STUDIES OF NONWOVEN FABRICS FOR WATER FILTRATION

Landage S. M.*

Wasif A. I.*

Sapkal P. P.*

Abstract: *Water filtration is the process of removing undesirable chemicals, biological contaminants, suspended solids and gases from contaminated water. The goal is to produce safe and clean water for a specific purpose. In this paper we reported on the water filtration behaviour of double layering of nonwoven fabrics produced from polypropylene fibres and compared the filtration efficiency of nonwoven fabric with polyester woven filter fabric. Four different types of needle punched nonwoven fabrics were produced by varying the needle punching density. The filtration was carried out by varying the flow rates. Properties and fabric efficiency for nonwoven fabric were evaluated by measuring total suspended solids after effluent filtration and air permeability of fabrics. The time required for filtration and GSM of fabric after filtration of fabric were also measured. The result showed that as needle punching density increases the filtration efficiency increases and air permeability decreases. It is also observed that nonwoven fabric having better filtration efficiency than woven fabric.*

Keywords: *Nonwoven, Filtration, Suspended Solids, Textile Effluent, Water Filtration*

***D. K. T. E. S. Textile &Engg. Institute, Ichalkaranji, Maharashtra, India**

1. INTRODUCTION

Water filtration is the process of removing undesirable chemicals, biological contaminants, suspended solids and gases from contaminated water. The goal is to produce safe and clean water for a specific purpose. The filtration process of water may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi and a range of dissolved and particulate material derived from the surfaces that water may have made contact with after falling as rain [1, 2].

Filtration is defined as "it is the mechanical or physical operation which is used for the separation of solids from fluids (liquids or gases) by interposing a medium through which only the fluid can pass."

Nonwoven filter media is a generic term that includes a wide variety of filtration and separation media. Needle punching is mechanical bonding method for producing nonwoven web structure. The water flow through the nonwoven fabrics plays important role in determining the characteristics of fabrics and efficiency of fabrics [3-5]. Efficiency is the most critical performance data to consider when comparing two different filter media. Data of efficiency which identifies the capability of the medium to remove and retain particulate under specified test conditions. It is a common practice to compare filter media based on micron ratings instead of removal efficiency. However, such practice is flawed as it does not indicate the degree of efficiency for the rating and allows for wide variations in filter performance of different filters having the same micron rating [6].

Ideally, filter media should be compared according to their removal rating and the test conditions (single pass vs. multiple pass), as well as the retention efficiency at various percentages. The removal rating is directly related not only to the end quality of the fluid being filtered, but also to how the medium interacts with the catalysts and various additives.

The permeability characteristics in nonwoven fabrics vary from region to region, due to variation in the orientation of fibres and processing parameters. Through a porous medium fluid will pass which indicates permeability of the fabric. The pressure drop is inversely proportional to the permeability of the filter medium. Therefore, a medium with high permeability is desirable [7-16].

The objective of this study is to investigate the efficiency of nonwoven fabric for textile effluent filtration. Also to evaluate and compare the performance of woven and nonwoven fabric for filtration efficiency.

2. EXPERIMENTAL

2.1Materials

PP based nonwoven fabric having 200, 400, 600 and 800 needle punchdensity is used for the study and its results were compared with polyester woven fabric which is most commonly used for filtration.

Industrial textile effluent used for study. It is collected from the equalization tank of Common Effluent Treatment Plant, Ichalkaranji.

2.1.1. Details of Raw Material

Table 2.1 - Properties of woven fabric

Sr. No.	Parameters	
1.	Type	100% Polyester
2.	Weave	Plain
3.	Warp Count	33.70 Ne
4.	Weft Count	31.58 Ne
5.	EPI X PPI	58 X 38
6.	GSM (gm/m^2)	87.60
7.	Thickness (mm)	0.24
8.	Tensile Strength (kgf)	84.00 (warp way) 77.00 (weft way)
9.	Breaking Elongation (%)	23.75 (warp way) 22.50 (weft way)
10.	Bursting Strength (bar)	1.05
11.	Air permeability (cm^3/cm^2/Sec.)	32.95
12.	Water permeability (lit./min./ cm^2)	2.67

