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Design Comparison between the Gravity and Pressure Sand Filters for Water Treatment, Review

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ABSTRACT

Hygienic engineering has dedicated a lot of time and energy to studying water filtration because of how important it is to human health. Thorough familiarity with the filtration process is essential for the design engineer to keep up with and profit from advances in filtering technology and equipment as the properties of raw water continue to change. Because it removes sediment, chemicals, odors, and microbes, filtration is an integral part of the water purification process. The most popular technique for treating surface water for municipal water supply is considered fast sand filtration, which can be achieved using either gravity or pressure sand filters. Predicting the performance of units in water treatment plants is a basic principle. For that reason, this research was executed to compare gravity and pressure sand filters in terms of construction, use, efficiency, filtration rate, cost, benefit, and drawbacks to predict the performance of those units under different conditions and from an economic standpoint. It also served as a presentation and review of previous studies dealing with the evaluation and development of pressure and gravity filters. This paper gives a brief overview of filtration theory, the types and properties of filter media, filter backwashing, and operational problems that can be avoided in the filtration process.

Keywords: filtration, gravity filter, pressure filter, surface water, drinking water.

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مقارنة بين تصميم مرشحات الرمل بالجاذبية والضغط لتصفيه المياه ، مراجعه

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الخلاصة

كرست الهندسة الصحية الكثير من الوقت والطاقة لدراسة تنقية المياه نظرًا لأهميتها بالنسبة لصحة الإنسان. يعد الإلمام التام بعملية الترشيح أمرًا ضروريًا لمهندس التصميم لمواكبة التقدم في تكنولوجيا ومعدات الترشيح والاستفادة منها مع استمرار تغير خصائص المياه الخام. نظرًا لأنه يزيل الرواسب والمواد الكيميائية والروائح والميكروبات ، فإن الترشيح جزء لا يتجزأ من عملية تنقية المياه. تعتبر التقنية الأكثر شيوعًا لمعالجة المياه السطحية لإمدادات المياه البلدية هي الترشيح الرملي السريع، والذي يمكن تحقيقه باستخدام إما مرشحات الرمل بالجاذبية أو الضغط. التنبؤ بأداء الوحدات في محطات معالجة المياه هو مبدأ أساسي. لهذا السبب تم إجراء هذا البحث لمقارنة مرشحات الرمل بالجاذبية والضغط من حيث البناء والاستخدام والكفاءة ومعدل الترشيح والتكلفة والفائدة والعيوب للتنبؤ بأداء تلك الوحدات في ظل ظروف مختلفة ومن وجهة نظر اقتصادية. كما كان بمثابة عرض ومراجعة للدراسات السابقة التي تتناول تقييم وتطوير مرشحات الضغط والجاذبية. تقدم هذه الورقة لمحة موجزة عن نظرية الترشيح ، وأنواع وخصائص وسائط المرشح ، والغسيل العكسي للمرشح ، والمشاكل التشغيلية التي يمكن تجنبها في عملية الترشيح.

الكلمات الرئيسية: الترشيح ، مرشح الجاذبية ، مرشح الضغط ، المياه السطحية ، مياه الشرب.

1. INTRODUCTION

The growing population, lack of water sources, and contamination make it harder to get drinkable water. Governments, community organizations, universities, academic research institutes, and other entities support studies, research, and projects to improve water quality and efficiency. Clean, affordable water is a challenge. **(Al Zubaidy et al., 2017)** Most of Baghdad's water treatment facilities are struggling due to low raw water quality and mounting worries about treatment quality and effectiveness **(Al-Nakeeb et al., 2018).** Drinking water treatment is a complex problem that varies by legislation, contaminant removal targets, and prices **(Bennie, et al. 2002).**

In the majority of developing nations, surface water is regarded as an essential supply of water. The major issue is the high concentration of clay and organic compounds, suspended particles, and disease-causing germs such as parasites, viruses, and bacteria, which can cause cramps, nausea, and diarrhea, as well as provide food and habitat for pathogens **(Muchukuri et al., 2014).** The treatment process describes the procedures used to make the water suitable for a certain purpose once it has been treated. This includes applications of potable water, as well as industrial and other settings. A water treatment plant's main goal is to remove or reduce plankton and toxins from the water so that it may be used for its intended purpose **(Firehouse and Lalitha, 2015)**. A large amount of time and effort was invested in developing and upgrading water treatment technologies during the previous studies. Coagulation, flocculation, sedimentation, filtration, and disinfection are all phases in the treatment of water. Filtration is the final step in the water purification process, and it has received a lot of attention since it is the most cost-effective technology due to its ease of use and upkeep (**Sobey et al., 2002).**

