Experimental Analysis Of Ground Water For Its Recycling In Water Jet Weaving

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Abstract: The rapid increase in synthetic fabric production promotes the development of water jet looms and water jet weaving technology. Water jet looms are particularly characterized by their high insertion speeds and low energy consumption. However, the main drawbacks of these machines are their excessive water consumption that leads to water wastage. Even though water is a finite, valuable resource and should be used in an effective manner, very little research has been focused on the recirculation of used water and the usage of ground water in water jet weaving. Therefore, the author attempts to design a filtering system that can recirculate the water used in water jet weaving. The water quality of ground water has also been analyzed for its suitability in the weaving process. In order to have a uniform weft that minimizes greigefabric defects and mitigates machine damages, an experimental analysis was executed. The acquired data shows the parameters of ground water that should be controlled during recirculation. Finally, an objective assessment of test results was used to develop a suitable, simple, and cost effective filtering system. The system can be utilized to recycle ground water and to minimize both water wastage and consumption in water jet weaving.

Keywords: Water jet weaving, water consumption, ground water, recycling, filtering system

1. INTRODUCTION

Water jet looms are similar to air-jet looms, but they differ in construction, operating conditions, and performance. During fabric formation, a water jet is capable of maintaining its initial spurt across the width of the warp shed which attributes to its greater distance of force comparative to an air-jet. The flow and configuration of the jet in the vicinity of the nozzle exit of weft yarn insertion in a water-jet loom have been theoretically analyzed[2]. Water jet looms are less noisy and energy efficient as well. In the event that the collimated water beam breaks up, it simply goes into droplets; this action creates little turbulence and does not disturb the weft. The experimental observations reported by Dawson et al[1],[3] relate water jet speed and weft velocity while qualitatively discussing the advantages of the basic insertion system. However, the high water consumption has impeded the further development of water jet weaving. The textile manufacturing industry is facing an era in which the quality, cost, and efficient use of resources are of paramount importance. They are the most basic factors to a successful business as well as having a better quality product at a lower cost. However, maintaining quality standards at a lower price is a challenge. The research done by D.Mattioli et al[5]. shows the key factors that affect the cost of a woven fabric. An energy analysis of a weaving mill has also been compared to the data published in the literature[4]. Effluent water is usually treated in a waste water treatment plant after being used in manufacturing. Though this is a common practice in the textile industry, it can be avoided in water jet weaving. This water is neither highly polluted nor contaminated by any organic matters since only synthetic yarns are used in water jet weaving. The fact that this fairly unpolluted water is receiving the same treatment as the effluent water from other textile processes is costly and unnecessary. The quality of the water used in water-jet must be free of impurities (hardiness, color, iron, and various mineral matters) for poor water quality can partially clog nozzles and lead to short picks. Additionally, the weft insertion device and steel parts could be subjected to scaling and rusting resulting in the discoloration of greige fabric. Therefore, a waste water recirculation system with a suitable filtering system is vital for the further development of water-jet weaving. An overview of demanded water quality and the direct impact of waste water on textile production are reported in the literature[7]. While the most critical parameters in production are hardness, pH, and the metal content of the water, some processes can be done with low quality water with some additional sand or gravel filter treatment. Many research papers have been devoted to the recirculation of waste water, yet only few were focused on the use of recirculated water on jet looms. Khanittha Charoenlarp[8] compares different waste water treatment methods that include chemical coagulation and electro coagulation which are suitable for a centralized water treatment that has the ability to treat water with a high degree of contamination. Various tools and technologies that can recover and reuse waste water in the textile and other industries have also been reported[6]. However, the authors failed to discuss a method of using recycled water in water jet weaving. Any industry that consumes a large amount of water should understand that it is a valuable economic resource. A comprehensive understanding of this concept will further ensure the effective and efficient use of water in an equitable manner. It will hold with the social-economic, and environmental needs of the present and future generation. The required quality of water for jet weaving can be obtained through pipe born water, surface water, and ground water. However, not all of these options are logical to use in water jet weaving. The use of pipe born water, which is suitable for human use and has a far superior quality than needed for weaving, would increase the production cost. There is also

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a worldwide scarcity of drinking water, so it is not ethical to use such water for industrial purposes. Surface water contains various chemicals, impurities, and other harmful substances such as organic and microbiological compounds according to the project carried out[10]. Another major issue with surface water is the variation of its quality in different conditions relative to the time and environment. Because of these variations, the treatment of this water would need a high capital investment and a large space. Furthermore, using surface water requires the water jet weaving plant to be in close proximity to an abundance of surface water. Such a remote location would increase the transportation cost of both the raw materials and finished products. Compared to surface water, ground water quality is quite uniform in a given area. Hence, for a particular region, the ground water can be processed at a competitive cost throughout the year. Ground water is available in any part of the country and can therefore be used as the main source of water for water jet weaving. The water quality analysis of a certain region is given in Table.1 demonstrating various parameters that need to be taken into account for water jet weaving [6].

