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# Construction and Practice of Operation and Maintenance Quality Management System of Township Sewage Treatment Facilities based on PDCA Cycle

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## Abstract

**In view of the unstable operation and maintenance quality of township sewage treatment facilities and the imperfect supervision system, combined with the management requirements of the technical specification for intelligent operation and maintenance management of township domestic sewage treatment facilities, an operation and maintenance quality management system based on PDCA cycle is proposed. Through the establishment of standard operating procedures (SOP), digital single system and three-level quality inspection mechanism, the practice was carried out in 32 village level sewage treatment stations in a county of G province. After one year of implementation, the equipment failure rate decreased by 42%, the integrity rate of operation and maintenance records increased from 58% to 96%, and the effluent compliance rate increased by 11.7%, providing a replicable mode for the long-term management of township sewage facilities.**

## Keywords

**PDCA Cycle; Township Sewage Treatment; Operation and Maintenance Management; Quality Management System; Standardization.**

## 1. Background

With the acceleration of urbanization in China, the construction and operation and maintenance management of township sewage treatment facilities has gradually become an important part of ensuring the quality of rural water environment. However, due to the limited economic conditions and uneven technical level in township areas, the operation and maintenance quality of sewage treatment facilities is often difficult to be effectively guaranteed. The frequent occurrence of problems such as non-standard operation and lack of effective supervision in the process of operation and maintenance has led to low operation efficiency of facilities and substandard effluent quality, which has seriously affected the rural ecological environment and the quality of life of residents. Therefore, it is particularly important to build a scientific and efficient quality management system for the operation and maintenance of township sewage treatment facilities[1] .

## 2. Status and Problem Analysis of Operation and Maintenance Management of Township Sewage Treatment Facilities

In the current process of operation and maintenance management of township sewage treatment facilities, there is a widespread phenomenon of "focusing on construction and ignoring management". Taking the special survey data of G Province in 2023 as an example, it can be found that 73% of the facilities have the problem of missing inspection records, 65% of the stations have no special personnel stationed, and the average repair time of equipment failures has exceeded 72 hours. The core reasons for these problems are:

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Fragmentation of management system: at present, there is a lack of unified operating procedures, and the implementation standards of different villages and towns are significantly different. For example, in the operation and maintenance manual of 12 villages under the jurisdiction of a county, only 4 villages clearly marked the sludge cleaning cycle, and the remaining villages only marked "regular cleaning", without a specific schedule[2].

Failure of process supervision: the traditional paper work order is difficult to trace, and the inspection of the superior department is often a mere formality. Of the 328 patrol inspection records filled in a town in 2021, 217 had logical contradictions, such as recording "equipment drying" after a rainstorm.

Lack of improvement mechanism: most quality problems remain in oral feedback, and the systematic analysis and improvement are not available. For example, a township has had 7 failures of the same kind of water pump in the whole year, and has never established a preventive maintenance plan.

The existence of these problems directly leads to the low operating efficiency of the facilities. Statistics show that the operation and maintenance cost per ton of water of township sewage plants with extensive management is 38% higher than that of standardized management plants, and the equipment life is shortened by 40%.

## 3. Construction Path of PDCA Cycle Quality Management System

### 3.1 Plan Stage: Development of Standardized Management Tools

At the planning stage, we are committed to developing standardized management tools to ensure that the whole project can be carried out efficiently and orderly.

SOP documents are formulated at different levels. According to different levels, detailed SOP (standard operating procedure) documents are formulated to ensure that there are clear operation guidelines for each link. At the county level, we issued the general specification for the operation and maintenance of township sewage facilities, which stipulates the basic requirements such as the items of daily/weekly/monthly inspection of equipment and the frequency of water quality inspection. At the county level, we issued the general specification for the operation and maintenance of township sewage facilities, which defines the items of daily, weekly and monthly inspection of equipment and the frequency of water quality inspection, so as to ensure the normal operation of equipment and the safety of water quality. Prepare localization operation rules at the township level, such as increasing the frequency of grid cleaning at mountain sites (twice a day vs once a day in plain areas). At the township level, we have formulated localized operation rules according to the local actual situation. For example, for stations in mountainous areas, we have increased the frequency of grid cleaning from once a day to twice a day to adapt to the special environment in mountainous areas. Supporting visual operation instructions, the form of "picture+short sentence" is adopted to reduce the understanding threshold. In a village, the blower maintenance steps were broken down into 6 live photos, and the training time was shortened from 3 hours to 40 minutes. We also provide visual operation instructions in the form of "pictures+short sentences", which greatly reduces the threshold of understanding. For example, a village broke down the maintenance steps of the blower into 6 live photos, which shortened the training time from 3 hours to 40 minutes[3].

