Multi-stage water purification method for car wash wastewater

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Abstract:

The invention relates to a method for purifying and reusing water in car wash facilities through a multi-stage treatment process. The method includes mechanical cleaning, filtration, and disinfection. A key feature of the method is a sequential filtration system comprising three stages: sand, activated carbon, and zeolite filters.

Prior to filtration, the water undergoes coagulation and flocculation using an inorganic coagulant and an anionic flocculant. Additionally, the pH level of the water is automatically adjusted to a range of 6.5 to 7.0. After passing through the carbon filter, water turbidity is continuously and automatically monitored using a flow-through turbidimeter.

If turbidity exceeds a specified threshold, a warning signal is generated indicating the need for filter maintenance or system cleaning. This ensures consistent water quality and allows for automated control of the purification process.

The invention enhances purification efficiency, reduces water consumption, and lowers operating costs.

Keywords: Transport System, Digital Technology, Water Purification.

1. Introduction

Technical Field:

The invention relates to water purification and treatment systems, and more specifically to improved methods for treating and reusing water in car wash facilities.

Background and Purpose of the Invention:

The objective of the invention is to enhance the efficiency of treating wastewater generated by car wash stations, reduce the consumption of clean (fresh) water, minimize environmental impact, and ensure the high clarity and quality of recycled (circulating) water for reuse.

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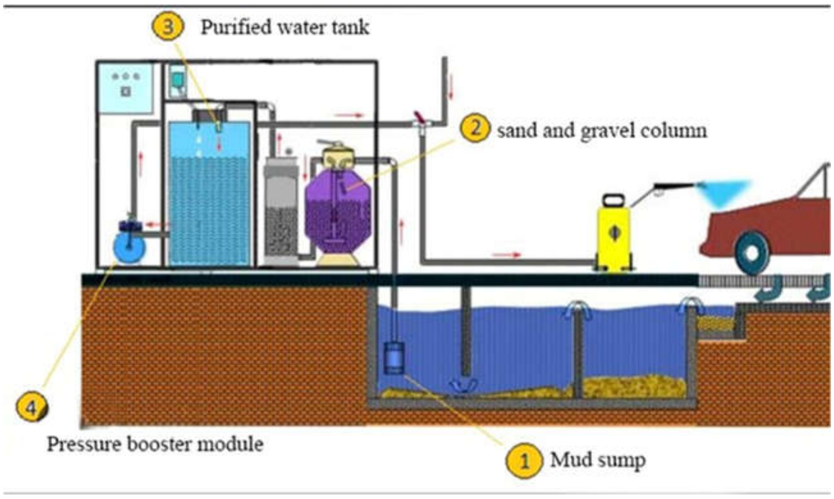


Figure 1. *Technical Methods of Water Purification*

Background of the Invention:

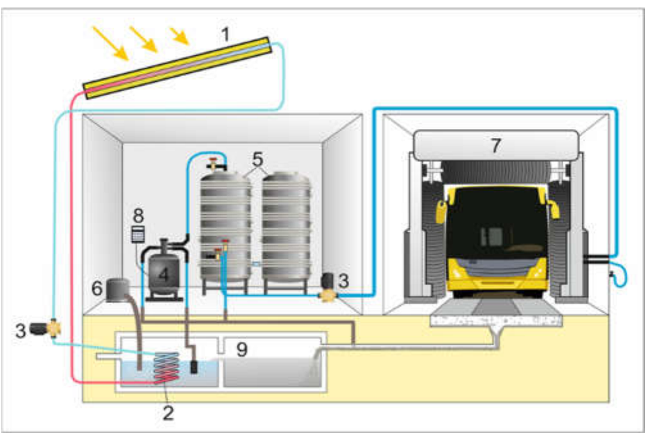
As shown in Figure 1, the purification of wastewater generated by car wash facilities is a critical challenge in the context of environmental protection and resource efficiency. This type of wastewater has a complex and variable composition. It typically contains suspended solids (such as sand and dirt), petroleum products (including oils, gasoline, and diesel fuel), surfactants from cleaning agents, dissolved organic compounds, heavy metal ions, and various other pollutants that accumulate on vehicle surfaces.

If inadequately treated, these wastewater streams contribute to environmental contamination and result in the inefficient use of water resources.

