Study on a new water purification equipment with spiral lamellas

X R Feng¹,²
¹College of Civil Engineering and Architecture, Hainan University, Haikou 570228, China
²E-mail: fxrgreat@163.com

Abstract. A new water purification equipment was introduced, especially the section of spiral lamellas. Utilization of spiral lamellas made the sedimentation space reach to 100%, not only improving sedimentation efficiency and reducing the cover space, but also saving investment. Production test results showed that the new water purification equipment with spiral lamellas had characteristics of excellent treatment efficiency and high shock resistant capacity. As the treatment water volume was 240 m³/d, when the turbidity, COD₅₅ and UV₂₅₄ were 203 NTU, 1.90 mg/L and 0.030 cm⁻¹ in raw water, they were 0.32 NTU, 0.72 mg/L and 0.011 cm⁻¹ respectively in effluent water, which could fully meet the drinking water hygiene requirement.

1. Introduction
The water purification equipments take surface water and shallow groundwater as water sources and closely combine coagulation, sedimentation and filtration processes together [1], which is equal to a small water supply treatment plant. Whether on operation and management, or on investment and scale, the water purification equipments are fit for small towns and rural areas that are shortage of farmland. As the conventional water treatment plants cover large areas and are managed complexly, their large scale construction is difficult in small towns and rural areas [2]. The development of efficient integrated water purification equipments has great significance to solve the safety problems of drinking water in rural areas.

Currently, water purification equipments on the market generally have disadvantages. Firstly, traditional oblique tube sedimentation device inevitably exist in a certain area of stagnant water [3], which obviously decreases the sedimentation efficiency. Secondly, by the volume restriction, flocculation time is short and floc particles are small and loose which are easy to be taken out of the tank [4], resulting in the deterioration of water quality. Finally, because of difficult installation of oblique tubes in circular cylinder walls, shapes of water purification equipment are mostly in rectangular, which need thicker sheets, increasing the cost of construction [5].

In order to overcome these shortcomings, this paper introduced a new integrated water purification equipment with spiral lamellas which was also sent into production trials in western mountain rural area of China.

2. Materials and methods

2.1. A new water purification equipment with spiral lamellas
This device used a new self-developed spiral lamella sedimentation technology which integrated
intensive grid coagulation and cyclone grit technology (figure 1). Raw water containing flocculant entered the bottom of the first flocculation chamber by tangential direction from inlet pipe, flowed rotating movement along the cylinder wall and then into the first flocculation chamber, of which large grain of sands were removed by cyclone grit sedimentation. There are six layers of grids in the first flocculation chamber, which are gradually decreased in perforation size from top to bottom. There are four layers of grids in the second flocculation chamber, which are gradually increased in perforation size from top to bottom. The speed of water flows was gradually slower through the grid perforation which made the floc particles obtain good flocculation conditions, while at the same time avoiding destruction of the formed floc particles.

**Figure 1.** Integrated water purification equipment with spiral lamellas (a), and installation of spiral lamellas (b).

Lamellas were uniform spirally distributed between outer cylinder and internal cylinder walls in elliptical ring shape (figure 1 (a)). The long axis and short axis of the ellipse were determined by inner and outer cylindrical diameter of sedimentation area and spiral inclination angle. Spiral lamellas were fixed on the barrel walls of inside and outside sedimentation area. Water spirally flowed forward along the cylindrical columns (figure 1 (b)). Spiral lamellas were arranged in a ring sedimentation area, close to cylinder wall, so it would not appear short flow phenomenon and not had stagnant water region. The space utilization of sedimentation area reached to 100%. At the same time, it had advantages of high sedimentation efficiency, conducive to mud separation and easy installation of spiral lamellas.

This new water purification equipment adopted quickly downward flow filtration. Short shank filter heads were used into water distribution, which had less head loss and uniform water distribution. Filter materials adopted refining quartz sands.

