanwhile, activities of flocs within the internal part of the vortex reactor are fully utilized so that the amount of coagulants required in the micro-eddy flocculation technique is significantly lower than that required in the traditional technique [11,12].

2.2.2.6. Long-term service and easy maintenance The vortex reactor is made of ABS plastic materials, and its service life is up to several decades. Compared with grid coagulation, wall holes of the vortex reactor are not likely to get clogged, which is because the vortex reactor in the water is in a semi-suspension state, and its rotation motion could enable floating debris that might clog wall holes to float on the water surface and then be removed by hand. Even if the vortex reactor is clogged, it could be removed from the tank conveniently for a thorough clearage.

2.2.3. Requirements of micro-eddy coagulation technique

The core of micro-eddy flocculation technique is the vortex reactor, and the design of the vortex reactor could be flexible according to water quality, structure shape, and other characteristics. Specifically, requirements of micro-eddy coagulation technique include the following:

- Keep water flowing vertically as much as possible so that the upward or downward flow is perpendicular to the horizontal plane. The vortex reactor must be placed in water with vertical flowing direction. Otherwise, floc deposition will occur within the vortex reactor. The coagulation zone which is generated when the vortex reactor is put into the upward flow is also called the upward coagulation zone, whereas the coagulation zone which is generated when the vortex reactor is put into the downward flow is also called the downward coagulation zone.
- Both the upward coagulation zone and the downward coagulation zone could be flexibly combined according to specific circumstances, and their combination forms could be "downward-upward," "upward-downward,""downward-upward-downward," "upward-downward-upward,""downward-upward-downward-upward," "upward-downward-upward-downward," and so on. For each segment, water flow rate will be gradually reduced or remain unchanged, and water retention time in each segment should be no less than 5–8 min [13–16].
- Vortex reactors with different surface-opening hole diameters and opening ratios are used to control water flow velocity through the hole. Theoretically, the flow velocity through the hole in the front region should be slightly larger than the flow velocity through the hole in the rear region. Meanwhile, reactor diameters of the front region should be slightly smaller than reactor diameters of the rear region. However, under normal circumstances (e.g., when water quality is stable), in order to facilitate the construction and maintenance process, same vortex reactors could also be used.
- Sludge clearage zone should be established reasonably according to the principle that sludge clearage device should be installed at the bottom of tanks where sludge

deposition is more likely to be produced. Because the vortex reactor could also contain suspended sludge, the sludge outside the vortex reactor should also be got rid of completely.

3. Results and discussions

3.1. Engineering applications

3.1.1. Engineering background and process modification

The water treatment plant in Guangdong Province studied was built in the 1980s with a design capacity of 100,000 ton/d. The related technological process is raw water → grit chamber → perforated swirling-flow tank → advection sedimentation tank → ordinary rapid filter → filtrated water tank. There are two sets of structures in the water treatment plant, with a design capacity of 50,000 ton/d for each set. As time goes by, the original design capacity of the water treatment plant could not meet the increasing needs for local rapid development. To solve the supply/demand contradiction, local government asks the water plant to expand its production scale to satisfy daily water supply requirement of 18 million ton. Because the construction of a new water treatment plant is not only time-consuming but also requires large investments, local government decides to have the old water treatment plant expanded or modified. Due to the constraint of geological locations of the old plant, the expansion of a new group of structures is unlikely, and the only hope is to achieve the goal of increasing water storage capacity through plant modification and technological innovation. The company once considered the application of grid technique as one way of technological innovation, but had to give it up due to high precision requirements and large investment expenses during the construction processes. Taking into account technical, economic, duration, and other important factors, the water treatment plant finally decides to adopt the micro-eddy flocculation technique developed by East China Jiaotong University. The original structures of the water treatment plant remain intact except for some minor modifications [17]:

- Both the grit chamber and the reaction cell are transformed into the micro-eddy reaction tank. In order to enhance water production, the reaction time can be extended around 0.8 min when the grit chamber is transformed into the micro-eddy reaction tank (water inflow part is approximately handled) to ensure the coagulation reaction effect.
- HJTM1 and HJTM2 type vortex reactors are installed in the original reaction tank, for which HJTM2 type reactors are installed in 1–3 cells, both HJTM1 and HJTM2 type reactors are installed in 4–9 cells, and HJTM1 vortex reactors are installed in 10–16 cells.
- After water production is enhanced, overflow is likely to occur in 2–3 cells of the original reaction tank; therefore, part of the cell body should be increased 0.5 m in order to increase the tank volume. Furthermore, the size of submerged orifice is expanded for the outflow area of the sedimentation tank. In contrast, the filter tank remains unchanged (there were three sets of filter tanks in the original design, but only two sets were used. Therefore, all three sets have been used during this modification process).