Limitations of Existing Methods:

Conventional water treatment methods typically involve mechanical processes such as sand traps and sedimentation chambers, oil separators (oil-petroleum separators), and, in some cases, basic filtration systems—for example, sand or carbon filters.

However, these conventional methods have several significant drawbacks.:



Picture 3 . Device component names: 1. Solar collector, 2. Heater spiral, 3.

Pump, 4. Filtered pump, 5. Water Garden, 6. Cleanliness in the head, 7. Washing machine, 8. Control device, 9. Water purification pond (clarifier).

Limitations of Conventional Treatment Methods (continued): Conventional filtration systems are generally ineffective at removing micro-particles and dissolved organic compounds. Basic filters are not capable of fully eliminating colloidal particles, surfactants, or dissolved organic pollutants. This leads to degraded water quality, the development of unpleasant odors, and the formation of sediment.

The primary drawbacks of such systems include:

a) **Low Quality of Recycled Water:**
Inadequately treated recycled water may cause visible spots on vehicle surfaces, clog equipment, and ultimately reduce the quality of service provided.

b) **High Consumption of Fresh Water:**

Due to the insufficient quality of recycled water, car wash operations frequently need to replace it with fresh water, leading to increased resource usage.

c) **Difficulties in Sludge Management:**

The treatment process produces sludge (sediment) that requires special disposal, posing logistical and environmental challenges.

d) **Lack of Automation and Monitoring Capabilities:**

Many existing systems lack automated mechanisms to monitor water quality in real-time. As a result, treatment processes must be manually controlled, leading to operational inefficiencies.

2. Materials and Methods

At present, a variety of technologies and systems are known for wastewater treatment, many of which are based on a combination of physico-chemical and biological methods.

For example, U.S. Patent No. **US8366936B1** [1] describes a **water filtration system utilizing layers of zeolite and activated carbon**. This system employs multilayer filtration to improve water quality for various applications. However, the system is not specifically adapted to address the complex composition of wastewater generated by car wash facilities. In particular, it lacks a dedicated **coagulation/flocculation stage** in combination with **pH monitoring**, which is critical for the effective removal of surfactants, oils, and microparticles.

Furthermore, the patent does not incorporate **automated turbidity monitoring** to manage filter operation. Such monitoring is essential for maintaining stable water clarity under the variable conditions typical of car wash environments.

Another known system is described in **Russian Utility Model Patent RU152746U1** [2], which outlines a water treatment system incorporating various purification and disinfection components. However, this system is general-purpose and not specifically tailored to the distinctive composition and treatment requirements of wastewater from car wash facilities. These types of generic systems often lack detailed design considerations, such as the **selection and sequencing of specialized filtration media**, and do not include **coagulation/flocculation processes** or **automated pH control**.

Moreover, these systems typically do not incorporate advanced technologies for **automated monitoring and control of treated water quality**, which is crucial for managing the water recirculation process. This results in **inefficient use of water resources** and **inconsistent quality of recycled water**.

Closest Prior Art and Technical Solution:

The closest prototype to the present invention is the scientific article titled *“Treatment of Wastewater from Car Washes Using Natural Coagulation and Filtration System.”* This article demonstrates the purification of wastewater from car wash facilities using natural coagulation and filtration systems. It confirms that coagulation and filtration are effective treatment methods and emphasizes the importance of pH in the coagulation process.

However, the article does not describe the automatic adjustment of pH as a controlled stage of the treatment process. Furthermore, it does not specify the exact sequence or combination of three types of filters—sand, activated carbon, and zeolite. The article also lacks elements such as automated real-time turbidity monitoring to control the quality of treated water, which limits the ability to ensure consistent water clarity and the accuracy of water reuse.

Additionally, the article does not provide detailed considerations for selecting filtration media specifically tailored to the composition of wastewater generated by car wash facilities.

In contrast, the method proposed in the present invention incorporates automatic pH adjustment, which enables controlled chemical treatment, alongside a well-defined sequence of filter media (sand, activated carbon, and zeolite), and automated turbidity monitoring to maintain high-quality water reuse.

