International Journal of Global Science Research **ISSN: 2348-8344 (Online)**
Vol. 5, Issue. 2, October 2018, pp. 771-785 DOI: 10.26540/ijgsr.v5.i2.2018.104
Available Online **at www.ijgsr.com**

Research Paper

Comparison of Percolation Losses of Guar gum and Carboxymethylcellulose (CMC) polymer treated and untreated soils Under Laboratory Conditions

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Received: 13/07/2018
Revised: 20/07/2018
Accepted: 28/07/2018

Abstract: The present study was carried out to compare percolation losses of soil treated with Guar gum and Carboxymethylcellulose (CMC) polymer at different concentrations with untreated soil under laboratory conditions. These polymers are water soluble, physiologically inert, biodegradable, economical, do not produce any harmful effect when applied to the soil, and easily available materials were applied in four different concentrations i.e., 0.01%, 0.025%, 0.05% and 0.1% separately by weight of water to the soil columns in four mild steel cylinders supported by iron frame. The cylinders have approximately 60 cm depth, 30 cm diameter and 16 gauge thickness having conical bottom with opening. These cylinders were placed vertically on a platform supported with frames made of Engle iron, and measuring conical flasks were kept just below the small hallow rod at bottom of each cylinder to collect the percolated water. The data was collected for control and polymer treated soils in different concentrated solution of polymers applied in the soil column after 24 hours. The readings were noted after every 15 minutes just after pouring the water in each cylinder. The recorded observations indicated in general, that polymer treatment to the soils resulted in reduced percolation loss. The efficacy of polymer treatment to reduce percolation loss in soil were found to be better at higher concentration.

Keywords: Carboxymethylcellulose polymer, Guar gum polymer, percolation loss, soil column, soil treatment

INTRODUCTION

The conservation of natural resources in terms of their quantity and quality by applying proper management and protection techniques is everyone's responsibility. Water is essential for maintaining an adequate food supply and a quality environment for the human population, plants, animals, and microbes on the earth. Growing population, rapid urbanization and increasing industrial and agricultural production put together are resulting in tremendous pressure on this precious and finite resource. Though everybody should feel concerned and must

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favourably contribute towards meaningful conservation of natural resources like soil, water and environment in order to ensure sustainability of the entire system but the major part of responsibility lies on researchers and scientists to evolve methodologies for increasing water use efficiency by minimizing its loss.

The productivity of coarse textured soils is mostly limited by their low water holding capacity and excessive deep percolation losses. Thus the management of these soils must aim at increasing their water holding capacity and reducing losses due to deep percolation. The water holding capacity of coarse textured soils can be improved with the addition of soil conditioners. Soil conditioners primarily the cross-linked polymers can absorb water and swell up to hundreds of times of their dry weight. The large quantity of water retained by the polymer provides extra available water to the plants. This facilitates better plant growth while reducing the losses due to deep percolation. More available water in soil also means less frequent watering or irrigation. New generation polymers have high molecular weights, low application rates, and important environment, soil conservation and irrigation efficiency benefits for general agriculture, making the use of these products economically feasible (Sojka and Lentz, 1994). The use of gel-forming hydrophilic polymers have been tested to increase the water holding capacity of sandy soils (Stewart, 1975; Taylor and Halfacre, 1986; Silberbush *et al.*, 1993). Sivapalan (2001) demonstrated that the amount of water retained by a sandy soil increased by 23 and 95% by adding very small amounts (0.03 and 0.07% by weight, respectively) of polymer to the soil. This increase in water retention can reduce the amount of water otherwise lost by deep percolation. His study also demonstrated a 12 and 18 times increase in water use efficiency of soybean plants grown in soils treated with 0.03 and 0.07% polymers, respectively. A significantly higher irrigation water use efficiency of wheat under polyacrylamide treatment was reported by Stern *et al.* (1992). Polymers in soil were also able to reduce the amount of water lost from the soil through evaporation (Al-Omran and Al-Hardi, 1997; Sivapalan, 2001).