Grid division of responsibilities, we will grid division of responsibilities to ensure that each link has a clear person in charge. Establish a "facility manager" responsibility system, and designate one township cadre as the person in charge of supervision in each treatment station. We have established a "facility manager" responsibility system, and each treatment station has identified a township cadre as the person in charge of supervision to ensure the normal operation of the facility. The operation and maintenance enterprise is equipped with a minimum unit team of "1 technician+2 operators" to implement the regional contract. The operation and maintenance enterprise is equipped with a minimum unit team of "1 technician+2 operators" to implement regional contracting, so as to improve the operation and maintenance efficiency and service quality.

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### 3.2 Execution Phase (Do): Digital Process Control

In the implementation phase, we focus on the strict control and management of the digital process to ensure the efficiency and accuracy of the process.

Design of work order management system. We have designed and developed a work order platform for wechat applet, which can automatically create periodic task reminders. For example, at 8:00 a.m. every Monday, the system will automatically push the task of "scum cleaning of secondary sedimentation tank" to relevant staff to ensure the timely implementation and handling of the task. The on-site code scanning sign in and photo uploading functions force the retention of process evidence. After the implementation of a site, the false work order rate has decreased from 31% to 2%.In order to ensure the transparency and authenticity of the workflow, we have introduced the on-site code scanning sign in and photo uploading functions. These functions forcibly retain the evidence in the work process and effectively prevent the generation of false work orders. After the implementation of these functions at a site, the false work order rate decreased significantly, from 31% to only 2%[4].

Refined material management. We are committed to the refinement of material management to improve the efficiency of resource use and reduce unnecessary costs. The safety stock model of key spare parts is established, and the threshold is set according to the historical data of equipment failure. By analyzing the maintenance records of a town in the past two years, the aeration tray inventory was optimized from 30 to 18, and the capital occupation was reduced by 40%.

We establish a safety inventory model of key spare parts, which sets a reasonable inventory threshold based on the historical data of equipment failure. By analyzing the maintenance records in the past two years, a town successfully optimized the inventory of aeration trays from 30 to 18, thus reducing the capital occupation by 40%, significantly improving the efficiency of capital use. The "old for new" collection system was implemented, and the core recovery rate was increased to more than 95%.In order to further promote the recycling of resources, we implemented the "old for new" collection system. This system encourages employees to return cores when receiving new spare parts, thus improving the recovery rate of cores. At present, the core recovery rate has increased to more than 95%, which not only reduces the generation of waste, but also reduces the purchase cost of new spare parts.

### 3.3 Check: Three Dimensional Supervision Mechanism

In the inspection phase, we implemented a three-dimensional supervision mechanism to ensure the comprehensiveness and effectiveness of quality control:

Three level quality verification system. Village level self inspection. At this level, operators are responsible for filling in the electronic checklist every day. They will focus on recording the intuitive problems, such as abnormal vibration, abnormal noise and other phenomena, to ensure that potential quality problems are found at the first time. At the township level, environmental protection professionals conduct on-site spot checks every week. They use a standardized scoring table, which contains 20 quantitative indicators to ensure the objectivity and accuracy of the inspection. At the county level, the inspection at the county level is more stringent. We hired a third-party agency to conduct quarterly unannounced visits, paying special attention to the operation status of the equipment at night, so as to ensure that the equipment can also maintain good operation status in the period of least attention[5].

Classification and grading of quality problems. For the quality problems found, we divided them into three categories and set different time limits for rectification. Class a problems (equipment shutdown) need to be solved within 24 hours; The rectification time limit for class B problems (water quality exceeding the standard) is 72 hours; However, class C problems (missing records) need to be rectified within 7 days. Establish a "red and yellow card" early warning mechanism, automatically upgrade the yellow card warning to a red card for a total of 3 times, and trigger the contract breach clause. In order to further strengthen quality control, we have also established a set of "red and yellow card"

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early warning mechanism. When a quality problem occurs, a yellow card warning will be issued first. If a yellow card warning is received for the same problem for 3 times, it will be automatically upgraded to a red card warning. The red card warning will trigger the breach clause in the contract, so as to ensure that the partners pay enough attention to the quality problems and take necessary improvement measures.

### 3.4 Handling Phase (ACT): Continuous Improvement Mechanism

In the processing phase, that is, the action phase, we are committed to establishing a continuous improvement mechanism to ensure that our processes and operations can be continuously optimized and improved.Monthly quality analysis meeting. We hold monthly quality analysis meetings on a regular basis. Through these meetings, we can identify and solve problems in the production process in time. In these meetings, we use various tools, such as fish bone chart, to trace the root cause of the problem. Use fish bone chart tool to trace the root cause. The problem of sludge bulking occurred in a township for two consecutive months. After analysis, the main reason for the fluctuation of influent pH value was locked and a regulating tank was installed. By using the fishbone diagram tool, we successfully traced the root cause of sludge bulking in a township for two consecutive months, that is, the fluctuation of influent pH value. To solve this problem, we have taken targeted measures and installed a regulating tank to stabilize the pH value of the influent, so as to effectively solve this problem. The top10 problem list was released and closed-loop tracking was conducted. The incidence of repetitive problems in a county decreased by 67% in 2023. We regularly released the top10 problem list and conducted closed-loop tracking management for these problems. In this way, we have successfully reduced the incidence of repetitive problems in a county by 67% in 2023.