Table 2.2 - Properties of nonwoven fabric

Sr. No.	Characteristics	Needle Punch Density (punches/inch²)			
		200	400	600	800
1.	GSM (gm/m²)	264.52	384.20	537.40	724
2.	Thickness (mm)	3.16	4.53	4.83	6.24
3.	Tensile Strength (kgf)	40.27 (MD) 63.05 (CD)	120.06 (MD) 70.18 (CD)	140.10 (MD) 99.86 (CD)	219 (MD) 136.18 (CD)
4.	Breaking Elongation (%)	113.95 (MD) 115.05 (CD)	99.85 (MD) 113.55 (CD)	71.60 (MD) 98.5 (CD)	66.60 (MD) 71.00 (CD)
5.	Bursting Strength (bar)	17.32	24.08	36.68	41.87
6.	Air permeability (cm³/cm²/Sec)	67.46	28.03	10.33	6.93
7.	Water permeability (lit./min./ cm²)	10.50	6.20	4.63	3.57

Table 2.3 - Characteristics of Effluent

Sr. No.	Characteristics	
1.	pH	8.5
2.	TSS	600 mg/lit
3.	COD	1105 mg/lit
4.	BOD	480 mg/lit

2.2Methods

2.2.1. Nonwoven Filter Fabric

Here, double layer of nonwoven fabric (having needle punch density 200, 400, 600, 800) was placed in the filtration device. Textile Effluent was passed through that filter fabric at flow rate 0.5, 1.0, 1.5 lit/min. at atmospheric pressure. And all filter fabrics were evaluated for filtration efficiency by measuring the amount of total suspended solids and time required for filtering the textile effluent through the filter fabric. Change in GSM of nonwoven filter fabric also measured after filtration.

The same method was followed for woven fabric and the results were compared with nonwoven fabric.

3. TESTING

The results obtained were evaluated using standard test methods. Filtration efficiency, air permeability, GSM, bursting strength of the fabric is measured according to ASTM D- 5141, ASTM D- 737, ASTM D-6242-98 respectively.

4. RESULTS AND DISCUSSION

4.1 Woven fabric

Table 4.1 – Double layer woven fabric

Sr. No.	Characteristics	Flow rate (lit./min)					
		0.5		1.0		1.5	
		Before Filtration	After Filtration	Before Filtration	After Filtration	Before Filtration	After Filtration
1.	GSM (gm/m^2)	175.200	175.822	175.200	175.749	175.200	175.378
2.	TSS (mg/lit)	600	571	600	578	600	58
3.	Filtration Efficiency (%)	4.83		3.66		2.00	
4.	Time (sec.)	93.68		65.43		22.69	
5.	Air Permeability (cm^3/cm^2/s)	59.67	52.64	59.67	54.48	59.67	57.36

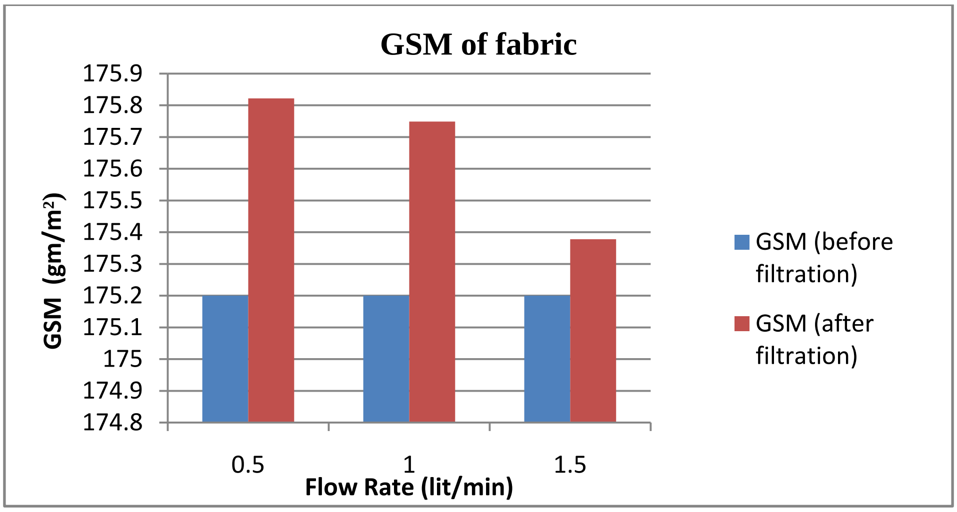

Figure 4.1 - Effect of flow rate on GSM of double layer woven fabric

It can be seen from Table 4.1 and Figure 4.1 that increase in GSM at after filtration. Before filtration fabric shows GSM 175.200. After filtration, at flow rate 0.5 lit/min. The fabric shows GSM 175.822 and at a flow rate 1.5 lit/min the fabric shows GSM 175.378. This may be due to the double layering of fabrics, so the density of fabric increased and increasing flow rate of filtration.