The automatic adjustment of pH ensures that the coagulation reactions occur under optimal conditions, significantly enhancing the efficiency of coagulation compared to uncontrolled or manually operated systems. Additionally, the use of three distinct specialized filters in a specific sequence, combined with an automated monitoring and control system, ensures a high level of purification and maintains consistent turbidity throughout the process. This results in substantially greater effectiveness than the capabilities demonstrated in the aforementioned article.

Technical Objective

The technical objective of this invention is to develop an optimized multi-stage water purification method for car wash facilities that:

- ensures efficient removal of diverse pollutants;
- reduces fresh water consumption by enabling high-quality water reuse;
- automates control and monitoring for consistent operation; and
- minimizes environmental impact.

Technical Result:

The technical result is achieved through a unique combination and optimization of purification stages.

Essence of the Invention:

The core of the invention is based on the integration and synergistic interaction of the following key elements:

The core of the invention is based on the integration and synergistic interaction of the following key elements:

- A **three-stage specialized filtration system** comprising sand, activated carbon, and zeolite filters, positioned after mechanical sedimentation and before disinfection. This specific sequence enables the stepwise removal of a wide range of pollutants — from large suspended solids to organic contaminants and heavy metal ions.
- **Coagulation and flocculation processes** conducted prior to mechanical sedimentation using specialized chemical agents (aluminum oxychloride and polyacrylamide-based flocculants). This effectively aids in the removal of fine particles, oils, and surfactants.
- **Automatic adjustment of the water's pH level** to a range of 6.5–7.0 before coagulation and flocculation, which optimizes the effectiveness of the coagulants and flocculants.
- **Continuous automated turbidity monitoring** of the water after the activated carbon filter using a high-precision turbidimeter. This provides real-time water quality control and automatically signals the need for filter maintenance or adjustment of purification parameters, thereby maintaining high water clarity and overall system performance.

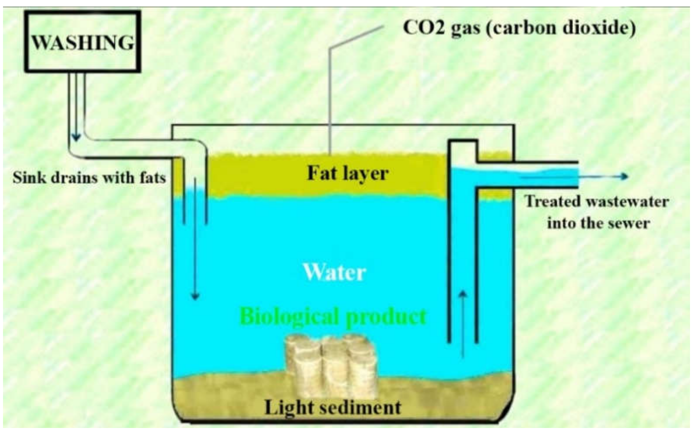


Figure 5. Metatenk

The proposed method ensures the production of high-quality recycled water suitable for use in all washing stages. This significantly reduces the consumption of fresh water and limits the environmental impact caused by toxic wastewater discharge.

The invention is an advanced multi-stage water purification method designed specifically for car wash facilities to ensure effective water recycling. The method is based on the integrated action of physico-chemical and biological processes, with their operation controlled by an automated system.

STAGES OF THE METHOD:

1. **Preliminary Preparation Stage (Coagulation and Flocculation with pH Adjustment):**

- Wastewater generated at the car wash is collected into storage tanks and directed to the preliminary preparation stage.
- Before starting coagulation, the pH of the water is automatically adjusted to the range of 6.5–7.0. This is achieved by dosing sodium hydroxide solution (to increase pH) or sulfuric acid solution (to decrease pH) via automatic dosing pumps controlled by a high-precision digital pH meter (with an adjustment error not exceeding ±0.1 pH). Maintaining the pH within this range creates optimal conditions for chemical reactions and promotes effective binding of microorganisms, oils, and surfactants.
- After pH adjustment, a mineral coagulant based on aluminum oxychloride and an anionic polyacrylamide-based flocculant are added in measured quantities. The dosage of reagents is determined experimentally based on the initial turbidity and chemical composition of the water and can be automatically adjusted depending on variations in the system load. The coagulant destabilizes colloidal particles, while the flocculant aggregates them into larger, settleable flocs. In this stage, 80–90% of suspended particles, as well as a large number of oily substances and surfactants, are removed.