Filtration is one of the most common processing methods for removing suspended solids and other particles via physical and electromagnetic paths, as well as disease removal from water. It can remove suspended matter (fine silt and clay) and biological materials (bacteria, algae, fungi, cysts, or other stuff) from the water. Passing the particles through a porous medium trap the scattered particles and removes them from the water. **(Hess et al., 2002).** The most economical technology for treating low-turbid surface water is coagulation-flocculation filtration since it is simple to operate and requires little upkeep. It is a purely physical approach for eliminating relatively large suspended particles from an input suspension, and it has been used to remove tiny particles from drinking water to minimize infections **(Burton, et al., 2003).**

Rapid gravity and rapid pressure sand filters are the two most common types of rapid sand filters (RSF). The quantity of head needed to drive water through the bottom of the media and the kind of vessel used to contain the filter unit are the two main distinctions between gravity and pressure filters. Pumping stations often utilize pressure filters, whereas both small and large plants use gravity filters due to the expensive cost of installing large pressure vessels. Pressure filters are frequently used in small pumping stations **(Qassim et al., 2000**).

The filter's medium is usually a bed of sand, anthracite, or other granular material, either alone or in a double arrangement. Sand media is used as a primary, if not single, component in several filters. Electrostatic interaction occurs when both the particles and the sand material in the group are negatively charged. Bacterium, virus, and mineral colloidal particles are examples of small or micro particle., may be resistant to pH levels and media, to destabilize particles and improve particle removal, coagulants like Fe and Al are frequently utilized. **(Viraraghavan, et al.,1988).**

Several studies have been conducted to improve and develop the performance evaluation of both pressure and gravity filters. To assess the effectiveness of a pressure filter, (**Rutledge et al., 2002)** compared crushed recycled glass to silica sand for dual media filtration. In general, the particle removal capabilities of the crushed-glass filter were slightly poorer than those of the sand filter. The dual-media crushed-glass filter was only marginally better than the dual-media silica sand filter in its ability to remove particles with diameters of >2 m during the six-month research, achieving a 1.4-log removal. (**Han et al., 2008)** investigated the mathematical modeling of particle removal and head loss in quick gravity filtering. A novel filtration model has been designed to completely characterize the operation of the three-stage filtration system (maturation, action, and penetration). This pilot study suggests that this model can accurately estimate particle removal and head loss during rapid gravity filtering. In addition,

Also, artificial neural network modeling was used by **(Tashaouie et al., 2012)** to forecast the efficacy of pressure filters in a water treatment facility. Based on statistical studies of 1,300 samples, the maximum and minimum effluent turbidity from the filter were calculated. Multiple neural network architectures with varying numbers of neurons were

studied to discover the optimal condition. The optimal Artificial Neural Network structure was selected and its indexes were proposed for future research; the multilayer Perceptron structure with the Back Propagation Training Algorithm has been demonstrated to be an effective tool for predicting the output turbidity from pressure filters. Several network architectural elements, such as the momentum coefficient and the training rate, were studied under various scenarios. Optimal conditions were, respectively, 0.5 and 0.2.
Subsequently **(Upton et al., 2017)** researched "Rapid gravity filtration operational performance assessment and diagnosis for preventative maintenance from online data." The operational diagnosis of subpar performance is then presented using this viewpoint on filtering performance as a machine learning classification issue. The Classification and Regression Tree (CART) algorithm is used to calculate operationally important predictor variables. It is demonstrated that the CART algorithm is a good diagnostic method, creating extremely accurate models that characterize circumstances related to greater filtrate turbidity. More than 90% of the time, weekly models for individual filters and monthly models for the entire filter bank accurately characterized increased turbidity situations. These diagnostic models were intuitive to comprehend and translate into operational and preventative maintenance decisions due to their engineering and use of operationally relevant predictor factors.
High filtration performance in terms of removing turbidity and residual particles, little filtration configuration adjustment required, and low head loss development was established by (**Samantaray et al., 2018)** in response to effluent filtered water turbidity and head loss development. The findings reveal that both parties agree on the desired outcome. (**Mesquita et al., 2019)** investigated the filtration efficiency of pressured sand filters. The purpose of this research is to look into how a commercial sand filter filters water at different filtration rates and sand particle sizes. The second goal is to evaluate the effectiveness of sand filters and compare the recommended method to the standard method. Sand filter removal efficiency increases as the filtration rate for used water quality improves and sand particle size decreases. Based on the experimental boundary conditions, it is recommended to employ a fine sand particle size (effective diameter of 0.55 mm) with filtration rates ranging from 60 to 75 $m^3/m^2/h$.
This work aims to assess the filtration process of gravity and pressure sand filters. Also, observations were made by comparing the gravity and pressure sand filters in terms of how they were built, how they were used, how efficient they were, how fast they filtered water, how much they cost, what their benefits were, and what their drawbacks were. This was done to predict how well these units would work under different conditions and from an economic point of view.