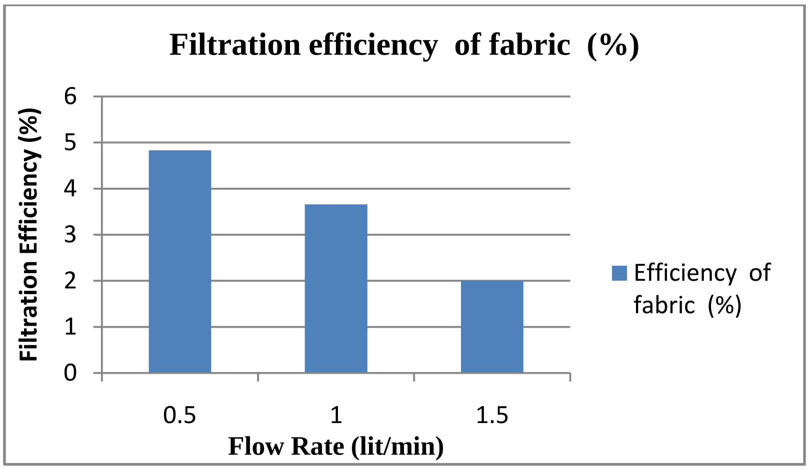

Figure 4.2 - Effect of flow rate on filtration efficiency of double layer woven fabric

It can be seen from Table 4.1 and Figure 4.2 that increase in filtration efficiency of fabric with decreasing flow rate of filtration. From the Table, it is observed that at 0.5 lit/min flow rate the value of raw effluent was 600 mg/lit and after passing through the woven fabric the TSS shown was reduced 571 mg/lit and this gives 4.83% efficiency in TSS reduction. At flow rate 1.5 lit/min., the value of raw effluent was 600 mg/lit and after passing through the woven fabric the TSS has shown was reduced 588 mg/lit and this gives 2.0% efficiency in TSS reduction. The reason for the decrease in filtration efficiency with an increase in flow rate of filtration is due to double layering of fabrics, so decrease in air permeability of woven fabric.

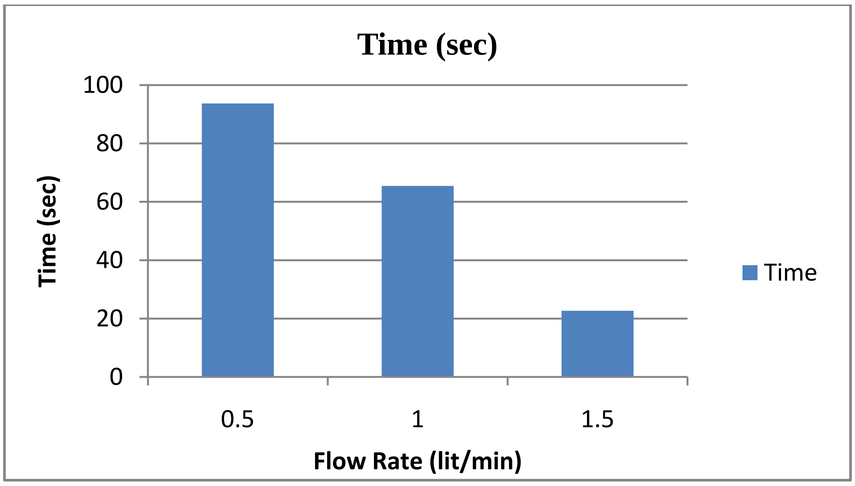

Figure 4.3 - Effect of flow rate on time required for filtration through a double layer woven fabric

It can be seen from Table 4.1 and Figure 4.3 that decrease in time with the increase in flow rate of filtration. At 0.5 lit/min flow rate, the fabric requires 93.68 Sec. Time and at 1.5 lit/min flow rate, the fabric requires 22.69 Sec. time for effluent filtration. This is may be because of the double layering of fabrics and increase in flow rate of filtration and the weave of fabric.