Table 1. Different Water Quality Levels

Particulars	Municipal Water	Soft Water	Demineralized Water
Turbidity, ppm	4.0	Less than 1	Less than 1
pH	7.8	8.0	6.7 to 7.0±0.2
Total Hardness ppm	44.0	4.0	Below 0.01
Cations	64.0	64.0	Below 0.03
Anions	64.0	64.0	Below 0.03
Residual (evaporated)	80.0	80.0	Below 0.1
Conductivity (Micro Siemen /cm)	80-110	80-100	0

Turbid Water– Contains organic (Plants etc.) and inorganic (salts, rocks) compounds- causes problems of scaling, rusting, damaging the pump cylinder, and nozzle clogging. The pH-a function of hydrogen ion concentration- causes corrosion and rusting of weft insertion devices when it is not neutral (pH=7). Heavily acidic (pH<4) or strong alkaline (pH>9) water can severely attack the machine parts in a very short period of time. Water hardness-a function of dissolved calcium and magnesium salts- causes machine part scaling and nozzle clogging. Hard water can even shorten the life of fabrics and the end products (clothes). Cations–It contains iron and magnesium compounds which cause scaling. Anions–free chlorine causes problems of corrosion. Ground water contains iron in both ferrous and ferric form. If iron-contaminated water is used for industrial purposes, it could damage various machine parts and negatively impact technological processes. Ferrous irons, called clear water irons, oxidize to ferric when exposed to air and ferric irons give the ground water a reddish-brown color. In order to reduce the production cost on the water jet loom and to have a better water resource management, the average water consumption of the loom should be reduced. The best way to achieve this objective is to recirculate and reuse the ground water with an in-line filtering system. In this research, the author analyzes the ground water for various physical and chemical properties and concludes its suitability for water jet weaving. Finally, this publication proposes a novel water recirculation method that can reduce the wastage of water. It also suggests how to maintain the chemical and physical parameters of ground water with a filtering system so that it will eliminate the damages to the weft insertion system and to the other components in the loom.

2. METHODOLOGY

2.1 Testing Methods for Ground Water Quality

The following Chemical and Physical properties were tested and reported in this research: Chloride, Total alkalinity, Sulphate, pH, Total Hardness, Iron, Electrical Conductivity, Turbidity, Total suspended solid, and Color. Standard procedure was followed to obtain the ground water samples and all the collected samples were labeled with the date, time, location, and collection depth before collecting. All the collected data were utilized to calculate the reported mean values.

a. The chloride content of ground water was tested according to the ASTM STD vol.11.011993. The ground water sample was tested by titration with a standard $AgNO_3$ solution, then the chloride content was calculated from the following equation. Chloride mg/L = (A –B) x N x 1000 / ml of sample. where A = ml of titrant used, B= ml of titrant for blank, and N= normality of $AgNO_3$

b. The Alkalinity test was done according to the method for chemical analysis of water & waste standardsEPA/600/4-79/020.The ground water samples were tested by titration according to standard. Finally, the alkalinity of the samples was calculated from the following standard equation: Alkalinity as $CaCO_3$ mg/L= A´N´50000/ml of sample where A= ml of sulfuric acid used and N= Normality of sulfuric acid (Fzanson A, M. 1985).

c. Conductivity is used to measure how well a water sample conducts electricity; it depends on the various minerals in ground water that produce ions. Ground water samples were tested by the method of chemical analysis of water & waste and according to the standard EPA/600/4-79/020. The conductivity was measured using a calibrated conductivity meter.

d. A hardness test was done according to standard EPA/600/4-79/020 (a method of the chemical analysis of water & waste).The amount of dissolved calcium and magnesium in water determines its “hardness”.