2. FILTRATION PROCESS CONCEP

The major filtering approach is impacted by the physical and chemical properties of the water, as well as the particles to be filtered, the filter medium, and the earlier chemical treatment. When the particles in suspension that must be eliminated are smaller than the medium's interstices, the particles will come into contact with the filter media's surface if they had followed the fluid streamline, and the flow would not have been cleansed. When particles approach a filter grain, however, an attachment force is required for the particles to stay on the filter grain or deposit particles as previously. **(Jegatheesan et al., 2005).**

The filtering mechanism requires the movement and attachment of suspended particles. For particle movement, there are three ways that particles might enter the filter medium: Brownian diffusion (molecular effects), interception (contact caused by fluid flow at the surface of porous media), and sedimentation (gravity effects) Electrical and chemical interactions play a prominent role in particle attachment to the media surface, including electrostatic attraction or repulsion within the electrical double layer, as well as van der Waals attractive forces acting at close ranges between particles and surfaces. These are electrical and chemical interactions that are dominant in particle attachment to the media surface. **(Yao et al., 1971; Elimelech, and O'Melia, 1990).** The basic ways that water is moved during filtration are described below and shown in **Fig. 1.**

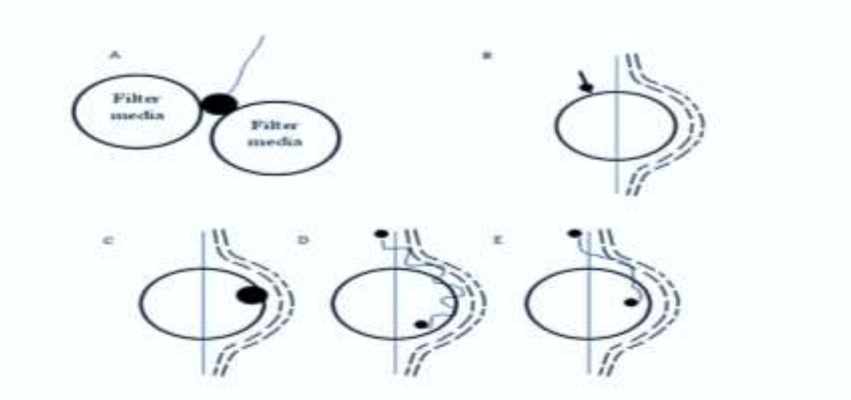

Figure 1. Mechanisms of transport in water filtration **(Yao, 1971)**

A. **Straining**: It is undesirable because the collected particles clog up the upper part of the bed, making it hard to use the filter **(Ives, 1970)**
B. **The mechanism of sedimentation** is caused by the force of gravity and the associated settling velocity of the **particle**, which causes the particle to cross the streamlines and reach the collector. This is preferred when the density of the suspended substance exceeds that of water. The collecting efficiency of this mechanism will be enhanced by the presence of larger particles and slower filtration speeds **(O'Melia, 1985).**
C. **Interception:** It is usual for big particles to be intercepted. Similar to straining, the mechanism is dependent on the particle diameter to media diameter ratio. If a particle of sufficient size follows the streamline, which lies very close to the surface of the media, it will collide with the media grain and be caught. Its efficiency increases as particle size and collector size decrease **(Stevenson, 1997).**
D. **Diffusion:** is effective for particles with a size of less than 1 micron, such as viruses. The thermal energy of the fluid is transferred to the particles, causing them to drift away from the streamlines and move at random within the fluid. The smaller the particle size, the greater the significance of diffusion **(O'Melia, 1985).**
E. **Inertia:** Inertia occurs when larger particles move quickly enough to leave their streamlines and collide with medium-sized grains, inertia arises. Particles with sufficient inertia could continue unaffected and influence the grains. Due to tiny mass and density differences, the impact of particles on water grains during filtration is insignificant **(Ives, 1970). Furthermore**, physicists have shown that every particle in a pore is subject to hydrodynamic action, caused by the velocity gradients within pores.

As it experiences higher velocities on one side, the particle tends to rotate and create an additional spherical field, which causes the particle to move across the flow field **(Ison, 1969).**

3. THE FILTRATION PROCESS'S OPERATIONAL PROBLEMS