3.1.2. Modification diagram of micro-eddy reaction tank (unit: m)

- The modification diagram of the grit chamber is shown in Fig. 5 (front elevation) and Fig. 6 (side elevation).
- The modification diagram of the reaction tank is shown in Fig. 7.

3.1.3. Calculation of critical process parameters

3.1.3.1. Reaction time of micro-eddy current The height of the vortex reactor that could be installed in the original grit chamber is 2.4 m, and the total volume is $4.5 \times 4.5 \times 2.4 = 48.6$ (m^3).

The height of the vortex reactor that could be installed in the original reaction tank is as follows: the first grid is 3.0 m, the second grid is 2.7 m, the third grid is 2.5 m, the fourth to sixteenth grid is 2.5 m, 2.3 m, 2.2 m, 2.1 m, 2.0 m, 1.9 m, 1.8 m, 1.7 m, 1.5 m, 1.4 m, 1.3 m, 1.1 m, and 1.0 m, respectively

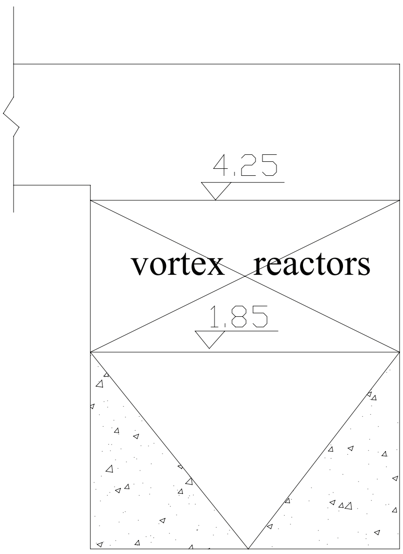

Fig. 5. Front elevation.

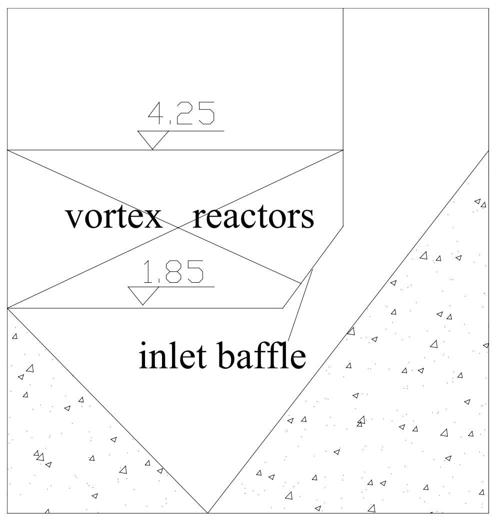

Fig. 6. Side elevation.

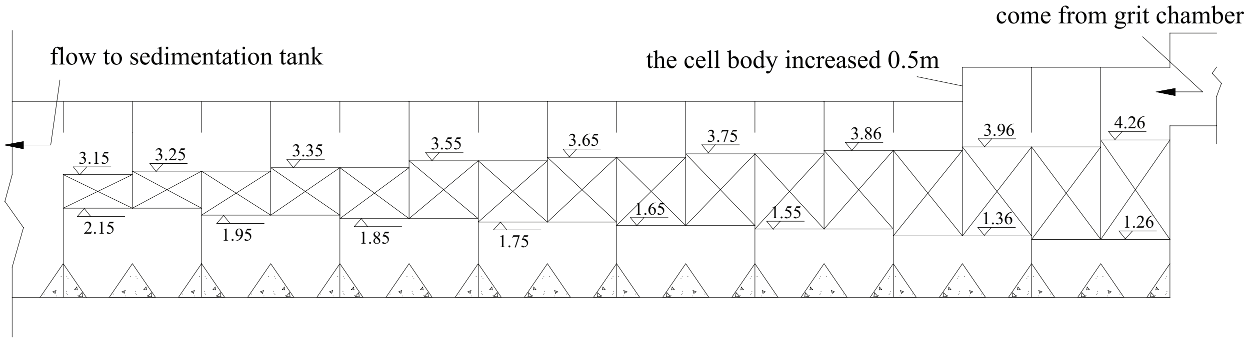

Fig. 7. The modification diagrammatic sketch of the reaction tank.