Ground water samples were titrated with standard EDTA solution. Then the hardness was calculated by the formula given below: Hardness mg/L=A´N´50,000/ml of sample ;Where A=ml of EDTA used and N = Normality of EDTA

e. The Turbidity test was done according to standard EPA/600/4-79/020 (a method of the chemical analysis of water & waste). Turbidity is the amount of particulate matter that is suspended in water. The Turbidity was tested by nephelometric methods and measured in nephelometric turbidity units (NTU). Nephelometric turbidity unit =A x (B+C)/C Where A- NTU found in diluted sample; B-volume of dilution water (ml);C-sample volume takes from dilution (ml)

f. The pH of water was tested by means of a calibrated pH meter.

g. The total amount of suspended solid in the ground water sample was tested according to gravimetric methods and calculated from the following standard equation. Nonfilterate residue= (A-B) x1000 /C (mg/l) Where A-weight of filter with residue (mg); B-weight of filter (mg); C-vol.of sample filtered (ml)

h. The sulfate content in ground water was tested by turbidimetric methods and according to the ASTM standards vol.11.02.1986.Microbiological impurities were not tested since they have an insignificant influence on the synthetic yarns, fabrics, and metal (or synthetic) parts of the weft insertion system.

i. The Iron content in ground water was tested by an atomic absorption method and measured by the atomic absorption spectrophotometer according to the standard EPA/600/4-79/020 (a method for the chemical analysis of water and wastes). This method can also be used to analyze drinking, surface, and saline waters as well as domestic and industrial waste water.

The Iron concentration was calculated from the following standard equation.Iron concentration, mg/l= $\frac{V_1(A_s \times C_{std})}{V_2(A_{std} - A_s)}$ Where,V_1= volume of the dilute sample;V_2=Volume of the original sample; A_s= absorbance of dilute sample; A_{std}= absorbance of one of the standard addition;C_{std}= concentration of the same standard addition asA_{std}in mg/l Since there are two standard additions, calculate for each and average the two.

3. Experimental Procedure

i. The ground water, pretested for water quality, was circulated through the loom without a filtering system for six cycles. The water discharged from the loom was then collected and tested for the water quality parameters of each and every cycle according to ASTM standards. The number of cycles was decided as to collect the required quality of water for testing purposes.
ii. Depending on the test results that were obtained after the water circulation on the water jet loom, a filtering system which is based on gravimetric methods and iron exchange methods was implemented.

iii. Ground water was supplied and recirculated through the proposed filtering system and then into the water jet loom. After every cycle, the water discharged from the loom was tested for the same chemical and physical properties as the used ground water.

4. Theoretical Analysis of Water Consumption During Water Jet Weaving

Force P required to insert the weft yarn through the shed can be written as follows:

$$P = m_0 \, L \frac{dv}{dt} - - - - (1)$$

Where,m_0 -Mass of the unit length of the pick, L-Length of the inserted pick The tractive force exerted by the water jet to pull the yarn across the shed depends on various factors and can be expressed as:

$$P_t = \rho \mu D L (V_w - V_y) - - - - (2)$$

Where- P_t-tractive Force; ρ- Specific density of water; μ- Yarn density; V_w- Speed of water jet; Vy-Speed of yarn;D – yarn diameter The condition for optimum weft insertion by a water jet is when P=P_t

Then $m_0 \, L \frac{dv}{dt} = \rho \mu D L (V_w - V_y)$-------- (3)

Let us assume that for a given type of yarn,m_0 μ, D andρ are constant

Then from equation (3) we have

$$\frac{dt}{k} = \frac{dv}{(Vw - Vy)} \text{--------- (4)}$$

Where $\frac{\rho \mu D}{m_0} = \frac{1}{K} - - - - (5)$

By integrating the equation (4) when t=0 ;$Vy = 0$ and t=t ;$Vy = Vy$

The expression of the weft yarn speed can be derived

$$Vy = (1 - e^{tK}) \text{ ------------- (6)}$$

According to the width of the reed and the time required to insert the weft, we derive:

$$Vy = \frac{W_1}{t_1} \text{ ------------- (7)}$$

$$t_1 = \frac{\theta}{6 n_1} \text{------------ (8)}$$

Where's W_1-Width of the reed; t_1- Time taken for the weft insertion,

θ- Angle of main shaft rotation duting which the weft is inserted; n_1 –rpm of the main shaft

Solving equations (6), (7), and (8) the expression for the speed of water released from the water jet nozzle is derived,

$Vw = 6W_1 n_1/\theta\ (1 - e^{tK})$ ------------ (9)

Therefore water consumption of water jet loom per hour as follows

Q=$Vw\theta\ (1 - e^{tK})\ W/6W_1$------------ (10)