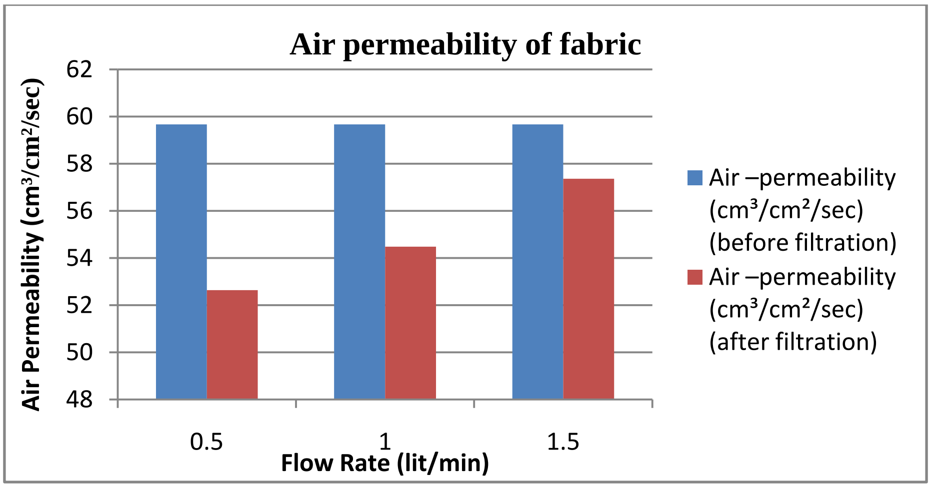

Figure 4.4 - Effect of flow rate on air permeability of double layer woven fabric

It can be seen from Table 4.1 and Figure 4.4 that after filtration decrease in air permeability. Before filtration, fabric shows air permeability 59.67 ($cm^3/cm^2/Sec$). After filtration, at 0.5 lit/min flow rate, fabric shows air permeability 52.64 ($cm^3/cm^2/Sec$) and at a flow rate 1.5 lit/min fabric shows 57.36 air permeability. This is due to the double layer of fabrics, the density of the fabric and increase in flow rate of filtration.

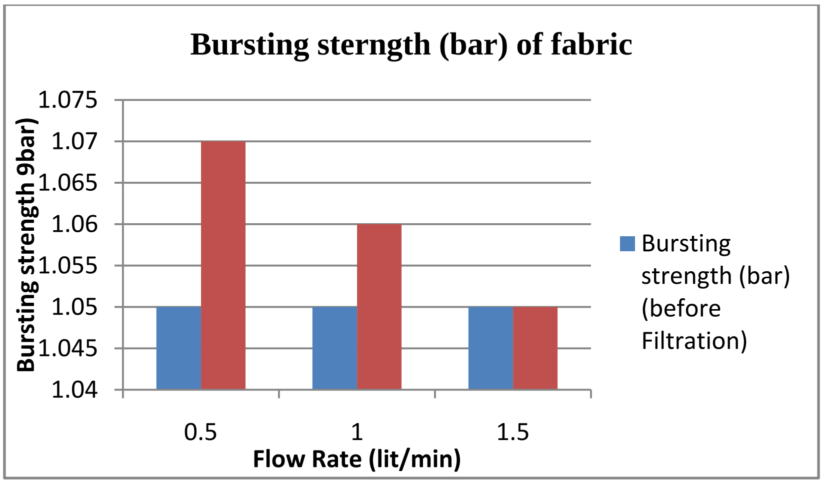

Figure 4.5 - Effect of flow rate on the bursting strength of double layer woven fabric

It can be seen from Table 4.1 and Figure 4.5 that increase in bursting strength with an increase in flow rate of filtration at after filtration. Before filtration, fabric shows bursting strength 2.15 bar. After filtration, at 0.5 lit/min a flow rate, fabric shows bursting strength 2.18 bar and at a flow rate 1.5 lit/min fabric shows bursting strength 2.16 bar. This is due to the double layer of fabrics and increase in flow rate of filtration.