It can be concluded that the total height is 31.1 m, and the total volume is 1.7 × 1.7 × 31.1 × 2 = 179.8 (m^3).

The total volume of each micro-eddy reaction zone is 48.6 + 179.8 = 228.4 (m^3).

If the design capacity is set as 70,000 tons/d, the reaction time of micro-eddy current is (228.4 ÷ 70,000) × (24 × 60) = 4.7 (min).

According to the design requirements of micro-eddy current reaction, the reaction time is generally between 5 and 8 min, and the total volume of original grit chamber and reaction tank is (4.5 × 4.5 × 4.0) + (1.7 × 6 × 1.7 × 6 × 4.0) = 497.2 (m^3).

The reaction time of non-micro-eddy current is (497.2 – 2 28.4) ÷ (70,000) × (24 × 60) = 5.53 (min).

Therefore, the total reaction time is 4.7 + 5.53 = 10.23 (min).

Based on previous experience, the reaction effect could be guaranteed.

3.1.3.2. Velocity of micro-eddy current reaction zone The velocity of micro-eddy current reaction zone should be controlled between 60 and 80 m/h. Otherwise, gland facilities should be installed in the upwelling area to prevent the vortex reactor from floating.

After the grit chamber is transformed into micro-eddy reaction tank, the upwelling velocity is (70,000 ÷ 24) ÷ (4.5 × 4.5) = 144 (m/h).

Therefore, gland facilities are needed after the transformation of the grit chamber.

After the reaction tank is transformed into micro-eddy reaction tank, the upwelling velocity is (70,000 ÷ 24) ÷ (2 × 1.7 × 1.7) = 505 (m/h).

Therefore, gland facilities are also needed after the transformation of the old reaction tank.

3.1.3.3. Average velocity gradient G value and GT value $G = [(\gamma \times h) \div (60 \times \mu \times T)]1/2(T = 15°C)$ Based on on-site estimation, water loss of the vortex reactor per meter along water flow direction is about 7 mm. Therefore, water loss though the entire vortex reactor is 7 × (31.1 + 2.4) ÷ 1,000 ≈ 0.24 (m).

With data input, $G = [(1{,}000 \times 0.24) \div (60 \times 0.1165 \times 10^{-3} \times 7.95)]1/2 \approx 65.7(s^{-1})$

$GT = 65.7 \times 7.95 \times 60 = 3.15 \times 10^4$.

It matches classic coagulation control indicator.

3.1.3.4. Settling time Overall water production is enhanced after the transformation. The settling time is shortened to (91.8 × 12.0 × 3.2) ÷ (70,000 ÷ 24) = 1.21 (h).

Because the micro-vortex reaction could improve the flocculation effect, the sedimentation effect could be guaranteed.

3.1.4. Results

The entire transformation process is simple and convenient to carry out with short construction period (approximately 20 d). After 2 m trial operation was conducted, the effect is satisfactory. Overall, after the micro-eddy reaction technique is applied, the entire reaction process is complete, and water quality is greatly improved compared with the original process. The specific performance includes the following: First, condensed alum in the reaction tank is clear with obvious particles and good settling characteristics. In contrast, condensed alum could only be found in the sedimentation tank before transformation. Second, the muddy water area of the sedimentation tank is dramatically reduced. Water from 2/3 of the sedimentation tank before transformation is yellowish, whereas water from 2/3 of the sedimentation tank after transformation is greenish, thus indicating that water quality is significantly improved. Third, the filter working cycle is extended, and the backwash time is shortened (the source of backwash water is the water tower). Backwash water consumption is reduced by approximately 30%, indicating that the turbidity of water that needs to be treated is reduced, and alum flocculation quality is enhanced. Fourth, water turbidity before filtration process remains at about 3 NTU, but is reduced to 1 NTU or less after filtration process (for most cases water turbidity is below 0.5 NTU). Table 1 compares some parameters before and after the modification of the water treatment plant.