Here are some of the most frequent issues that can develop throughout the filtration process: According to **(Punmia et al., 1995)**, the accumulation of particles on a filter's upper surface causes fissures and blockages. When lime is used for water treatment, sand incrustation can result from the crystallization of calcium carbonate or the deposition of sticky gelatinous components from the influent water. When dissolved gases and air escape from the water, air-binding occurs, resulting in the formation of bubbles. Sand boils and jets can occur during backwashing due to minute changes in the porosity and permeability of sand and gravel.

4. FILTER MEDIA.

4.1 The Filter Media Characteristics

The materials used in filtration must be characterized by the following: good hydraulic properties (permeability), do not interact with the materials in the water (inert and easy to Types of clean), solid, double, free of impurities, do not dissolve with water. (**Bourke, et al., 1995)**

4.2 Type of Filter Media

The most commonly used filtration materials are sand: It is a cheap medium for the filtration and is widely used It uses quartz sand and quartzite, a natural material that comes in sizes It has different colors and properties and is used as a filter medium effectively in removing pollutants, activated carbon: consists of a carbon coefficient with a positive charge, to make it more attractive to the ions in the water passing through it, Ceramic: is a natural substance consisting of a mixture of calcium carbonate and silica manganese, and has been used significantly in the treatment of drinking and Garnet: It is an expensive media for filtration **(Sasongko, et al., 2021)**

5. FILTER BACKWASHING

Backwashing is essential to the longevity of a filter and the quality of the water it produces, as it eliminates any foreign material that has accumulated in the filter bed after an operation. In filters with insufficient backwash, mud balls tend to accumulate because the filter bed is not consistently fluidized throughout. As long as the floc deposit stays after backwashing, the backwash becomes less effective, which makes it harder to keep the filter bed clean and reduces the filter's efficiency **(Brouckaert et al., 2006).**

Backwashing has at least three goals: bed expansion, grain rubbing, and dirt flushing; as the filter should be backwashed when it has been too long since the last backwashing, the head loss is excessive, and effluent productivity is increasing. **(Viraraghavan et al., 1988)**. It is accomplished by progressively carrying water from the bottom to the top of the filter until the channels are reached. This results in the expansion of sand and gravel (**Garcia-Avila et al., 2020).** The filtration efficiency of pressurized sand filters was dependent on several variables, including the efficiency of the backwash technique **(Brouckaert et al., 2006).** Backwashing is an important part of running these devices because dirty filter beds cause pressure loss to go up and the efficiency of removing suspended particles to go down. **(Elbana et al., 2012).**

To backwash, water that has already been filtered must be pumped through the filters in the filtration set in the opposite direction of the filtration process (often upward) at a high enough velocity to adequately expand and disturb the filter bed **(Turan et al., 2003)** found that the amount of surface velocity needed for filter bed expansion during backwash varies a lot between the different sand filter drain designs, the desired level of expansion, and the size of the filter media.

Fluidization increases the length of a filter bed by 10 to 50 percent, and backwashing consumes between 2% and 3% of a plant's total flow and between 1% and 5% of daily productivity. **(Deus, 2016).** According to **(Ratnayaka et al., 2009),** the total backwash water usage is equivalent to approximately 2.5-bed volumes when air scouring is used. They also say that the amount of water used in the backwash is a key factor in how much the treatment facility costs.