1. Mechanical Sedimentation Stage:

- The water containing formed flocs is sent to a sedimentation unit (a sedimentation system with an oil and gasoline separator can be used). Here, heavy flocs and sand settle by gravity, while lighter organic substances such as oil and gasoline float to the surface. The sludge and petroleum products collected are periodically removed from the system. This stage significantly reduces the load on subsequent filtration stages.

2. Three-Stage Sequential Filtration Stage (after mechanical sedimentation, the water sequentially passes through the following three filters):

- **Sand Filter:**

At the first stage, the water passes through a sand filter with a granule size of 0.8–1.2 mm. This filter is designed to capture suspended particles that have not settled (up to 20–30 microns). Continuous backwashing ensures the filter's operational efficiency and long service life.

- **Activated Carbon Filter:**In the next stage, the water is passed through an activated carbon filter made from coconut shell, with an iodine number of at least 900 mg/g. This activated carbon has high adsorption capacity and effectively removes dissolved organic substances—including surfactants (PAM), phenols, dyes—as well as odors and tastes caused by organic residues. Coconut shell carbon is distinguished by its high hardness and plant-based micro-porous structure, providing durability and high efficiency over long-term use.

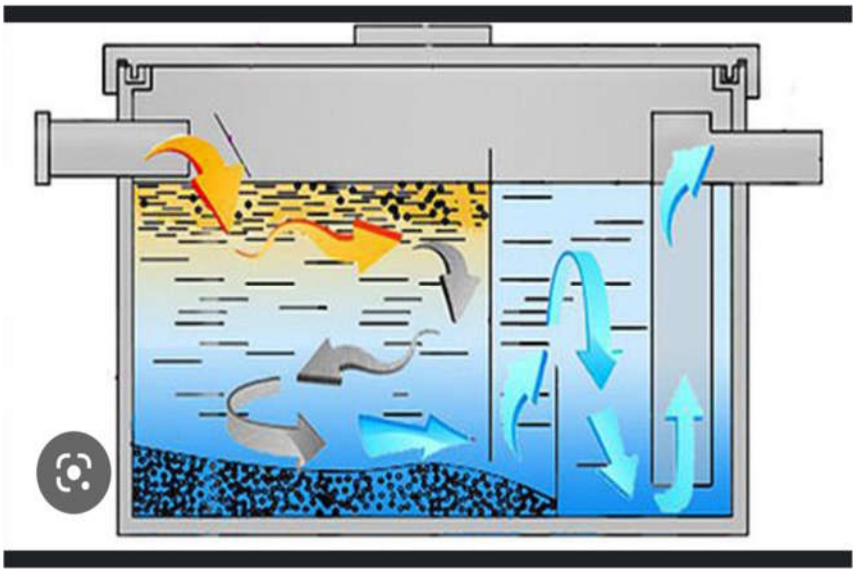


Figure 6. Vertical Settler

- Zeolite Filter:

In the final filtration stage, the water passes through a filter made from natural clinoptilolite zeolite with a particle size of 2–5 mm. Zeolite is a natural sorbent and ion exchanger that effectively removes heavy metal ions (such as lead, copper, zinc), as well as ammonium ions. Additionally, it helps to remove the remaining suspended particles and improves water clarity. The use of zeolite acts as the final "polishing" step for water quality.

1. Disinfection Stage:

- The purified and filtered water is directed to the disinfection stage. The preferred method is ultraviolet (UV) disinfection, as this effectively destroys bacteria, viruses, and other microorganisms without producing harmful byproducts associated with chlorine use. Alternative methods such as ozonation may also be employed. The disinfection process ensures the biological safety of the water.

2. Automated Monitoring and Control Stage:

- A key element of the invention is the automated system for continuous turbidity monitoring of the water filtered after the activated carbon filter. A flow-type turbidimeter with a measurement range of 0–10 NTU and accuracy of ±0.05 NTU is used.
- Data from the instrument is transmitted to the control system. If turbidity exceeds a predefined threshold (e.g., 0.5 NTU), the system automatically issues commands to perform filter maintenance (such as backwashing) or adjusts treatment parameters (such as increasing coagulant/flocculant doses). This proactive quality control prevents the use of inadequately treated water and ensures consistently high clarity and quality of the recycled water. The system can also send alerts to operators or initiate automated service procedures.