The control on water loss will help greatly in improved irrigation planning and more area can be brought under irrigation with the existing potential of the available water resources. Puddling has been found to be effective in controlling percolation losses, however, in soils of lateritic belt in eastern zone of the country and other medium and coarse structured soils, in spite of puddling a large percentage of water is lost due to percolation. To mitigate the ill effects of imminent water scarcity, the available water resources are to be managed effectively by saving and conserving this scarce resource. Thus, there has been a need to evolve some better methods for controlling water losses through percolation and seepage. The agricultural productivity of sandy soils is also limited by their low fertility status, low water holding capacity, and deep water percolation losses. Thus efficient water use is of primary importance in agricultural development. There has been growing interest over the last two decades in the use of supergel materials to improve soil physical properties and increase water use efficiency. These gel-forming conditioners proved to be effective in increasing water holding capacity and consequently decreasing deep percolation losses in sandy soils (Miller, 1979 ; Hemyari and Nofziger, 1981 ; Al-Omran *et al.*, 1987). These materials can thus increase water supply to growing plants and improve water use efficiency (El-Hady *et al.*, 1981 ; Terry and Nelson, 1986 ; Al-Harbi *et al.*, 1996). Polymers are the materials having very high molecular weight, consisting of several structural units called monomers

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which are bound together by covalent bond. In this study an attempt has been made to apply Guar gum and Carboxymethylcellulose (CMC) polymer separately in soils under laboratory conditions, at four different concentrations to to study percolation loss of soil. Guar gum is one of the outstanding representatives of the new generation of plant gums. Its source is an annual pod-bearing, drought resistant plant originating from India called Guar, or cluster bean (Cyamopsis tetragonolobus or C. psoraloides), belonging to the family Leguminosae. Guar gum is D-galactose and D-mannose i.e., a galactomannan. Carboxymethylcellulose (CMC) also called cellulose gum is a cellulose derivative with carboxymethyl groups (-CH2-COOH) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone. It is often used as its sodium salt, sodium carboxymethylcellulose. Both polymers are biodegradable and water soluble consist of several structural units called monomers, bound together by covalent bonds & easily available, inert in nature i.e., do not produce any harmful effect when used on soil. Both forms colloidal solutions of unusually high viscosity in hot or cold water even at very low concentrations. The viscosity attained is dependent on time, temperature, concentration and pH rate of agitation and practical size of the powdered gum used.

MATERIALS AND METHODS

The present study was carried out under laboratory conditions at Pantnagar, Distt U S Nagar, Uttarakhand state in India. The soil used for study was Sandy loam and its characteristics are given in the table below:

S.No.	Soil property	Description/range
1.	Texture	Less than 20% clay and 50 to 80% sand
2.	Structure	Granular
3.	Hydraulic conductivity	7.2 cm h^{-1}
4.	Basic infiltration rate	2.886 cm h^{-1}
5.	pH	8.4
6.	EC	240 mmhos
7.	TDS	140 ppm

In order to study the effect of polymer treatments of soil on percolation loss of soil four concentrations i.e., 0.01%, 0.025%, 0.05% and 0.1% by weight of water of Guar gum Carboxymethylcellulose polymer were selected and used on the soil column separately. The detailed procedure is described below:

Fabrication of experimental setup to study effect of polymer application on percolation loss under laboratory condition

The experimental setup was developed in order to determine the effect of polymers on percolation loss in sandy soil. The setup was designed (as shown in Fig.1) and fabricated in the University Workshop of G.B.P.U.A.&T Pantnagar. The experimental set up essentially consists of four mild steel cylinders supported by iron frames. The cylinders have approximately 60 cm depth, 30 cm diameter and 16 gauge thickness having conical bottom with a opening. These cylinders were placed vertically on a platform supported with frames made of Engle iron, the lower

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frame have thickness 5 mm and width 40 mm where as upper frame have same thickness but different width i.e., 35 mm. The cylinders were placed on mild steel sheet of 16 gauge thickness kept 30 cm above the ground level. At 45 cm depth a base plate made of small iron rods was welded inside the cylinders on which galvanized iron sieve of about 5 mm pore size was kept to hold gravel, sand and soil mass. A 15 cm height bottom portion i.e. closed end of the cylinder having 2 cm opening in each cylinder was welded. A 5 cm hollow mild steel rod was welded in each opening and projected outside to collect water percolated through the soil column. A measuring conical flask was kept just below hallow rod to collect the percolated water.