### 2.2. Experimental section

This water purification equipment with spiral lamellas was used into production test for three months in a town of southwest China. Treatment water volume was 240 m$^3$/d. Seasonal water treatment tests preceded in conventional water and high turbidity water respectively. The quality of raw water was shown in table 1.
Table 1. Quality of raw water.

| Indexes        | Average value |
|----------------|---------------|
| Water temperature (°C) | 25            |
| pH             | 7.8           |
| Turbidity (NTU)| 95.9-1927     |
| COD_{Mn} (mg·L^{-1}) | 1.90         |
| UV_{254} (cm^{-1}) | 0.030        |

3. Results and discussion

3.1. Turbidity removal efficiency

When dosage of polyaluminum chloride (PAC) was 10 mg/L, turbidity removal efficiency was shown in figure 2. Raw water turbidity was between 40.7 NTU and 203 NTU in August for average value of 95.9 NTU. The effluent turbidity of sedimentation tank was between 0.32 NTU and 1.46 NTU for average value of 0.83 NTU, at the same time, the average removal efficiency was 99.02%. The turbidity of effluent water after filtration was between 0.09 NTU and 0.4 NTU for average value of 0.18 NTU. The turbidity removal efficiency was more than 98% in flocculation sedimentation, especially in high turbidity season which remained below 1 NTU. It can be seen that this device had the superiority of good sedimentation effect and strong shock resistant capacity.

Due to heavy rains, raw water turbidity increased rapidly in July. Continuous tests results showed that the treatment efficiency was high by the PAC dosage of 40 mg/L. Take data on July 20 for example, when average turbidity of raw water was 1927 NTU and effluent water turbidity of sedimentation tank is 4.55 NTU, turbidity removal efficiency reached above 99.38%. Results indicated that effluent water turbidity of sedimentation chamber was stable and this equipment had excellent turbidity removal efficiency.

3.2. UV_{254} removal efficiency

UV_{254} value reflects the content of large organic matters such as lignin, humic substance, aromatic
compounds and so on, which is an important control parameter of organic matters in water, at the same time, it can also be used as an alternative parameter of total organic carbon (TOC), dissolved organic carbon (DOC) and trihalomethane formation precursor (THMFP). Early as 1978, UV$\text{$_{254}$}$ had been adopted into water quality monitoring conventional index in Japan.

When dosage of PAC was 10 mg/L, UV$\text{$_{254}$}$ removal efficiency was shown in figure 3. During the experimental period, UV$\text{$_{254}$}$ value of raw water was between 0.018 cm$^{-1}$ and 0.064 cm$^{-1}$ for average value of 0.030 cm$^{-1}$, while in sedimented effluent water, UV$\text{$_{254}$}$ value was between 0.011 cm$^{-1}$ and 0.039 cm$^{-1}$ for average value of 0.018 cm$^{-1}$. As a result, the average UV$\text{$_{254}$}$ removal efficiency was 37.15%.

![Figure 3](image1.png)  
**Figure 3.** UV$\text{$_{254}$}$ removal efficiency under continuous work condition.

![Figure 4](image2.png)  
**Figure 4.** COD$_{\text{Mn}}$ removal efficiency under continuous work condition.

3.3. COD$_{\text{Mn}}$ removal efficiency
COD$_{\text{Mn}}$ is commonly used as a composite index of pollution level caused by organic and reducing inorganic substances in surface water. It has good correlation with UV$\text{$_{254}$}$. When dosage of PAC was 10 mg/L, COD$_{\text{Mn}}$ removal efficiency was shown in figure 4. COD$_{\text{Mn}}$ value of raw water changed between 0.98 mg/L and 2.98 mg/L for average of 1.90 mg/L. The average value of effluent water was 1.11 mg/L. The COD$_{\text{Mn}}$ removal efficiency reached to 39.68%.

4. Conclusions
Spiral lamellas in the new water purification equipment had superiorities of easy installation, uniform distribution, no short-flow and stagnant water areas, at the same time, with high sedimentation efficiency and 100% of space utilization. When the treatment water volume was 240 m$^3$/d and the dosage of PAC is 10 mg/L, turbidity removal efficiency reached to 99.6%, with 42.19% of UV$\text{$_{254}$}$, 50.7% of COD$_{\text{Mn}}$. In rainy season, despite that raw water turbidity was more than 3000 NTU, turbidity removal efficiency still reached to 99% by increasing the PAC dosage to 40 mg/L. The effluent water turbidity of sedimentation basin was below 5 NTU and of filtration basin was under 1 NTU. This water purification equipment had characteristics of less investment, easy manipulation and economic space occupation, fitting for small urban areas with weak economic, poor geography and low management level.

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