2. Results and Discussion

The proposed multi-stage wastewater treatment system for car wash facilities demonstrates several significant advantages over existing technologies:

1. **Superior Purification Efficiency:**

The combined process of automatic pH adjustment, optimized coagulation/flocculation using aluminum oxychloride and polyacrylamide-based flocculants, followed by sequential filtration through sand, activated carbon, and zeolite layers, effectively removes a broad spectrum of contaminants. These include suspended solids, oils, dissolved organic compounds, and heavy metal ions. The synergistic effect of these treatment stages ensures high removal rates, thereby significantly improving the overall water quality.

2. **Enhanced Water Conservation:**

The system enables efficient reuse of treated water with minimal quality degradation, resulting in up to an 80–90% reduction in fresh water consumption. This not only conserves valuable water resources but also reduces operational costs associated with water procurement and discharge fees.

3. **Environmental Impact Reduction:**

By effectively treating wastewater before reuse or discharge, the system substantially lowers the release of hazardous pollutants into the environment. This contributes to reducing soil and water pollution and aligns with sustainable environmental management practices.

4. **Stability and Reliability of Operation:**

   Continuous real-time monitoring of water turbidity through an integrated turbidimeter allows for automated adjustments in coagulant and flocculant dosing, as well as filtration backwashing schedules. This closed-loop control system maintains consistent water quality and prevents system failures due to sudden variations in influent water characteristics.

5. **Prolonged Equipment Longevity:**

   Utilization of clean, treated water in car wash operations minimizes the accumulation of abrasive or corrosive residues on mechanical components, thereby extending the service life of pumps, nozzles, and other equipment.

6. **Operational Efficiency and Automation:**

   The incorporation of automatic pH control and turbidity monitoring enhances process automation, reduces manual intervention, and improves overall system responsiveness and adaptability to fluctuating wastewater loads.

CLAIMS

1. A method for multi-stage water purification used in car washes, comprising mechanical cleaning, filtration, and disinfection steps, characterized in that the filtration steps sequentially use a sand filter, an activated carbon filter, and a zeolite filter.
2. The method according to claim 1, characterized in that prior to the mechanical cleaning step, a coagulation and flocculation step is performed by adding an inorganic coagulant based on aluminum oxychloride and an anionic polyacrylamide flocculant, with the dosage determined based on the initial turbidity of the water, to enhance the sedimentation of finely dispersed contaminants.
3. The method according to claim 2, characterized in that before the coagulation and flocculation step, automatic pH adjustment of the water is performed to a range of 6.5–7.0 using a sodium hydroxide or sulfuric acid solution, with pH controlled by a digital pH meter having a permissible error margin no greater than ±0.1 pH, thereby ensuring optimal conditions for the coagulant and flocculant and improving coagulation efficiency.
4. The method according to claim 1, characterized in that after the activated carbon filtration step, continuous automated monitoring of the purified water's turbidity is conducted using a flow-through turbidimeter with a measurement range of 0–10 NTU and a permissible error margin no greater than ±0.05 NTU; if the turbidity exceeds a set threshold of 0.5 NTU, a signal is generated to indicate the need for filter maintenance and/or cleaning mode adjustment, ensuring stable purified water quality and automatic process

Conclusion

No membranes: The method does not use membrane technologies, which are expensive and require frequent maintenance. Instead, the method uses simpler, more reliable and technically accessible measures. This allows for a significant reduction in capital and operating costs.

Results and success of the method: With the detailed development of all stages from an environmental and technical point of view, as well as the integration of an automated control system, this method offers a highly efficient and cost-effective solution for water purification and reuse. This is a significant improvement compared to current treatment methods.

Claims:

A multi-stage water purification method for reuse in car wash systems, comprising:

- mechanical pre-cleaning;
- sequential filtration through sand, activated carbon, and zeolite filters;
- chemical coagulation and flocculation using an inorganic coagulant and an anionic flocculant;
- automatic pH adjustment to maintain a range of 6.5 to 7.0; and
- continuous turbidity monitoring via a flow-through turbidimeter.
- The method of claim 1, wherein exceeding a preset turbidity threshold triggers an automatic warning for filter maintenance.
- The method of claim 1, wherein the purification system is operated under automated control to maintain consistent water quality and optimize resource usage.

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