Where; w-water consumption per single pick and depends on the water ejected from the pump during a weaving cycle. The volume of water required for one weft insertion can be determined by the dimensions of the water pump.

w=$\pi D_1^2/4$ x S -------------- (11)

Where; D_1-diameter of the Cylinder plunger in mm; S-stock length of the plunger in mm

w-volume of water supplied per weft insertion in mm ^{3}

Therefore the water consumption of a water jet machine per given time can be given as:

Q= $\pi D_1^2/4$ x S x n_1 x60 mm ^{3}/Hour---------- (12)

Where n_1-RPM of the water jet loom, Picks/min; Q- volume of water required per given hour

5. CONCEPTUAL DESIGN OF GROUND WATER FILTERING SYSTEM FOR WATER JET WEAVING

The data obtained for the recycled ground water that was cycled several times without a filter system showed that the chemical parameters such as chloride, sulphate, pH, and change in electrical conductivity were insignificant. Therefore when designing a suitable filtering system, the above mentioned parameters were not considered. The results also showed that chemical and physical properties such as total suspended solids, turbidity, and color were increased as the number of recirculation increased. In water jet weaving, the presence of iron presents a serious technical challenge since it tends to produce yellow or brown stains in the weft yarn and causes problems for weft insertion. These problems can be minimized7 as long as the iron concentration in the ground water is maintained below 0.05 mg/l. These facts make it evident that the removal of iron content is critical in water jet weaving.To use ground water in water jet weaving and then to reuse it on the same loom, a properly engineered filtering system is essential. In this research work, the author proposes the use of a gravimetric filter which consists of activated carbon, sand, and gravel of different granule sizes followed by a Zeolite filter (Fig.1). A Zeolite filter is used to reduce the water hardness of recycled ground water. In addition to having no sludge formation, Zeolite filters are also cost effective as they could easily be regenerated with sodium chloride.As reported in the project,actiated carbon is used to remove organic compounds from water to make water suitable for use in manufacturing[9]. The dimensions of the prototype filter depend on both the quantity of accumulated discharged water during the weaving process and the rate of filtering. If the rate of filtering is less than the water consumption of the loom, then an external water supply should be incorporated to ensure a continuous water flow that would guarantee a smooth loom operation.

6. THE DESIGN OF PROTOTYPE FILTER

The cross sectional area of the square shape filter column depends on the filtration rate of the sand bed and the water consumption of the water jet loom whereas the height of the filter column depends on the degree of waste of filtration. The required quantity of filtered water, or the required flow rate for the loom to run continuously, can be calculated from equation (12).