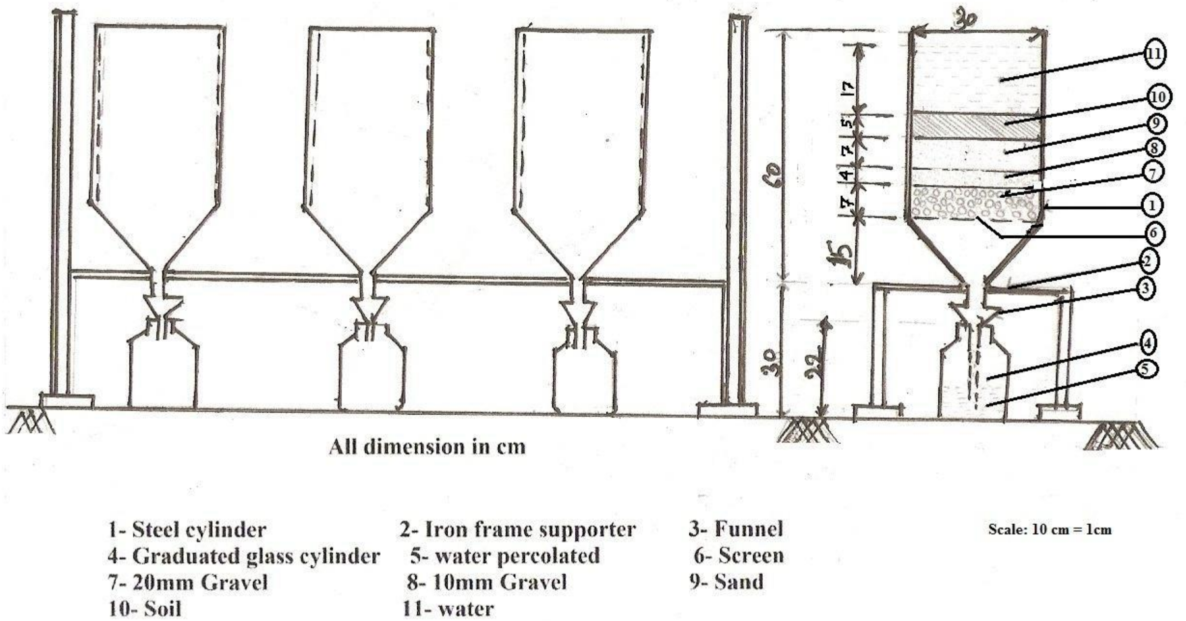

Figure 1. Laboratory experiment setup for percolation losses

Preparation of soil column in experimental setup

In order to provide a filtering effect, the cylinders were filled by 20 mm gravel, 10 mm gravel and course sand layers. The bottom layer consists of 20 mm gravel up to 7 cm (which was approximately 8 kg in weight) from the sieve, then 10 mm gravel up to 4 cm (approximately 4 kg), then course sand up to 7 cm (approximately 10 kg). Once this filter was ready, the soil up to 5 cm (approximately 5 kg) was filled. In order to achieve natural soil conditions water up to 17 cm (approximately 12.5 litres) was filled and the soil was allowed to settle for 24 hours. When soil is settled, the excess water was removed through the bottom outlet and soil column was ready for the experiment.

Preparation of polymer solution

The polymer solutions were prepared separately in four concentrations i.e., 0.01%, 0.025%, 0.05% and 0.1% by weight of water i.e., 0.1 g, 0.25g, 0.5g and 1g in 1000 ml of water respectively. The known quantity of polymer was added to the luke warm water (40^0C) and manually stirred continuously for 20 minutes to ensure that it gets dissolved completely. The solution was then kept for 24 hours under room temperature so that it forms a thick viscous gel depending on polymer concentration.

Polymer treatment to the soil columns

The polymer solutions were employed in the soil columns at the pre-decided concentration after the preparation of soil column in cylinders. One litre solution for each concentration of polymers were prepared separately and then readings were taken after 24 hrs i.e., when the polymer applied soil became completely dry and a very thin layer was formed on it. The entire set-up was kept under shaded room in order to protect the top surface of soil from direct sunshine which helped to prevent any cracks in the polymer sheet.

Observation on percolation loss of soil

To observe the polymer effect on percolation loss of soil at selected concentration i.e., 0.01%, 0.025%, 0.05% and 0.1% in laboratory experimental setup were measured. When soil column was ready for the experiment, then reading was collected for control and polymer treated soils in different concentrated solution of polymer applied in the soil column after 24 hours. The measuring conical flasks was kept just below the small hallow rod at bottom of each cylinder to collect the percolated water. The readings were noted after every 15 minutes just after pouring the water in each cylinder and these readings were compared with each other.