An analysis based on Table 1 shows that after the application of the vortex reactor, the backwash rinse of the filter tank is clean and thorough, the filtering effect is improved, the filtration cycle is extended, the rinsing frequency is reduced, and the amount of backwash water required is reduced. Table 2 displays a comparison of the working status of the filter tank before and after the transformation of the reaction tank. It can be seen from the data that the reduced amount of backwash water each time for each filter cell is 100 m^3, and nearly 30% of the backwash water is saved. Or, in other words, before the transformation, the amount of rinse water throughout the entire year for each filter cell is 811,920 ton, but is reduced to 555,120 ton after transformation, so the amount of water saved annually is 256,800 ton. If the cost of water is 0.5 RMB per ton, then 128,400 RMB can be saved

Table 1
The change of some parameters before and after modification

Comparison project	Before modification	After modification	Remarks
Water production, m^3/d	50,000	70,000	
Dosage input ($AlCl_3$), mg/L	12	10	
Flocculation reaction time, min	12	8	
Retention time in the sedimentation tank, h	1.90	1.21	
Alum status	Unclear	Clear particles	Within the reaction tank
Water turbidity before filtration, NTU	10	3	
Filtration rate, m/h	8	10.8	
Filter cycle, h	22	34	
Backwash strength, $L/s.m^2$	13	13	Provided by water tower
Backwash time, min	9	6	
Backwash effect	Incomplete	Clean and complete	
Amount of backwash water within each cell, m^3/d	340	240	Water production as 50,000 ton/d
Water turbidity after filtration, NTU	1	0.5	

Table 2
Filter flushing before versus after modification

Comparison project	Before modification	After modification	Saved water amount	Saved percentage
The amount of backwash water per cell, m^3	340	240	100	29.4%
Filter cycle, h	22	34		
Annual times	398	257		
The amount of backwash water per cell each year	135,320	61,680	73,640	54.4%
The number of filter cells	6	9		
The amount of backwash water for the entire filter tank	811,920	555,120	256,800	31.6%

annually. As the source of backwash water is the water tower and the amount of needed backwash water is reduced, certain amount of power cost is saved as well. According to a preliminary estimation, the transformation cost could be regained within 4 or 5 years after the application of the vortex reactor.

4. Conclusion

Vortex reactor technology is easy to carry out during the transformation processes. Although the coagulation effect is enhanced with the application of the vortex reactor, the destabilization effect is realized under the premise that dosage amount is appropriate. Because the flow volume is increased by 20%, the retention time in the reaction and sedimentation tank is greatly shortened, and the filtering velocity is enhanced, more stringent requirements regarding the operation and management process are needed, especially dosage amount should be controlled more cautiously. Also, the coagulation effect of the vortex reactor could be more obvious if the automatic dosage addition process is realized. Observations during the debugging process show that the micro-eddy reaction can achieve the best results under a long and stable flow operation condition. This is because with such a steady flow operation condition, the sludge inside the reactor will gradually accumulate and the flocculation (adsorption) effect could be optimized. For the studied water plant, the time span between the transformation design and trial commissioning is less than a month, but the outcome is obvious. It has operated smoothly and stably for several years, with the amount of finished water remaining below 0.5 NTU.

Both theory and practice have proved that after the application of the micro-eddy flocculation technique, the hydraulic conditions of the system have been greatly improved, the flocculation reaction efficiency of the water purification process has been enhanced, the flocculation time has been shortened, the amount of dosage required has been reduced, and the quality of purified water has been improved. Meanwhile, a large amount of backwash water has been saved, and the anti-change adaptation capacity of the entire water purification system has been greatly improved. The successful transformation of this water treatment plant fully demonstrates that the micro-eddy flocculation technique is both feasible and effective. Also, with a high practical value regarding water quality and social benefits, application and promotion of this new technique in practice is promising.

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