Water-only, water-and-air, and air scour are three of the most frequent types of backwashing techniques. Air is incorporated into the backwash to agitate the filter material and rinse away the surface dirt. According to researchers **(Cleasby et al., 1977)**, the best way to clean out quick gravity filters is with a mixture of air and water. **(Ratnayaka et al., 2009)** say that uniformity in deep filter beds can be maintained with a simultaneous air scour and water wash, followed by a water rinse. This way, hydraulic grading is not needed.

The period of the wash is determined by the washing method and the effectiveness of the filter. When air and water are used concurrently in a design, the air is introduced first, then the water is added after about 1.5–2 minutes to allow the airflow to establish itself, and the combined wash lasts about 6–8 minutes. The water flow then resumes while the airflow is turned off, rinsing the bed for an additional 8 to 10 minutes. Depending on the head loss, a filter is taken offline for washing for a total of around 30 to 45 minutes, including 15 to 30 minutes for emptying the filter down **(Ratnayaka et al., 2009).**

6. RAPID SAND FILTERS

Rapid sand filtering was developed in the United States in the 1880s and has since acquired widespread adoption for water treatment applications because of its smaller footprint, higher production capacity, and capacity to filter water with varying turbidity. Rapid sand filters are extensively used today since their flow rate is significantly more than that of the Slow Sand Filter S.S.F., which achieves 120–200 m^3/m^2/day and hence saves space and time for a nominee with the help of rapid sand filters, turbidity can be reduced by at least 90 percent, making it more manageable for further treatment, In this filter, sedimentation happens across the sand layer not only to remove particles in suspension but also to eliminate bacteria during the treatment of drinking water (**Letterman, 1999).**

6.1 Rapid Gravity Filters.

Rapid gravity sand filtration is a technology that is widely used for the production of drinking water all over the world. This technology provides a high rate of filtration, and it is used as a technology for removing turbidity and microbial contaminants from pre-treated surface water and groundwater. In most large municipal water supply systems, these filters serve as the final barrier to particulates. **(Razak, et al. 2015).** Rapid gravity sand filters are typically used to trap as much particulate matter as possible in the filter as quickly as possible, which necessitates the employment of chemicals to first coagulate and then flocculate the particles in the water **(Ratnayake, 2009).**

Gravity sand filters are usually impermeable open rectangular structures, typically constructed with reinforced concrete and filled from the top with sand and gravel typically, the chamber's height ranges from 1.5 to 2 meters. The water is directed to the top of the sand bed, where it is permitted to filter as it goes through the gradated sand and gravel layers. The area is drained using a network of perforated-bottom pipes at the bottom of the gravel layer that connects water to the outlet details. The sand layer of thickness of 30–75 cm has an average diameter of 0.85–1.4 mm and is frequently carried on a layer of gravel and similar material of a thickness of 15–45 cm. It is also worth noting that some of the modern filters have a false bottom made up of porous concrete slabs and perforated slabs, which remove suspended solid particles by passing water through the filter medium **(Spellman, 2013)**

Rapid filtration by gravity often achieves removal efficiencies of more than 90%, and under optimum leaching conditions, these efficiencies can go as high as 99.5%. However, when inadequate pre-treatment is used, these efficiencies fall below 50%. The quality of the raw water to be treated, the effectiveness of the primary treatment filtration, the design of the filter unit, and the type and depth of the filter media all have a significant role in the effectiveness of removing suspended particulates **(Bourke et al.,1995).**

The primary disadvantage of rapid gravity sand filtration is that it reduces the filter's working time as a result of the filter holes becoming clogged quickly, especially when the turbidity of the water is high due to the removal of the majority of particles at the top of the sand layer and stratification in the sand layer, which causes minute sand particles to collect on the top face of the sand layer, thereby shrinking its pores. Consequently, filter head loss increases rapidly, necessitating additional backwash cycles **(Sutherland& Chase, 2011).**

The hydraulic degradation and subsequent impacts in quick gravity sand filters can be mitigated by using separate layers of various filter materials with varying densities and grain sizes, with the material with the highest density located at the bottom of the bed and the material with the lowest density located at the top of the bed. When water is added to the filter from the top, gravity forces the water to move downward through the filter, eliminating any impurities that may have been present **(Binnie, 2002).**