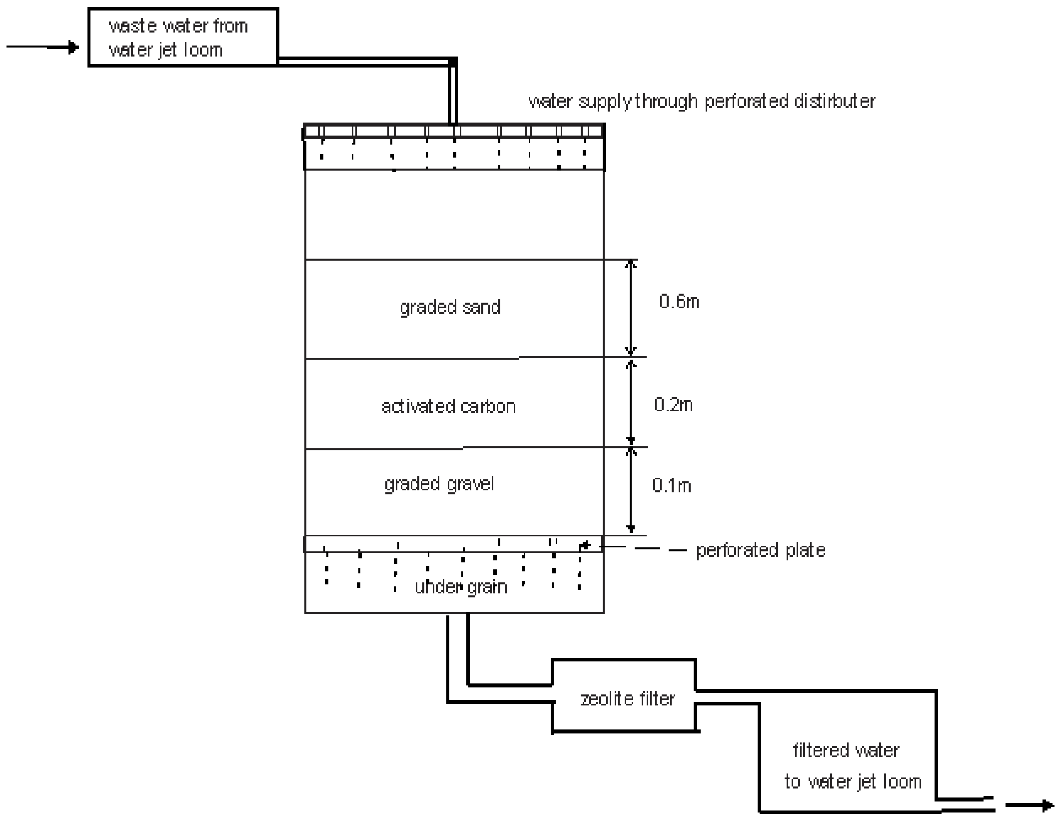

Fig 1. Prototype waste water filtering system for water jet loom

Filtration rate for this prototype filter can be calculated from the following equation:

Filtration rate= <u>required flow rate</u> (Q) $m^3/m^2/h$ Cross
area of the square filter (dxd)

Taken into account the depth and partial size of graded sand, the filtration rate was calculated to be 1.44 $m^3/m^2/h$, D_1=40mm; S=10mm;n_1 = 600rpm and the width of the sand bed (d) was calculated from the following equation.

$d = \sqrt{\frac{\pi D_1^2/4 \text{ x S x } n_1 \text{ x}60}{1.44}}, m$ =56 cm.. To provide the proper water consumption for water recycling in jet weaving, a cross sectional area of 56x56 cm2 is required.

To provide the proper amount of recycled water for jet weaving, a cross sectional area of 56x56 cm2 is required.

7. Experimental Results

Quality of ground water after recirculation with and without a filtering system

The water taken from the ground was tested for its quality according to Research laboratory Test Standards. The Average values of the Physical and Chemical Quantities of ground water for water jet weaving were also tested and are given in Tables 2. The tested ground water was supplied to the water jet and reused six times. After each cycle, the discharged water from the loom was tested. The test results are given in Tables 3 & 3a.

Table 2.Chemical & Physical quality of ground water

Chloride	Total alkalinity	Sulphate	PH	Total Hardness	Iron mg/l	Electrical Conductivity	Turbidity	Colour	Total suspended solid
8.52 mg/l	35.0 mg/l	6.66 mg/l	7.1	14 mg/l	0.35	60.3MicroSeimen/c.m	1(NTU)	4 H	100 mg/l

Table 3.Chemical quality of recirculated ground water without a filtering system

Particulars	1st Cycle	2nd Cycle	3rd Cycle	4th Cycle	5th Cycle	6th Cycle
Chloride(mg/l)	8.5	8.9	8.9	8.95	8.95	9.0
Sulphate(mg/l)	6.3	6.8	6.85	6.85	6.9	6.95
Iron(mg/l)	0.04	0.035	0.034	0.032	0.033	0.035
pH	7.1	7.1	7.1	7.1	7.1	7.1
Electrical Conductivity	77	77	78	80	83	87
Total Hardness(mg/l)	2	2	2.25	2.5	3.0	3.25
Total alkalinity(mg/l)	44	44	44	45	45	45

Table3a. Physical quality of recirculated ground water without a filtering system

Particulars	1st Cycle	2nd Cycle	3rd Cycle	4th Cycle	5th Cycle	6th Cycle
Colour H	5	6	6.4	7.5	8	8.9
Turbidity, NTU	1.4	3	5.2	8.1	14	16
Total suspended solid(mg/l)	100	120	124	131	140	152

The pretested ground water was supplied to the water jet and reused six times after passing through a filtering system. After each cycle, the discharged water was tested and the results are given in Tables 4 & 4a.

Table 4. Chemical quality of recirculated ground water with proposed filtering system

Particulars	1st Cycle	2nd	3rd Cycle	4th Cycle	5th Cycle	6th Cycle
Chloride(mg/l)	8.5	8.9	8.9	8.95	8.95	9.0
Sulphate(mg/l)	6.3	6.8	6.85	6.85	6.9	6.95
Iron(mg/l)	0.04	0.035	0.034	0.032	0.033	0.035
pH	7.1	7.1	7.1	7.1	7.1	7.1
Electrical Conductivity	77	77	78	80	83	87
Total Hardness(mg/l)	2	2	2.25	2.5	3.0	3.25
Total alkalinity(mg/l)	44	44	44	45	45	45