RESULTS AND DISSCUSION

On the basis of observed data of percolation for control i.e., untreated soil and polymer treated soils, a comparison of variation in percolation loss and Percent volume reduction in percolated water as compared to control was carried out. The volume and cummulated volume percolated for soil columns treated with polymers was found lesser in amount than untreated soil column as given in Table 1 to Table 4. The time taken to get the total water percolated had taken more time for the completion in polymer treated soils of the experiment than control as shown in Fig.2 and Fig. 3. The rate of percolation decreases with time except for 15-30 duration, because after first 15 min the water had already reached to bottom, hence maximum rate was found in next 15 minutes i.e., from 15-30 minutes. The cummulated volume percolated in soil columns treated with 0.01%, 0.025%, 0.05% and 0.1% concentration of Guar gum, Carboxymethylcellulose (CMC) and untreated condition was found to be 6500 ml, 4450 ml, 4350 ml, 3575 ml, 4490 ml, 4160 ml, 4210 ml, 2890 ml and 7640 ml respectively after 60 minutes. The time for the completion of the experiment was found to be different for different concentrations of polymer taken and it was found 150 min for control, 165 min, 240 min, 240 min, and 255 min for 0.01%, 0.025%, 0.05%, and0.1% Guar gum treated soil columns and 225 min, 210 min, 240 min, and 315 min for 0.01%, 0.025%, 0.05%, and0.1% Carboxymethylcellulose (CMC) treated soil columns. Both Guar Gum and Carboxymethylcellulose (CMC) polymer reduced the volume of water percolated as compared to control but the reduction in volume varies for these two cases at selected concentrations of polymer. The time taken to get a fixed volume of water i.e., 12.5 litres percolated is given in Table 1 to Table 4. In first 15 min the percent reduction in volume percolated as compared to control was found to be the maximum both for Guar Gum and Carboxymethylcellulose (CMC) polymer at selected concentrations as is evident from Fig.4 and Fig. 5. Similarly, the maximum percent volume reduction at 0.01% of Guar gum and 0.01% of Carboxymethylcellulose (CMC) was found to be 19.39% and 39.25% for 30-45 min and 15-30 min duration respectively as shown in Fig. 4(a). The minimum percent volume reduction at 0.025% of Guar gum and 0.025% of Carboxymethylcellulose (CMC) was found to be 20.17% and17.54 % for 90-105 min respectively as illustrated in Fig. 4(b). The percent volume reduction at 0.05% of Guar gum and 0.05% of Carboxymethylcellulose (CMC) decreased after 30 min and was found to be 16.67% and 21.05% for 90-105 min

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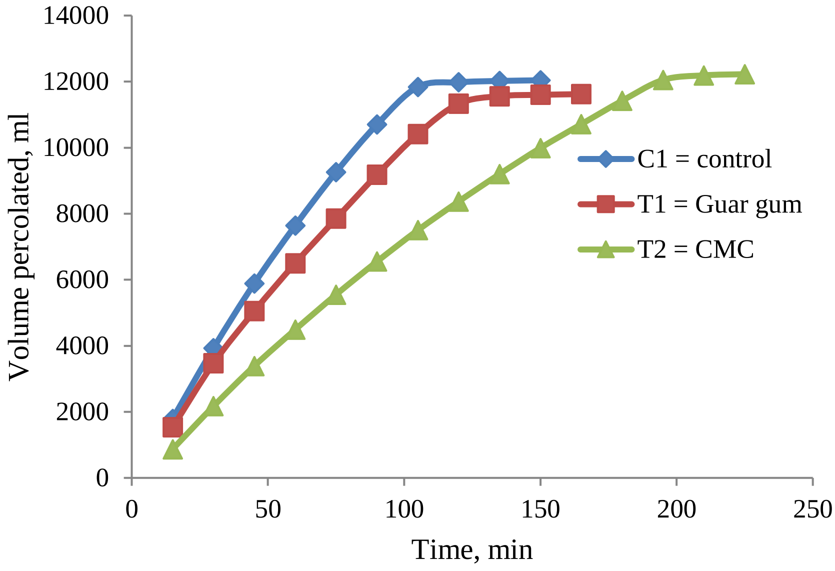
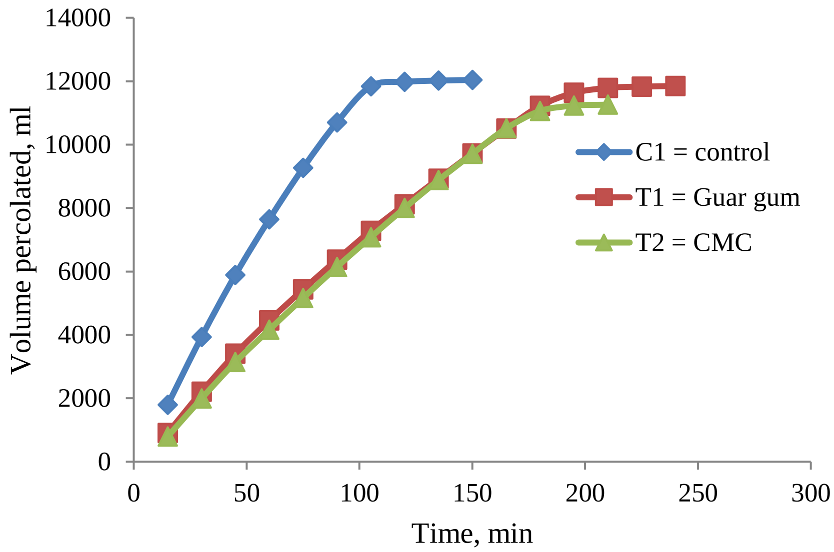
respectively, as shown in Fig. 5(a). The maximum value of percent volume reduction was found at 0.1% of Guar gum and 0.1% of Carboxymethylcellulose (CMC) in first 15 min were given as 70.39% and 75.98% respectively as is evident from Fig. 5(b).