4.2. Nonwoven fabric

4.2.1. Effect of Needle Punching Density of fabric on GSM of fabric.

Table 4.2 –Effect of needle punching density of fabric on GSM of double layer nonwoven fabric

Sr. No.	Needle punch density (punches/sq. inch)	Flow rate (lit/min)	GSM (gm/m²)	
			Before filtration	After filtration
1.	200	0.5	529.040	560.450
		1.0	529.040	554.104
		1.5	529.040	549.489
2.	400	0.5	768.416	866.018
		1.0	768.416	835.388
		1.5	768.416	831.844
3.	600	0.5	1074.800	1146.051
		1.0	1074.800	1144.166
		1.5	1074.800	1123.852
4.	800	0.5	1448.000	1531.311
		1.0	1448.000	1524.420
		1.5	1448.000	1495.968

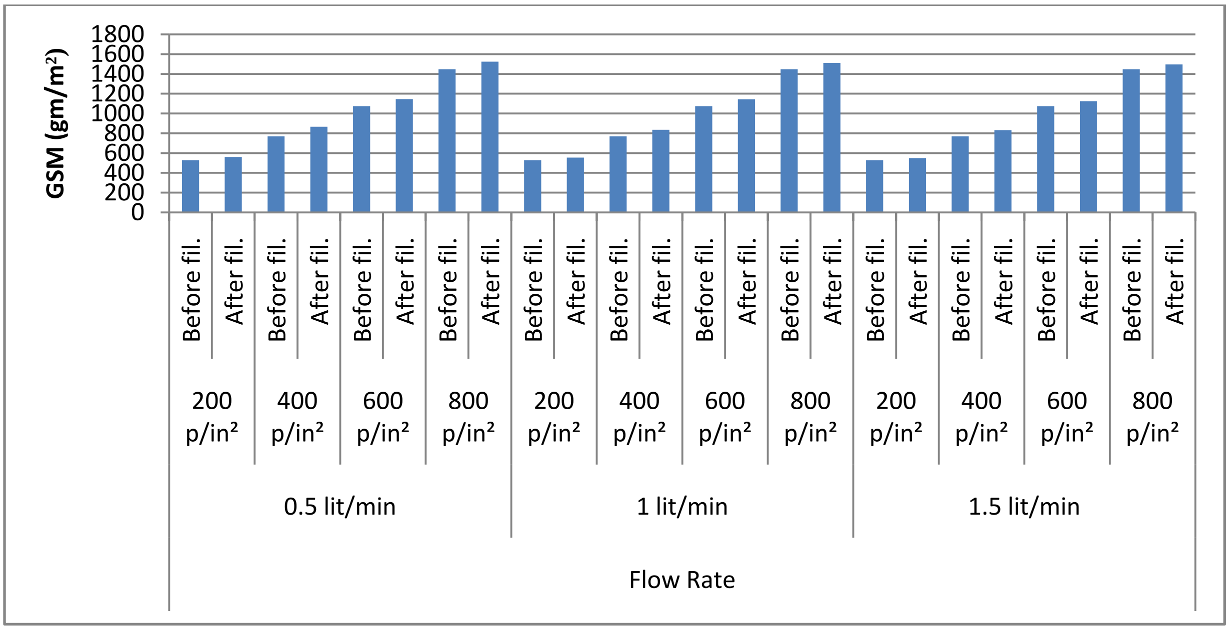

Figure 4.6 – Effect of needle punching density of fabric on GSM of double layer nonwoven fabric

It can be seen from Table 4.2 and Figure 4.6 that increase in GSM with the increase in the needle punching density. The fabric shows increase in GSM from 529.040 to 1448 before filtration for 200 and 800 needle punching density respectively. The fabric shows increase in GSM after filtration. At the lowest flow rate 0.5 lit/min. 800 needle punched density fabric showed highest GSM 1531.311 as compared to all GSM after filtration. This may be due to the higher needle punching density of fabric and double layering of fabrics. At the low flow rate increased the retention time of suspended solids during filtration.

4.2.2 Effect of needle punching density of fabric on filtration efficiency of fabric

Table 4.3 - Effect of needle punching density of fabric on filtration efficiency of double layer nonwoven fabric

Sr. No.	Needle punch density (punches/sq. inch)	Flow rate (lit/min)	TSS (mg/lit)		Filtration Efficiency (%)
			Before filtration	After filtration	
1.	200	0.5	600	410	31.66
		1.0	600	450	25.00
		1.5	600	550	8.33
2.	400	0.5	600	290	51.66
		1.0	600	350	41.66
		1.5	600	510	14.57
3.	600	0.5	600	70	83.33
		1.0	600	150	75.00
		1.5	600	450	25.00
4.	800	0.5	600	60	90.00
		1.0	600	70	88.33
		1.5	600	207	65.50

