INVESTIGATION OF A NEW WATER TREATMENT METHOD: BY FABRIC CAPILLARY ACTION

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ABSTRACT

A new water treatment method has been investigated which was accomplished by transmitting the water from a channel to another through technical fabrics by the capillary action, leaving the suspended solids as well as other pollutants at the inlet channel while the rest of the pollutants retained across the fabrics. This work has been conducted on both laboratory and pilot scale employing the fabric capillary action. During the testing period, the influent turbidity was up to 21 NTU while the effluent turbidity was less than 0.90 NTU. Moreover, it was found that the new method is capable of removing algae and bacteria with removal efficiencies up to 98 and 97% respectively. A new nonwoven multilayer polyester fabric was found to be the most suitable for such treatment. The design flow rate was reached to 0.60 $L.min^{-1}.m^{-1}$ of weir (fabric) length. The study revealed that the fabric capillary action can be considered a promising method for water treatment.

Key words: Water Treatment; Nonwoven Fabrics; Capillary Action.

1. INTRODUCTION

In developing countries like Egypt, the use of unconventional system faces obstacles that include insufficient public acceptance, technical risks and further uncertainties caused by the lack of awareness (Wintgens et *al*. 2005). Extending the safe water supply to small communities and rural areas in developing countries may be a big challenge.

The common surface water treatment systems in Egypt are based on coagulation, sedimentation and rapid filtration such as the compact units or the conventional plants. These methods may be not suitable for the rural areas in Egypt due to the absence of the skilful labours and the shortage of capital, operational, and maintenance costs. The presented work shows a new water treatment technique can be added to the water treatment portfolio which is rely on the fabric capillary action.

Over the past years fabrics have been used in the water treatment by different means such as membranes or filter bags. The distinctive porous structure of nonwovens geo textiles makes them ideal medium for liquid filtration applications in comparison with their counterpart because of the low cost of production and product can be manufactured in a very short time (El-Hadidy et *al*., 1986).

Capillary action means that the liquid moves through the porous spaces in a solid, due to the forces of adhesion, cohesion, and surface tension (Hartland, 2004). Water purification is accomplished by transmitting the water from a compartment or a channel to another through technical fabrics by the capillary action, leaving the suspended solids as well as other pollutants at the inlet channel.

The objective of this work is to explore the fabric capillary action as a new water treatment technique by identifying the process design and operational factors including the suitable type of fabrics, the process mechanism, the design flow rate, the removal efficiencies, the run length and the appropriate method of cleaning the fabric. However, much more work needs to be done to establish adequate design criteria.

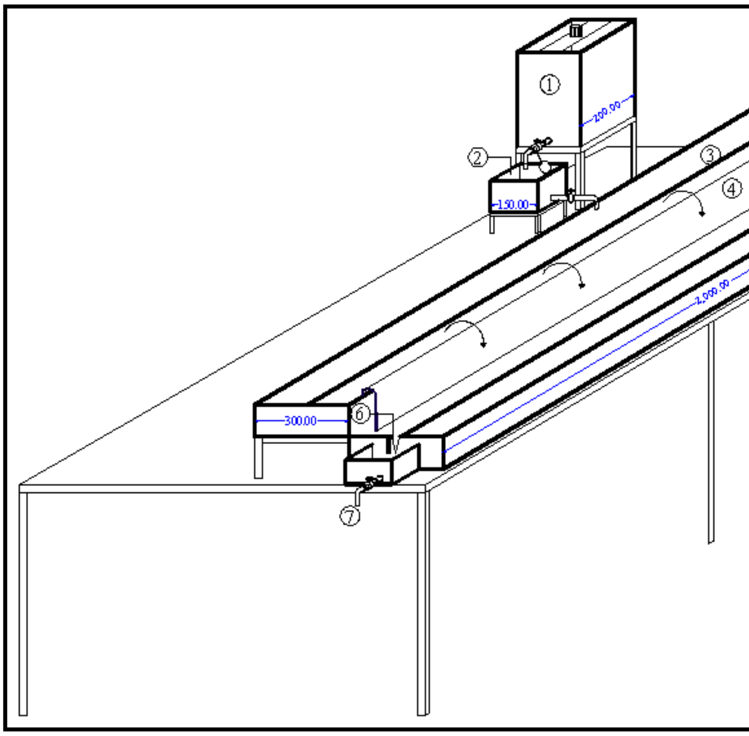
2. MATERIAL AND METHODS

The present research can be considered as a new technique for water treatment. Therefore, the literature review is limited or not available. From this point of view, the research was conducted on both laboratory and pilot scale. The results obtained from the laboratory scale plant are emphasized and utilized in the experimental work which is conducted on the pilot plant.