Fig. 2 depicts the following components of a fast sand filter **(Roos, 2019).** The filter shell is the first part of a filtration system. It is usually made of concrete or steel and can be square or round. Second, to keep the sand layer in place while the filter is being cleaned, a gravel support bed is often used. This bed is usually 1 to 2 feet deep. The third type of drainage system consists of a main tube and branch tubes with perforations. This system, which is buried under the gravel, gets water regularly and sends it to the main pipe, where it is filtered and put into a tank. Effluent from washing machines: Channels installed on top of the filter filling collect backwash water and direct it to the washing water basins, where it can be reused in the washing process. Filter Control Filters, washing water controls, pressure controls, and automatic sampling systems that take samples regularly are examples of filter controls.

6.2 Rapid Pressure filter

A pressure filter is a cost-effective approach to filtering untreated water. It consists of a rigid filter vessel, pipelines to distribute and collect water, and filter material, generally silica sand. Sand is inexpensive, resilient, and versatile. Anthracite coal is more expensive, but its jagged grains retain tiny particles or other granular materials. The media bed, the filter's densest layer, filters fluids. The media bed will have a base. These are usually larger pebbles chosen to support the filter bed while enabling robust flow through the support layer. The outflow header can take several forms, but it usually consists of a huge main pipe with multiple laterals. Lateral perforations enable pressurized water to flow through laterals and out the outflow header, where downstream components can use it. Below in **Fig. 3** is an illustration of a typical pressure filter (**Bové et al., 2018).**

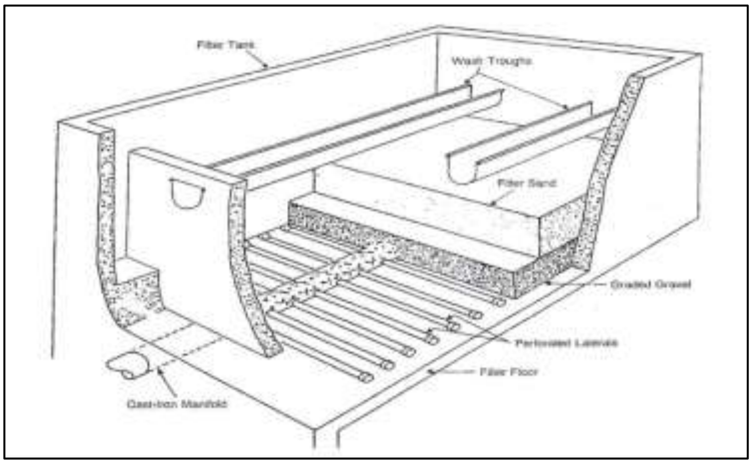

Figure 2. Rapid gravity filter **(Roos, 2019)**

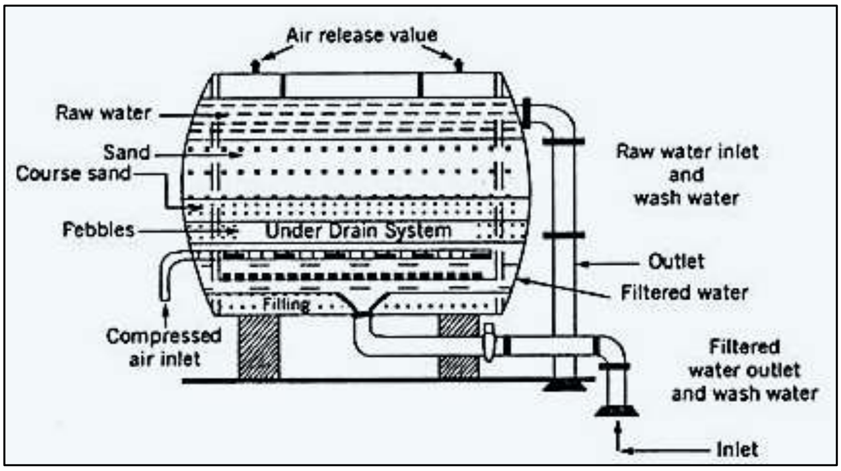

Figure 3. Rapid pressure filter (**Bové et al., 2018).**

A pressure filter is similar to a fast gravity filter except that the filter bed and filter bottom are kept inside a watertight steel pressure tank. Under pressure treated water is moved. Since water is forced through filters at a higher pressure than air, the water must be kept in airtight cylinders that can hold internal pressure. Usually, when raw water is pumped into vessels, the pressure ranges from 30 to 70 m head of water (300 to 700 kN/m^2). The majority of pressure filters operate at a rate of approximately 3 gallons per minute per square foot **(Mesquita et al., 2012)**