(a) For 0.01% concentration



(b) For 0.025% concentration

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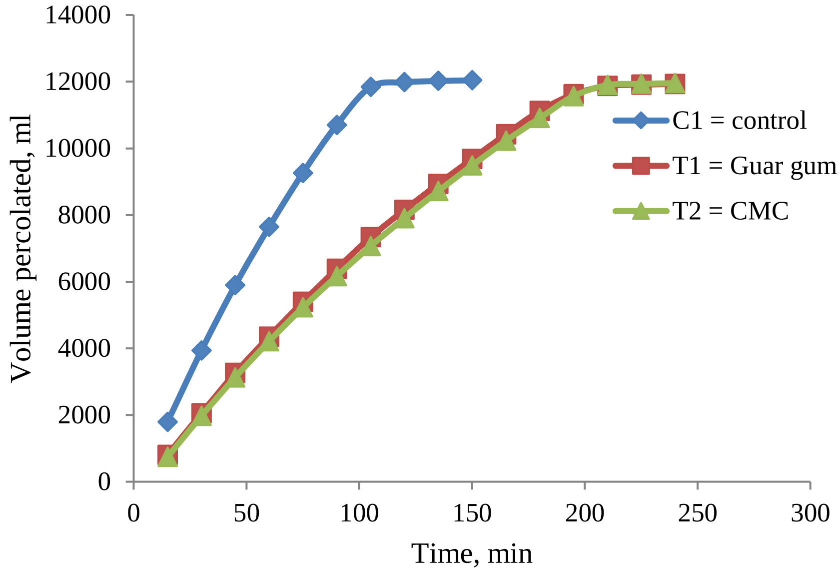
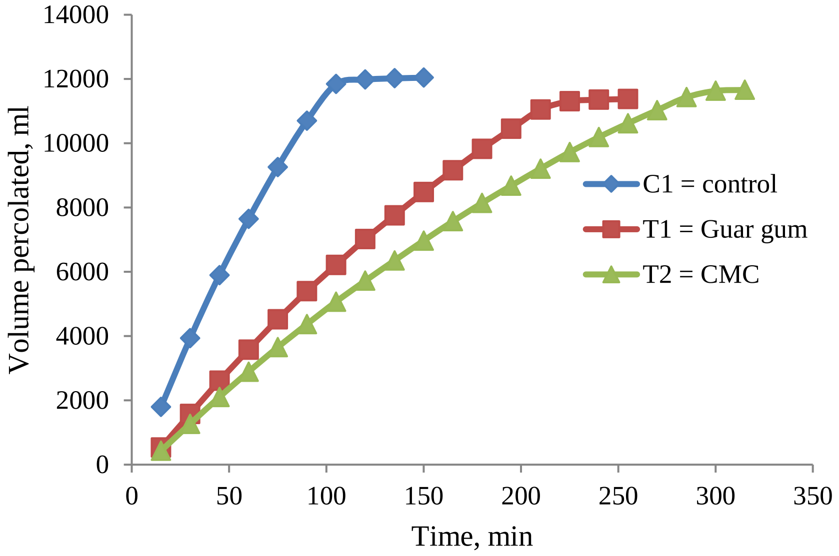
Figure 2. Cummulative percolation volume treated with 0.01 and 0.025 percent concentrations of polymers



(a) For 0.05% concentration



(b) For 0.1% concentration

Figure 3. Cummulative percolation volume treated with 0.05 and 0.1 percent concentrations of polymers