2.1 Laboratory scale plant

The laboratory experiments were conducted using synthetic turbid water, prepared by adding laboratory grade kaolin to tap water according to Standard Methods (APHA-AWWA-WEF, 1998). The influent turbidity was 7, 14 and 21 NTU.

The laboratory scale plant comprises: raw water tank with agitator, feeding pump, constant head tank with a stirrir to prevent settling, turbid water channel, multilayer nonwoven technical fabric, treated water channel and treated water tank. Figure 1 illustrates the laboratory scale plant.



No.	Description
1	Constant head tank
2	Inlet
3	Turbid water channel
4	Non-woven fabrics
5	Treated water channel
6	V-notch weir
7	Treated water tape

Figure 1 The laboratory scale plant.

2.1.1 Selection of fabrics

Different types of woven and nonwovens fabrics have been tested during the laboratory testing period. A factorial experimental analysis was employed to predict the best selection of tested nonwovens. Nine different structures of these fabrics were produced by varying the needling process parameters, i.e. fabric punching density, and needle penetration.

Nonwoven polyester fabrics were tested in two conditions: “New” (as received from the manufacturer, i.e. without finishing), and “Finished” (new and heat-treated). The physical properties of the tested nonwovens were: the water/fabric surface tension difference, the fabric packing density and the fabric porosity.

During the experimental work observations were taken including consequences of the: influent characteristics on the used fabrics, run length, flow rate, fabrics degradation, the removal capacity and the effect of the washing cycles on the fabrics performance and characteristics.

The structural characteristics of the used fabrics were enhanced by adding a layer of calendered nonwoven (base) as reinforcement to the high loft nonwoven (batt), in order to increase the fabric durability. Figure 2 illustrates the schematic of multilayer technical fabrics tested and Photo 1 shows the plan of the pilot plant with the used fabrics.

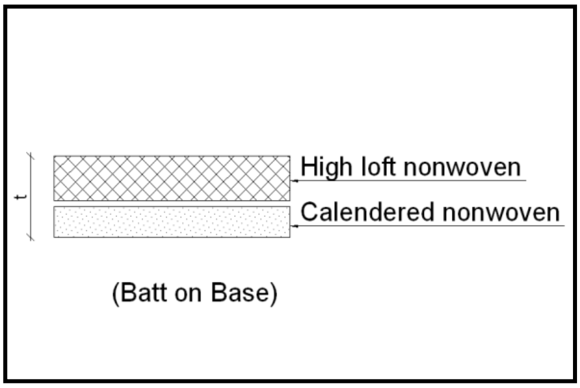


Figure 2 schematic of multilayer technical fabrics.

Photo 1 The tested nonwoven fabrics.

2.2 Pilot scale plant

The pilot scale plant was constructed on the premises of an existing natural source of surface water. The source of water was specified after a complete analysis was performed. The pilot plant consisted of a rectangular tank similar to the sedimentation tank configuration with some modifications. The flow direction is up-flow and the outlet weirs were arranged in a uniform shape at the top of the tank. The nonwoven fabrics were placed among the crests of the outlet weirs in order to transmit the settled water into the outlet channels.

The dimensions of the constructed tank are 1.5×1.5×2.50 m as illustrated in Figure 3. The tank comprises seven outlet channels contain fourteen weirs with 1.25 m of length for each weir. Photo 2 and 3 shows the constructed pilot plant.