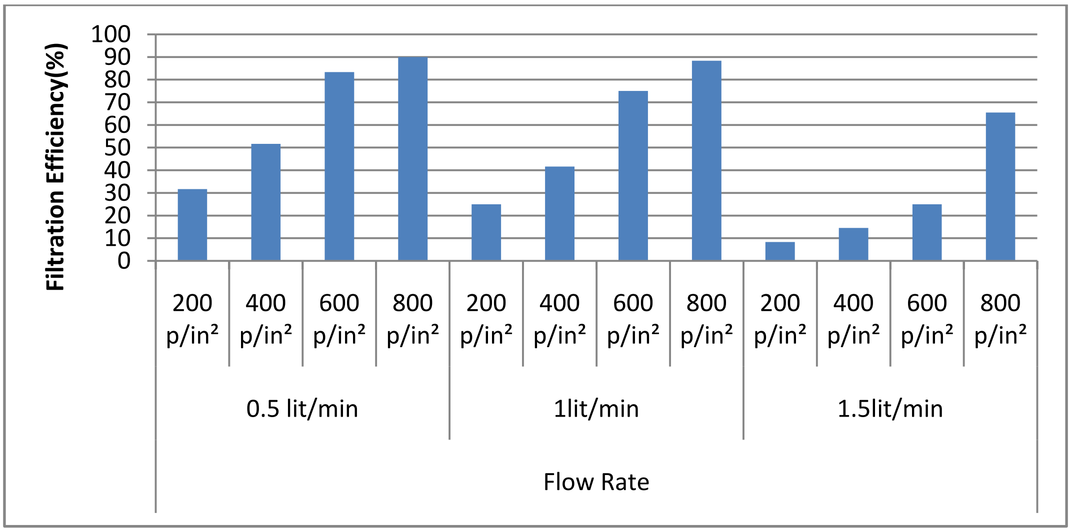

Figure 4.7 – Effect of needle punching density of fabric on filtration efficiency of double layer nonwoven fabric

It can be seen from Table 4.3 and Figure 4.7 that increase in filtration efficiency of fabric with an increase in needle punching density. From the Table, it is observed that at 800 needle punching density at the value of raw effluent was 600 mg/lit and after passing through the filter fabric at flow rate 0.5 lit/min the TSS has shown was reduced 60 mg/lit and this gives highest efficiency 90% in TSS reduction. The reason for the increase in filtration efficiency with increase needle punching density and using of double layering of fabrics is due to decrease in air permeability of nonwoven fabric. The low flow rate increased the retention time of suspended solids during filtration which blocked the pores of fabric so it reduced the air permeability and water permeability of fabric.

4.2.3 Effect of needle punching density of fabric on Time required for filtration

Table 4.4 - Effect of needle punching density of the fabric of time required for filtration through the double layer nonwoven fabric

Sr. No.	Needle punch density (punches/sq.inch)	Flow Rate (lit/min)	Time (Sec)
1.	200	0.5	59.13
		1.0	11.98
		1.5	9.78
2.	400	0.5	74.45
		1.0	30.32
		1.5	18.48
3.	600	0.5	92.58
		1.0	66.97
		1.5	24.66
4.	800	0.5	110.37
		1.0	89.25
		1.5	32.60