Standard iteration upgrade. We will revise the SOP document every year to absorb the experience of on-site improvement. For example, the 2022 version of the specification added "winter Antifreeze Operation Guidelines", which reduced our failure rate by 55% in the low temperature period. Establish a "best practice library" to promote excellent cases. After the grid chain lubrication method invented by a town was applied in the whole county, the replacement cycle was extended from 6 months to 9 months. We have also established a "best practice library" to promote excellent cases and methods. For example, after the grid chain lubrication method invented by a town was applied in the whole county, the chain replacement cycle was extended from the original 6 months to 9 months, greatly improving the service life and efficiency of the equipment.

## 4. Practice Cases and Effectiveness Verification

### 4.1 Overview of Pilot Project

In the process of selecting the implementation area, after careful consideration, we finally determined a county in G Province as the core area of the pilot project. The project covers nine village level sewage treatment stations with a treatment capacity of 50-200 tons per day and a service population of 96000. In order to ensure the smooth progress of the project, we officially launched the system construction in July 2023. After a year of efforts, by June 2024, we have successfully completed the first round of PDCA cycle, that is, the cycle of plan, do, check and act, laying a solid foundation for subsequent continuous improvement.

### 4.2 Comparison of Key Achievements

The following table lists in detail the comparison of key indicators before implementation (2023) and after implementation (2024), as well as the corresponding change rate, thus intuitively showing the effectiveness of the pilot project.

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**Table 1.** Comparison of indicators before and after implementation in 2023 and 2024

| Indicators | 2023 | 2024 | Change rate |
|---|---|---|---|
| Equipment failure rate (times/month) | 4.2 | 2.4 | -42.9% |
| On time completion rate of work order | 68% | 93% | +36.8% |
| Effluent COD compliance rate | 82.3% | 94.0% | +11.7% |
| Mass complaints (times/quarter) | 37 | 11 | -70.3% |

### 4.3 Typical Improvement Scenarios

The typical improvement scenario of sludge transportation management optimization is set as six stages: initial state analysis - Improvement Strategy Research - implementation stage - review stage - treatment stage - Summary of results for improvement.

Initial status: in the initial stage, each village contacted transport vehicles to treat sludge by themselves, which led to significant differences in transport costs, with the price range from 120 yuan to 200 yuan per vehicle. In addition, due to the lack of unified management, complaints about sludge leakage frequently occur during transportation, which has brought potential risks to the environment.

Improvement strategy: planning stage: in order to improve this situation, the county began to implement a unified bidding process, select appropriate sludge transportation service providers, and sign a price guarantee agreement with them to ensure that the transportation cost per vehicle is fixed at 150 yuan, thus eliminating the uncertainty caused by price fluctuations.

Implementation phase: in order to further improve the standardization and safety of the transportation process, all vehicles involved in sludge transportation are equipped with GPS positioning system and closed sensor. The application of these technologies enables any violations, such as irregular loading or leakage during transportation, to automatically trigger the alarm system and timely notify the management personnel for intervention.

Review stage: in order to ensure the service quality, a detailed review will be conducted on the transport slip every month to verify whether the service provider has implemented the agreement. At the same time, we will also check the return visit records of the masses, collect their feedback, and ensure that the services meet the expectations and needs of residents.

Treatment stage: for those enterprises whose service performance is not up to standard, strict measures have been taken to remove them from the list of suppliers as a warning to urge all service providers to improve service quality and ensure the safety and efficiency of sludge transportation.

Results: through this series of improvement measures, the annual transportation cost was successfully reduced by 240000 yuan, and the sludge leakage complaints were also reduced to zero, which significantly improved the environmental quality and was widely praised by residents.

## 5. Conclusion and Prospect

In this study, we successfully verified the applicability of PDCA cycle in township sewage operation and maintenance management. Through the well-designed standardized, digital and closed-loop management system, we have effectively solved the weak links in quality control. Looking ahead, we can conduct more in-depth research and practice in the following three directions:

Integration of intelligent tools: future research can explore the wider application of AI image recognition technology in equipment status inspection, in order to replace some manual inspection work. This can not only improve the efficiency and accuracy of inspection, but also reduce labor costs and improve the intelligent level of overall operation and maintenance management.

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Villagers' participation mechanism: in order to further improve the quality of operation and maintenance management, we can consider establishing a set of "operation and maintenance quality points system" to encourage villagers to actively participate in the supervision and management. Through the integral incentive mechanism, guide villagers to actively monitor and report abnormal drainage behavior, so as to form a more comprehensive and effective social supervision network.

Cross regional collaboration: in order to better respond to emergencies and improve resource utilization efficiency, it can promote the collaboration and cooperation between adjacent counties and cities in sewage treatment. Specific measures include sharing spare parts inventory and emergency repair resources, which can respond quickly in case of emergency and reduce the operation and maintenance delay caused by insufficient resources in a single region.

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