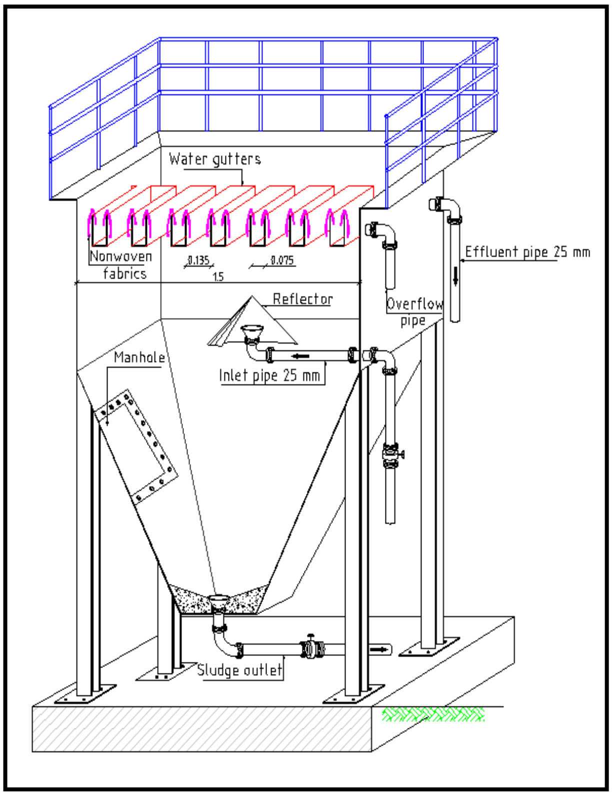


Figure 3 The constructed pilot plant.

Photo 2 The pilot plant.

Photo 3 Plan of the pilot plant.

2.2.1 Water sampling

Composite samples were daily collected from raw, clarified and treated water without chlorination. The following key water quality parameters were measured: Turbidity (NTU), Algae (Count/100 ml) and Bacterial (Count/ml). Turbidity was measured in situ by using Hi 83200 Multi parameter Ion specific meter. Algal and Bacterial counts were measured in the laboratory.

3. RESULTS AND DISCUSSION

3.1 Results from the laboratory-scale plant

The main Objective from the laboratory-scale plant was to examine the fabric capillary action as a new water treatment method. In general, under different types of fabrics and influent turbidities, the new method appears to be significant in removing suspended solids and turbidity from water with a significant amount of transmitted water. Based on this result, it was important to determine the appropriate design and operational factors.

3.1.1 Selected type of fabric

One troubleshooting has been arisen during the laboratory tests of the new nonwoven fabrics, this problem was the skipping of some free fibers or fine protruded fibers from the fabric surface which were detected by visual observation and microscopic analysis. The presence of these fine fibers in the effluent increases the effluent turbidity. Therefore, the used fabrics were bonded to needle punched geotextile (high loft-soft thickness, calendered) by the calendering process. The calendered surface is acting as a reinforcement to prevent the skipping of fibers or fine hairs from the used fabrics into the effluent. It was found that the most suitable type of the experimented fabrics is the new nonwoven polyester fabrics (100 % Polyester) with the following characteristics; 1.65 mm thickness, 480 gm.m^{-2} and consists of two layers (as shown in Figure 2).

3.1.3 Turbidity removal

As a preliminary study, turbidity was investigated as a key and surrogate parameter for the water quality. The laboratory plant was tested under different concentrations of influent turbidity. The average effluent turbidity in the treated water ranged from 0.35 to 0.95 NTU below the standard limits (1 NTU). During the laboratory experimental work, an investigation has been conducted to examine the performance of the successful fabric (Fabric I) at the high influent turbidity using synthetic turbid water. An influent turbidity of 320 NTU has introduced to the fabric; the effluent turbidity was measured and found to be less than 5 NTU. Also, it is relevant to mention that the discharge transmitted by the fabric has been decreased to less than 40 % compared to the previous conditions of the influent turbidity. Photo 4 shows the laboratory test at the high influent turbidity.

Photo 4 Laboratory test at high influent turbidity.

3.2 Results from the pilot-scale plant

Based on the results obtained from the laboratory tests, a conceptual design for the pilot-scale plant was implemented. The plant was designed to carry over an average flow of 8.50 $m^3.d^{-1}$ (i.e. surface loading rate is 4.25 $m^3.m^{-2}.d^{-1}$ which equivalent to the filtration rate of a slow sand filter).

3.2.1 Removal efficiencies

Turbidity removal: The plant was operated for 5 months. In the first two runs (no. 1 and 2), the raw water turbidity was 20 NTU, the clarified water turbidity was 8 NTU and the treated water turbidity was 0.90 NTU on average. Before the beginning of the third run, a routine inspection has been done for the water canal (source of raw water) by removing plants, silt and debris from the canal banks. As a result, the raw water turbidity has been decreased to 7.50 NTU. The clarified water turbidity was reduced to 4.00 NTU and the treated water turbidity was 0.70 NTU on average. Figure 4 illustrates the turbidity changes through the treatment processes for six different runs.