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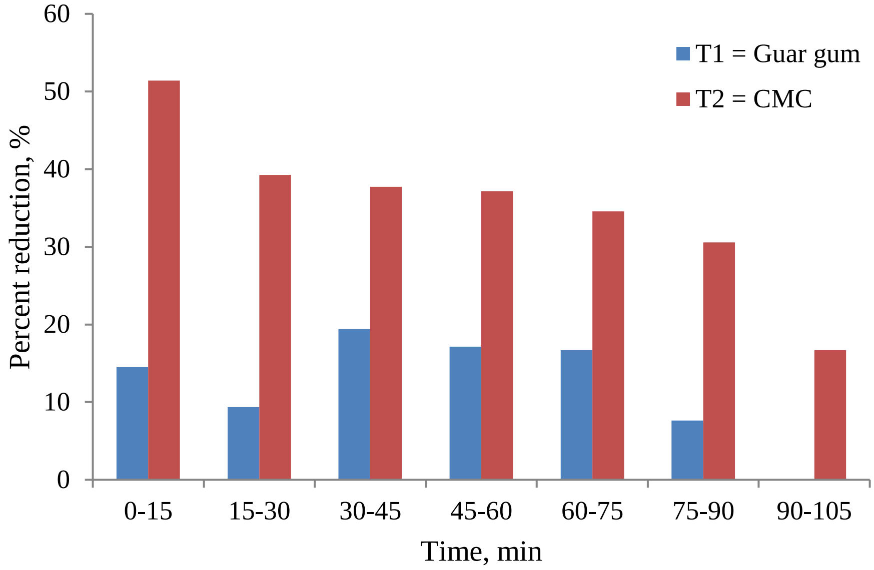
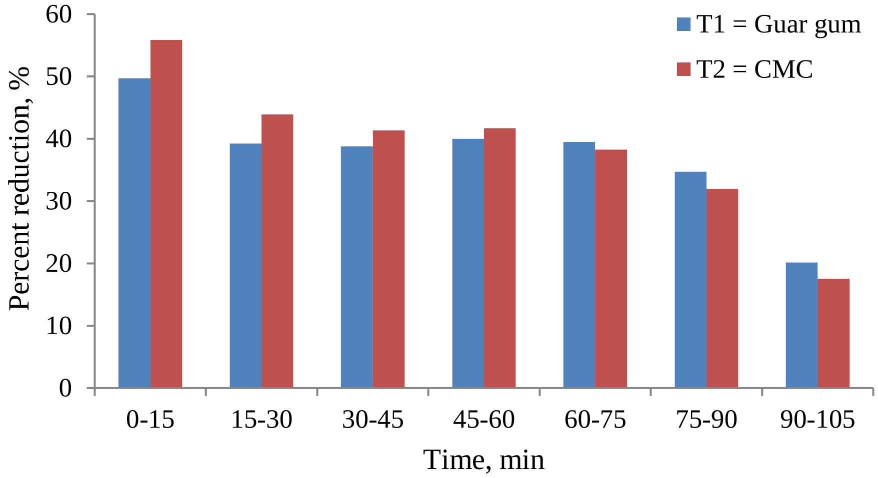


(a) At 0.01% concentration



(b) At 0.025% concentration

Figure 4. Percent volume reduction in percolation treated with 0.01 and 0.025 percent concentrations of polymers