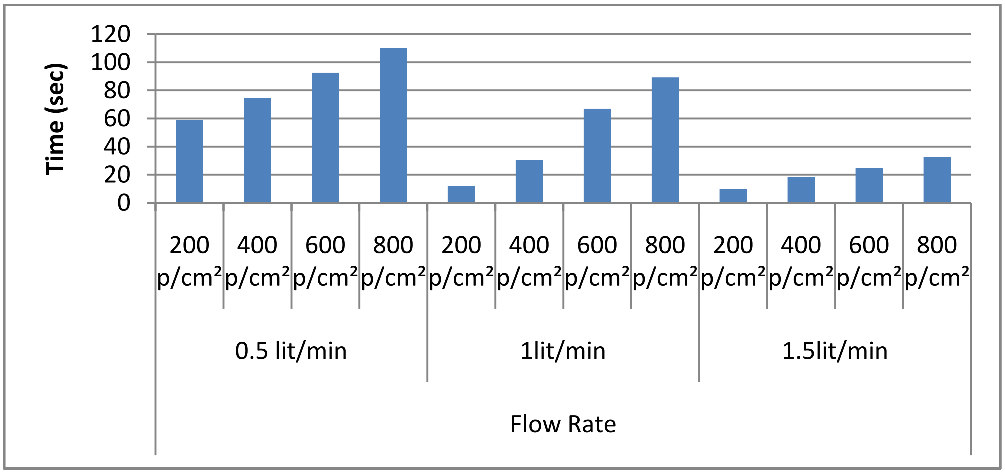

Figure 4.8 – Effect of needle punching density of fabric on time required for filtration through the double layer nonwoven fabric

It can be seen from Table 4.4 and Figure 4.8 that increase in time with the increase in needle punching density of the fabric. Fabric of 800 needle punching density required highest time 110.37 sec. for effluent filtration at flow rate 0.5 lit/min. This is may be because of the increase in needle punching density with decreasing of air permeability and water permeability and lowest flow rate of effluent filtration.

4.2.4 Effect of needle punching density of fabric on air permeability of fabric

Table 4.5Effect of needle punching density of fabric on air permeability of double layer nonwoven fabric

Sr. No.	Needle punch density (punches/sq. inch)	Flow rate (lit/min)	Air permeability (cm³/cm²/sec)	
			Before filtration	After filtration
1.	200	0.5	40.45	12.67
		1.0	40.45	14.05
		1.5	40.45	14.26
2.	400	0.5	16.45	7.14
		1.0	16.45	7.40
		1.5	16.45	7.47
3.	600	0.5	9.32	5.54
		1.0	9.32	5.79
		1.5	9.32	6.32
4.	800	0.5	4.62	3.11
		1.0	4.62	3.97
		1.5	4.62	4.31

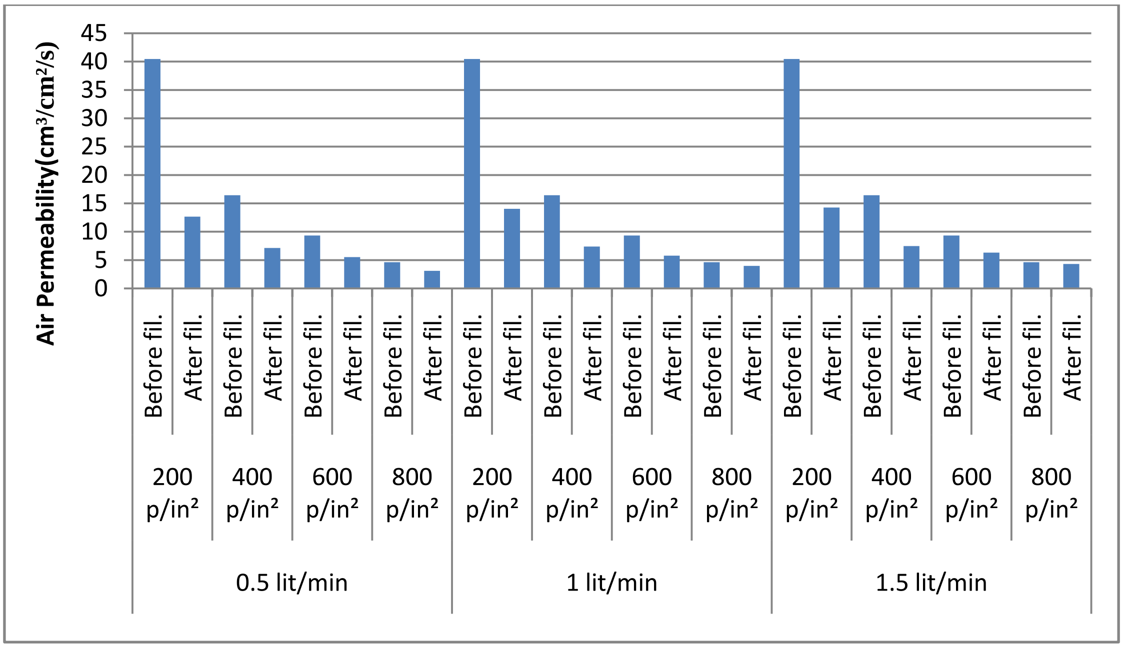

Figure 4.9 – Effect of needle punching density of fabric on air permeability of double layer nonwoven fabric