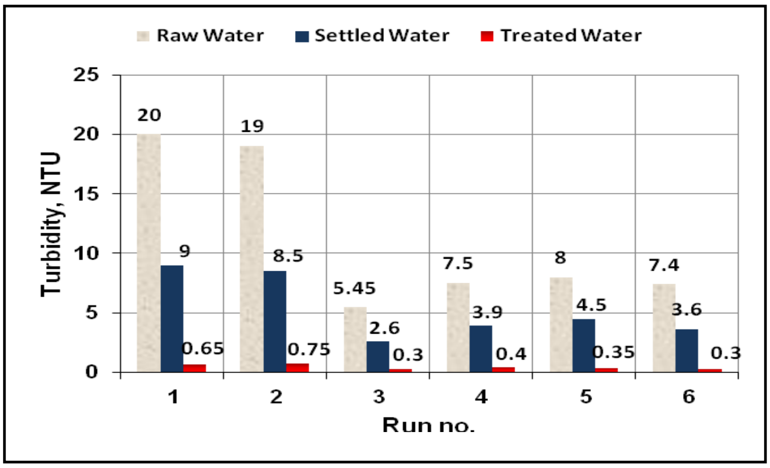


Figure 4 The turbidity changes through the treatment processes.

Algae removal: Results obtained from the analysis of well representative samples showed that the algal removal efficiencies were ranging from 92 to 98%. The algal count in the raw water was ranging from 5.3×10^4 to 7.7×10^4 count/ml. while the algal count in the treated water was ranging from 0.12×10^4 to 0.6×10^4 count/ml.

Removal of bacteria: A great reduction has been achieved in the bacterial count by fabrics without chlorination. The removal efficiencies of the bacterial species were ranging from 93 to 97 % through the fabrics. The bacterial count in the raw water was ranging from 7.40×10^3 to 9.4×10^3 count/100 ml. After the sedimentation step a slight reduction was observed while the bacterial count in the treated water was ranging from 0.25×10^3 to 0.52×10^3 count/100 ml.

3.2.3 Run length

The average run length was 4 days at the high influent turbidity (run no. 1 and 2) and up to 12 days at low influent turbidity (from run no.3 to run no. 6). At the low influent turbidity, the measured discharge at the beginning was 9.50 $m^3.d^{-1}$. After that, it was observed that the discharge of the pilot plant decreases among the run length combined with the increasing of the removal efficiency. The run was terminated when the effluent discharge decreases to below 8.00 $m^3.d^{-1}$ in order to maintain the average flow rate about 8.50 $m^3.d^{-1}$. Then, the fabric was cleaned by using water jet and chlorinated water.

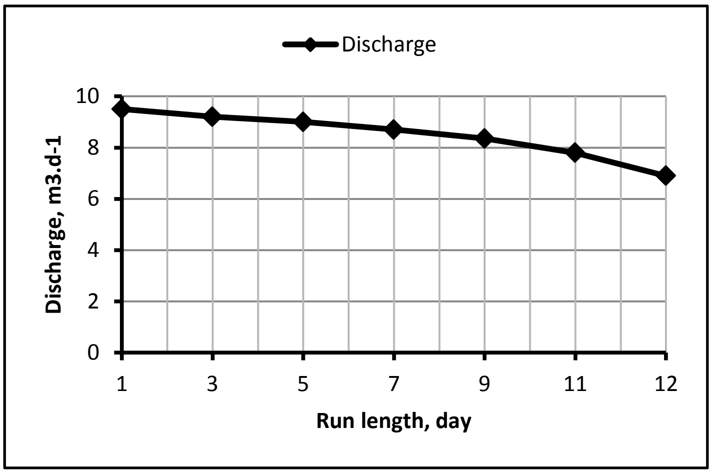


Figure 4 Plant discharge along complete run.

4. CONCLUSIONS

The following conclusions can be drawn based on the investigations of the laboratory and pilot-scale plants:

- The turbidity removal efficiencies obtained by this system, which functions under natural conditions and without using any chemical agents, were high, between 85 and 95 %.
- The average design flow rate for the new nonwoven multilayer polyester fabrics is 10.75 $L.h^{-1}.m^{-1}$ of weir length (fabric length).
- The suitable type of the experimented fabrics is the new nonwoven polyester fabrics (100 % Polyester) with the following characteristics; 1.65 mm thickness, 480 $gm.m^{-2}$ densities. Which was calendered to needle punched geotextile.
- The prior sedimentation is recommended to increase the run length of the fabrics.
- This system combines simple, low-cost operation and maintenance with high removal efficiencies which is suited to small waterworks. However, more work needs to be done to identify complete design criteria, optimum method for the cleaning of fabrics and its life time.

5. REFERENCES

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