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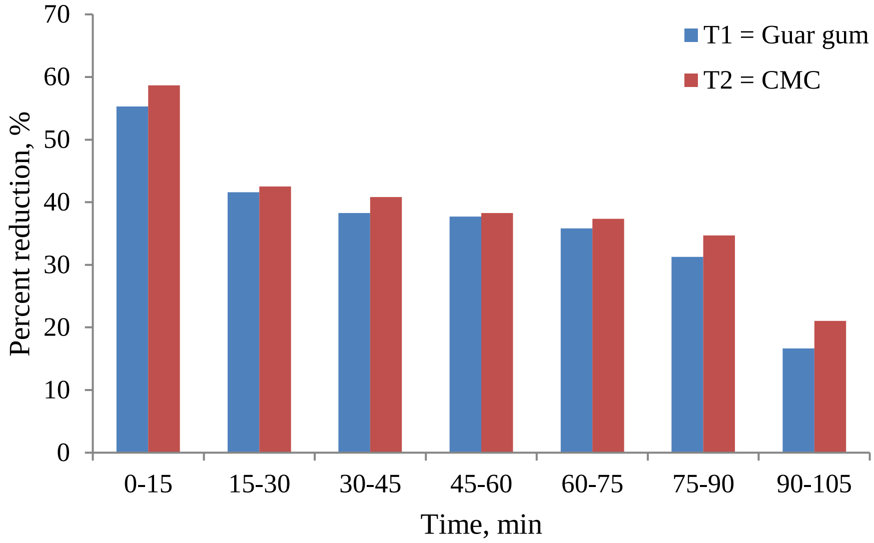
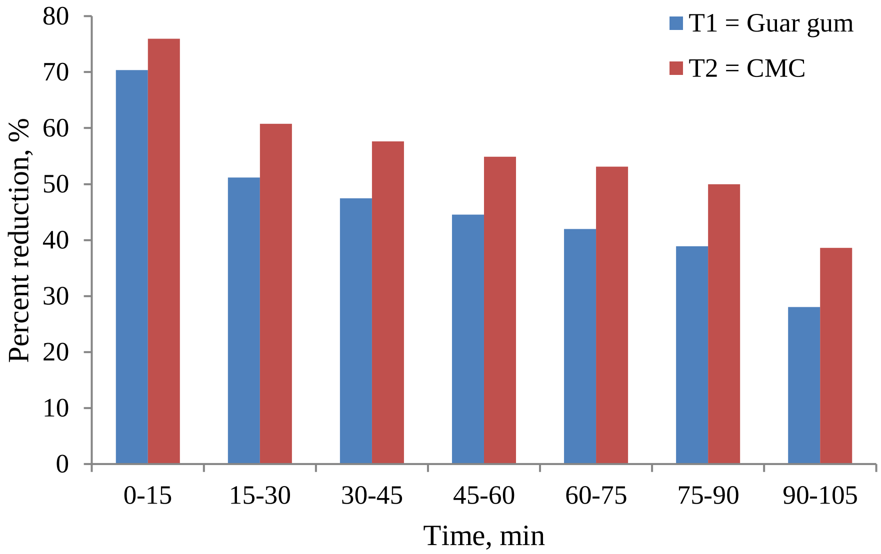


(a) At 0.05% concentration



(a) At 0.1% concentration

Figure 5. Percent volume reduction in percolation treated with 0.05 and 0.1 percent concentrations of polymers

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Table 1. Observation of percolation losses at 0.01% polymer treatment under laboratory conditions

Sl. No.	Time t, min	Cum. time t_c, min	Volume percolated, ml			Cum. volume percolated, ml			Percent volume reduction in percolated water as compared to control, %	
			Untreated	Treated		Untreated	Treated			
			C1	T1	T2	C1	T1	T2	T1	T2
1	15	15	1790	1530	870	1790	1530	870	14.52	51.39
2	15	30	2140	1940	1300	3930	3470	2170	9.34	39.25
3	15	45	1960	1580	1220	5890	5050	3390	19.39	37.75
4	15	60	1750	1450	1100	7640	6500	4490	17.14	37.14
5	15	75	1620	1350	1060	9260	7850	5550	16.67	34.57
6	15	90	1440	1330	1000	10700	9180	6550	7.64	30.55
7	15	105	1140	1230	950	11840	10410	7500		16.67
8	15	120	140	980	870	11980	11330	8370		
9	15	135	40	170	830	12020	11560	9200		
10	15	150	20	40	790	12040	11600	9990		
11	15	165		20	720		11620	10710		
12	15	180			710			11420		
13	15	195			630			12050		
14	15	210			140			12190		
15	15	225			35			12225		

C1 = control, T1 = 0.1% Guar gum and T2 = 0.1% Carboxymethylcellulose

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Table 2. Observation of percolation losses at 0.025% polymer treatment under laboratory conditions

Sl. No.	Time t, min	Cum. time t_c, min	Volume percolated, ml			Cum. volume percolated, ml			Percent volume reduction in percolated water as compared to control, %	
			Untreated	Treated		Untreated	Treated			
			C1	T1	T2	C1	T1	T2	T1	T2
1	15	15	1790	900	790	1790	900	790	49.72	55.86
2	15	30	2140	1300	1200	3930	2200	1990	39.25	43.92
3	15	45	1960	1200	1150	5890	3400	3140	38.77	41.32
4	15	60	1750	1050	1020	7640	4450	4160	40.00	41.71
5	15	75	1620	980	1000	9260	5430	5160	39.50	38.27
6	15	90	1440	940	980	10700	6370	6140	34.72	31.94
7	15	105	1140	910	940	11840	7280	7080	20.17	17.54
8	15	120	140	830	920	11980	8110	8000		
9	15	135	40	810	880	12020	8920	8880		
10	15	150	20	800	830	12040	9720	9710		
11	15	165		780	800		10500	10510		
12	15	180		720	550		11220	11060		
13	15	195		410	170		11630	11230		
14	15	210		160	30		11790	11260		
15	15	225		40			11830			
16	15	240		20			11850			