It can be seen from Table 4.5 and Figure 4.9 that as the needle punching density increases air permeability decreases in before and after filtration. The 200 needle punching density fabric shows air permeability 40.45 (cm^3/cm^2/Sec) and the 800 needle punching density fabric shows air permeability 4.62 (cm^3/cm^2/Sec) at before filtration. After filtration the 800 needle punching density fabric at flow rate 0.5 lit/min, after filtration shows the lower air permeability 3.11 (cm^3/cm^2/Sec). This is due to double layering of fabric and increase in fabric density with needling density and with this reduction in pore size. The lowest flow rate increased the retention time of suspended solids during filtration which blocked the pores of fabric so it reduced the air permeability of fabric.

CONCLUSIONS

From above results and discussion it is observed that,

- Woven fabric shows filtration efficiency 4.83% at 0.5 lit/min.
- Double layer nonwoven fabric having 800 needle punching density shows highest filtration efficiency 90% at 0.5 lit/min. as compare to 200, 400, 600 needle punched density fabric and other two flow rates.

Hence, we can conclude that nonwoven fabric has better filtration efficiency than woven filter fabric at lower flow rates. Results also indicate that nonwoven fabric having a lower air permeability which is responsible for better filtration efficiency. GSM of nonwoven fabric increases at lower flow rates as compared to woven fabric. Also observed that woven fabric takes more time for filtration than nonwoven fabric. So for better water filtration efficiency or to remove TSS from the effluent, the nonwoven filter fabric having higher needle punch density can be used in effluent treatment plant.

REFERENCES

1. Aadekunie A. A., Adejuyigbe S. B., *Fabrication of Plastic Water and Testing with Slow Sand Filtration Method,* The Pacific Journal of Science and Technology, Vol. 13, No. 5, 2012, P121-132.
2. Chaudhari S., Sakhe M., Filter fabrics: An Over View, *Synthetic Fibres,* July-Sept., 9-13 (2003).
3. Patanaik A., Anandjiwala R., Some Studies on Water Permeability of Nonwoven Fabrics, *Textile Research Journal*, 79(2), 147-152 (2009).
4. Nagaraj A. R., Application of Nonwoven in Filtration, www.technicaltextile.net

5. Ghosh S. K., Debnath C. R., Saha S. C., Physical Properties of Needle Punched Nonwoven Fabrics Made from Date-palm Leaf and its blends, *Textile Trends*, Sept., 43-45 (1987).
6. Chatterjee K. N., Nonwoven Filter Fabrics for Emission Control, *The Indian Textile Journal,* Dec., 132-154 (1990).
7. Shah R., Selecting a Nonwoven Filter Medium -That Is Right for Your Application,*International filtration news*, Jan/Feb29(1), 14-17 (2010).
8. Anon, *Needle Punched Nonwoven,* www.filterclothes.com
9. Patanaik A., Andjiwala R ., Water Permeability in Needle Punched Nonwoven using Finite elements Analysis, *South African Conference on Computational and Applied Mechanics,* March, 1-8 (2008).
10. Houghton J., Anand S. C., Purd A. T.,Characterisation of Fabrics Used for Wet Filtration, *Textile Asia*, 28(7), 59-66 (1997).
11. Sengupta S., Samajapati S., Ganguly P. K., Air Permeability of Jute Based needle Punched Nonwoven fabric, *Indian Journal of Fibre and Textile Research,* June, 103-110 (1999).
12. Rawal A., Structural Analysis of Pore Size Distribution of Nonwovens, *The Journal of The Textile Institute,* 101(4), 350-359 (2010).
13. Chaudhary A. K., Kumar N., Ranjan R., Charactrisation of Pore Size and Air Permeability of Nonwoven Filter Media, *Journal of Textile Association,* May-June, 19-26 (2009).
14. Epps H. H., Leonas K. K., Pore Size and Air Permeability of Four Nonwoven Fabrics, *International Nonwoven Journal*, 9(2), 1-8 (2000).
15. Industrial applications of membrane technology in Ireland: A Review Strive Environmental Protection agency Programme, report series no. 63, 1-60 (2007-2013).
16. Shipard S., Water Filtration – Advantages of Fabric Media, *69th Annual Water Industry Engineers and Operators' Conference, Bendigo Exhibition Centre,* Sept., 1-7 (2006).