The pressure filter is a vertical steel cylinder with a radius of 1 to 10 feet, a production capacity of 300 gallons per minute (GPM), If positioned horizontally, the filter has a length of 10 to 25 feet, a diameter of 8 feet, and a production capacity of 200 to 600 gallons. The performance of pressurized sand filters is affected by layer thickness, sand particle size, filtration rate, and equipment architecture. Internal drains and filter diffuser plates are fundamental components of the design, enabling precise management of water distribution across the sand bed **(Mesquita et al., 2017).**

Pressure filters have numerous advantages, including fast filtering; little land requirement, low cost, and high efficiency in removing turbidity with no restrictions on initial turbidity levels (if a suitable coagulant or flocculant is on hand and used properly). Backwashing takes only a few minutes, after which filters can be put back into use. In their construction, vertical or horizontal metal cylinders are employed based on the amount of available space. Pressure filters are uncommon in large treatment facilities because of their size. Frequently, they are utilized by smaller municipal water treatment facilities **(Tashaouie et al., 2012).**

Because the water is still under pressure, air binding won't happen in the filter, which is a benefit. Particles of iron and manganese can easily slip through the filter bed pores of pressure filters and enter the backwash. When using pressure filters to remove iron and manganese, the operator must constantly check the levels of iron and manganese in the filter effluent and backwash the filter before the breakthrough that occurs when the filter bed easily cracks, allowing iron and manganese particles to pass through the filter without being filtered. **(Punmia et al., 1995).**

High-pressure filters require minimal maintenance. Particularly when utilized with other automated controllers, actuated valves, and pump controls throughout their service lives, water cleansed by a modern pressure filter can be utilized directly or sent on for further processing. Pressure filters are commonly utilized in municipal water treatment facilities, industrial settings, well-water residences, and swimming pools. Due to their ability to keep particles as large as 20 millimeters in the sand bed, pressured sand filters are frequently used in irrigation systems due to their high retention efficiency **(Mesquita, et al., 2017)**.

Pressure filters have disadvantages such as the operator being unable to observe the backwash, the need for frequent cleaning (backwashing) (every 24–72 h), a high input of energy, and the need for skilled supervision (to regulate the flow rate and the concentration of disinfectant). It is possible to force the filtered material through the filter unless the machine has an automatic shutdown feature in case of high-flow turbidity **(Spellman, 2013)**.

7. CONCLUSIONS

This study compared gravity and pressure sand filters in terms of construction, use, efficiency, filtering rate, cost, benefit, and disadvantages also this essay provides a concise review of filtration theory, filter media types and qualities, filter backwashing, and filtration process operational issues. This review's key conclusions are:

- Filtration is the most important part of a water treatment facility due to it removes contaminants. Fast sand filtration is the most extensively used way of treating surface water due to its small footprint, high production capacity, and ability to filter the water of varied turbidities.
- Gravity filters need big, open basins, but pressure filters use steel tanks that are closed and don't need big spaces.
- Gravity filters are used in both small and large plants because large pressure vessels are expensive. Pressure filters, on the other hand, are used in small pumping stations like municipal water treatment plants, factories, homes with well water, irrigation systems, and swimming pool water filtration systems.
- Gravity filters are better at getting rid of contaminants than pressure filters, but the filtering rate is less, and, unlike pressure filters, they need pressure to pump water to the main network.
- Pressure filters are superior to gravity filters because they utilize greater pressure to force water through the filter, allowing for longer-running water flow.
- The operator is responsible for ensuring the efficient operation of the backwash cycle and the visual inspection of the filter media before and after backwashing is important due to the appearance of mud balls, and cracks, which are indicators of insufficient backwash since breakthroughs can be caused by insufficient flocculation, filter clogging, mud ball development, and filter cracking.
- Regular testing for turbidity in filtered water is a good indicator of filter efficiency.

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