C1 = control, T1 = 0.025% Guar gum and T2 = 0.025% Carboxymethylcellulose

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Table 3. Observation of percolation losses at 0.05% polymer treatment under laboratory conditions

Sl. No.	Time t, min	Cum. time t_c, min	Volume percolated, ml			Cum. volume percolated, ml			Percent volume reduction in percolated water as compared to control, %	
			Untreated	Treated		Untreated	Treated			
			C1	T1	T2	C1	T1	T2	T1	T2
1	15	15	1790	800	740	1790	800	740	55.31	58.66
2	15	30	2140	1250	1230	3930	2050	1970	41.59	42.52
3	15	45	1960	1210	1160	5890	3260	3130	38.26	40.82
4	15	60	1750	1090	1080	7640	4350	4210	37.71	38.28
5	15	75	1620	1040	1015	9260	5390	5225	35.80	37.34
6	15	90	1440	990	940	10700	6380	6165	31.25	34.72
7	15	105	1140	950	900	11840	7330	7065	16.67	21.05
8	15	120	140	820	840	11980	8150	7905		
9	15	135	40	780	810	12020	8930	8715		
10	15	150	20	750	770	12040	9680	9485		
11	15	165		740	740		10420	10225		
12	15	180		700	680		11120	10905		
13	15	195		500	660		11620	11565		
14	15	210		250	330		11870	11895		
15	15	225		40	40		11910	11935		
16	15	240		20	20		11930	11955		

C1 = control, T1 = 0.05% Guar gum and T2 = 0.05% Carboxymethylcellulose

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Table 4. Observation of percolation losses at 0.1% polymer treatment under laboratory conditions

Sl. No.	Time t, min	Cum. time t_c, min	Volume percolated, ml			Cum. volume percolated, ml			Percent volume reduction in percolated water as compared to control, %	
			Untreated	Treated		Untreated	Treated			
			C1	T1	T2	C1	T1	T2	T1	T2
1	15	15	1790	530	430	1790	530	430	70.39	75.98
2	15	30	2140	1045	840	3930	1575	1270	51.17	60.75
3	15	45	1960	1030	830	5890	2605	2100	47.45	57.65
4	15	60	1750	970	790	7640	3575	2890	44.57	54.86
5	15	75	1620	940	760	9260	4515	3650	41.97	53.09
6	15	90	1440	880	720	10700	5395	4370	38.89	50.00
7	15	105	1140	820	700	11840	6215	5070	28.07	38.60
8	15	120	140	800	650	11980	7015	5720		
9	15	135	40	740	630	12020	7755	6350		
10	15	150	20	720	620	12040	8475	6970		
11	15	165		680	600		9155	7570		
12	15	180		670	570		9825	8140		
13	15	195		620	540		10445	8680		
14	15	210		600	530		11045	9210		
15	15	225		260	510		11305	9720		
16	15	240		50	470		11355	10190		
17	15	255		20	430		11375	10620		
18	15	270			410			11030		
19	15	285			400			11430		
20	15	300			200			11630		
21	15	315			30			11660		

C1 = control, T1 = 0.1% Guar gum and T2 = 0.1% Carboxymethylcellulose

Conclusion: Application of polymer treatments in soil columns is found to be effective in reducing percolation loss of soil. The percolation loss in polymer treated soils was found to be lower as compared to untreated soil. The recorded observations reveal that percolation reduction in soil treated with Guar gum was 70.39% and Carboxymethylcellulose was 75.98% in first 15 minutes at 0.1% concentration. The maximum percolation rate was found from 15-30 minutes for all cases, because after first 15 min the water had already reached to bottom and the rate of percolation continuously decreases with time except for 15-30 min duration. The cummulated volume percolated in soil columns decreases with the increase in concentration of both polymers and maximum cummulated volume percolated was found for untreated condition. The time for the completion of the experiment increases with the increase in concentration polymers and minimum time was found for the control. This may be due to the reason that these polymers forms a viscous layer and chokes soil pores which leads to reduction in percolation loss of the soil and increases the completion time of experiment.

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