Table4a. Physical quality of recirculated ground water with proposed filtering system

Particulars	1st Cycle	2nd Cycle	3rd Cycle	4th Cycle	5th Cycle	6th Cycle
Chloride(mg/l)	8.5	8.9	8.9	8.95	8.95	9.0
Sulphate(mg/l)	6.3	6.8	6.85	6.85	6.9	6.95
Iron(mg/l)	0.04	0.035	0.034	0.032	0.033	0.035
pH	7.1	7.1	7.1	7.1	7.1	7.1
Electrical Conductivity	77	77	78	80	83	87
Total Hardness(mg/l)	2	2	2.25	2.5	3.0	3.25
Total alkalinity(mg/l)	44	44	44	45	45	45

8. Experimental method of measuring water consumption of water jet loom

In order to practically calculate the water consumption of the loom, a rubber container was fixed to the main nozzle and the ejected water was collected. Then the average water volume per single weft insertion was measured. It must be noticed that the average volume of water required for one weft insertion depends on the dimension of the pump and its stroke.

Average volume of water collected per pick = 4ml.

Speed of the water jet loom=500 picks /min

Then water consumption per hours

$$= \frac{4x500x60}{1000} = 120 \text{ L/hour.}$$

If we assume that the average water jet weaving plant operates 100 machines with 3 work shifts, then the total water requirement for the plant to operate would be about 120x8x3x100 =288,000 Liters/day. In general, 80% of the discharged water from the loom is collected using proto type water collecting system installed underneath the loom. Thus to keep the required water flow rate to the jet, around 10-20% of ground water should be externally supplied to the filtering system.

9. Discussion and Conclusion

Nowadays, the scarcity of water is a major worldwide problem not only for the textile industry, but also for hydro power generation and other industries that are heavily dependent on the high usage of water: a primary ingredient for human existence. Even though water jet weaving is known to have high weft insertion speeds and low energy consumption, the heavy usage and the wastage of water have a negative impact on the production cost which could potentially make water jet weaving economically unacceptable. Therefore, it is imperative to have water recycling systems that reuse the waste water generated in the weaving industry after bringing it to the required quality for reuse. Furthermore, water jet weaving is used in small to medium scale industries. Thus to minimize the operating cost while increasing the machine efficiency at the lowest capital investment, it is suggested to have in-line filtering systems for individual looms. Such filtering systems ensure eco manufacturing systems, which lead to higher profit margins. Designing a highly engineered water filtration system is a formidable task since the filtered throughput should meet the high water consumption of water jet looms. Designing a highly engineered water filtration system in which the filtered throughput meets the high water consumption of water jet looms is a formidable task. Evidently, the water quality during filtration should not deteriorate with the recursive reuse of it. In order to ascertain the quality measure of water in filtration, the recycle water is tested for quality. In order to ascertain the quality of the filtered water, the recycled water was thoroughly tested. The chemical and physical qualities shown in Tables 3 and 3a for recycled ground water without a filtering system indicate that the values of total hardness, color, and total suspended solids are increased with the number of recycles while other quality parameters remained almost constant. From tables 4 and 4a, it is evident that the average values of total hardness, color, turbidity, iron content, and total suspended solid were slightly increased during the recycling process but remained within the admissible limits. When designing the proposed water filter, the total water consumption of the water jet looms are taken into account. Equation (10) given in section 2.2 could be used to calculate the theoretical water consumption of a water jet loom. The approach given in section 2.5 can be used to measure the physical water consumption. The equation given in section 2, 5 could also determine the required cross sectional area of the square shape filter with respect to the filtration rate and water consumption of the loom. According to the experimental method, 80% of the water discharged from the loom was collected and recycled. Consequently, it is proven up to70% of water consumption by the loom can be reduced. Since the application provides promising results, it demonstrates indirect evidence of the validity of the underlying principle, i.e. the accuracy of the derived equations. A low-cost, low-maintenance, in-line filtering system was designed to use and effectively recycle the ground water while maintaining the required water quality which mitigates the clogging of the main nozzle, corrosion of parts and the loom components. This simple filtering system enables smooth weft insertion and it does not require any chemical addition and thus ensures an environmentally friendly manufacturing. However, basic maintenance such as periodic washing of the filter or replacement of sand is necessary to maintain a uniform waste water flow.

ACKNOWLEDGEMENT
The Author greatly appreciates the valuable input and contributions of Chantal Perera and François Perera from Raynham, Massachusetts.

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