Assessing the Effectiveness of Polymers as a Sealant Material to Control the Seepage Losses in Earthen Channels

Muhammad Awais[1], Muhammad Munir Babar[1], Joseph Scalia[2], Timothy K. Gates[2]

[1]*US-Pakistan Center for Advanced Studies in Water, Mehran-UET, Jamshoro, Sindh, Pakistan*
[2]*Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, U.S.A*

Abstract: **Earthen irrigation canals result in the loss of substantial amount of total supplied irrigation water due to seepage losses. The reduction of these losses can save a significant amount of water. In this study, the capability of some polymers in reducing the seepage losses in the earthen canal is evaluated. The objectives of this research: firstly, to evaluate the effectiveness of some polymers in reducing seepage; secondly, to quantify the interaction of polymers and suspended sediments (TSS). Three types of polymers (Linear Anionic Polyacrylamide (LA-PAM), Carboxymethyl Cellulose (CMC), and Modified Cellulose Gum (MCG)) were used. Each type is tested with three polymer loadings: (0mg/l (control), 50mg/l, and 75mg/l) under three different sediment contents (250ppm, 450ppm, 900ppm). Experimentation was performed in a soil column using the constant-head method. Polymers were added into the soil column, and suspended sediments were continuously added and mixed with an electronic mixer. The outflow rates were measured for each of the tests. Darcy's equation was used to calculate saturated hydraulic conductivities (K_{sat}). Results showed, the LA-PAM reduced K_{sat} 60 to 80%, but the reduction was less in CMC (20-40%) and MCG (8-30%). The results, when the quantity TSS increased by twice, also showed K_{sat} reduced 1.5 to 2 times.**

Keywords**: Constant head method, Hydraulic conductivity, Polymers, Seepage.**

I. INTRODUCTION

The preservation of water has become a significant concern. Mainly due to two inevitable reasons; firstly, the demand for this vigorous congenital resource is at rising. Secondly, prevalent as well as new sources of supply are depleting rapidly. Therefore, the aforementioned causes have posed a great threat over the water losses in the field of agriculture. Thus, making the study of sustention of the water resources, besides its multi-fold application, is a subject of great importance to the agriculture development of a country. During the transportation of irrigation water from the delivery point to farmlands, a sizeable amount of canal water is lost due to seepage through the channel's bed and sides. Around 50% of total water diverted to farms is lost during conveyance [1].

The losses in earthen canals of Pakistan are around 26% [2]. The loss of water in unlined field watercourses in Pakistan is about 66% [3]. Besides causing this invaluable resource to be wasted, seepage through channels leads to various negative impacts on the environment. Waterlogging and soil salinity are some of the consequences of the environmental degradation engendered by the seepage and result in declining crop yield [4]. Seepage through canals raises the groundwater table and eventually makes the land saline [5]. The repercussion of seepage, the backflow of groundwater to freshwater sources, conveys various pollutants [6]. Groundwater contamination could happen because of seepage [7].

In order to alleviate the issue, standard lining practices: cement concrete lining, geo-membrane lining, asphalt lining, etc., are being used globally. Cement concrete lining can reduce seepage up to 95% [8]. However, these methods are costly in terms of material, construction, and maintenance. So, substitutes that are efficient and cost-effective are needed. In recent studies, polymers are found to be effective materials in reducing seepage from earthen canals and a viable option in terms of efficiency and cost-effectiveness. Polyacrylamide (PAM) is a synthetic polymer composed of thousands of acrylamide monomers (-CH2CHCONH2-) linked together [9]. PAMs are of two types, cationic and anionic. Anionic PAMs can be cross-linked polyacrylamide (XPAM) or linear anionic polyacrylamide (LA-PAM). Due to its adverse impacts on the environment, XPAM is considered ill-adopted. LA-PAM is an inexpensive sealant material that can easily be applied to reduce seepage [10].

Applications can reduce seepage losses from 28 to 87% within 24 hours [11]. LA-PAM applications on earthen canals in the Lower Arkansas River Valley, Colorado, showed up to 100% efficiency in reducing canal seepage [9]. LA-PAM in granular form flocculates the sediments suspended in the canal water and settles down to the canal bed obstructing the water to seep through the bed [12]. The cost of LA-PAM applications per year can be less than 2% of the average annual cost of conventional lining methods [9].The organic polymers have the least negative impacts on the environment. The effectiveness of two organic polymers, Modified cellulose gum, and Carboxymethyl cellulose, is also assessed.

II. MATERIALS & METHODS

A. *Materials*

i. *LA-PAM:*

The polymer used in this study is Magnafloc LT27 AG portable water-electrolyte. This polymer has a very high molecular weight and is a polyacrylamide- based flocculants having an anionic chemical structure. Applications of LA-PAM include the treatment of drinking water, in plastic industries, and sugar processing resulting in high-quality sugar and higher yield.

i. *CMC and MCG*

Carboxymethyl cellulose and Modified cellulose gum are organic polymers. These are essential products of cellulose ethers produced by the modification of natural cellulose. CMC in acid form has poor water solubility, and it is kept safe as sodium CMC. Both CMC, as well as MCG, can be used as flocculating agents, chelating agents, water-retaining agents, sizing agents, and film-forming material.

ii. *Soil used*

The soil used in all experiments is a typical of Arkansas River Valley Canal having a loamy texture.

B. *Methods*

Constant head permeameter method in soil columns is used to conduct various experiments. The schematic diagram shown in (fig.1) illustrates the mechanism involved in conducting the experiments. A Permeameter of 49cm long and 15cm in diameter was used in which a 3-4cm layer of gravels is placed over which 20cm soil specimen was placed. The soil specimen and aggregates were kept separated by a non-woven geotextile of the size equal to the diameter of permeameter. Initially, the soil was made saturated by allowing water from the bottom side with a pipe to remove the air altogether. The water was then added from the top. An overflow pipe was provided to maintain the constant head. An over-head water supply tank was used to supply water continuously using a siphon pipe. Three types of polymers (LA-PAM, CMC, and MCG) were examined with different loadings and under various conditions of suspended sediments. Electronic mixers were placed at the over-head tank and the permeameter in order to let the sediments suspended. Flow rates were measured continuously at various time intervals until the equilibrium was achieved. The average flow rates were then converted to hydraulic conductivities using Darcy's law.

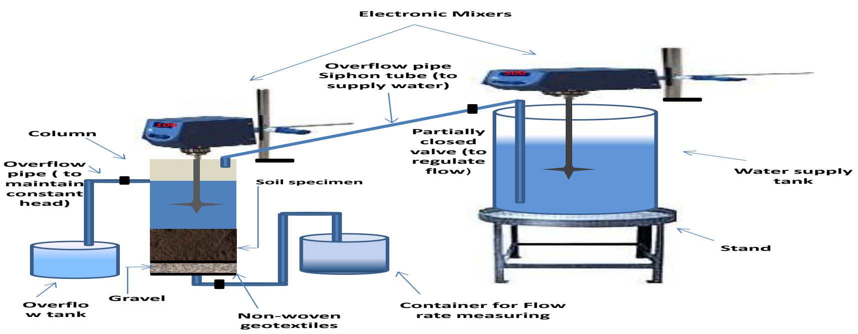

Fig. 1: Schematic diagram of the experimental setup

III. RESULTS

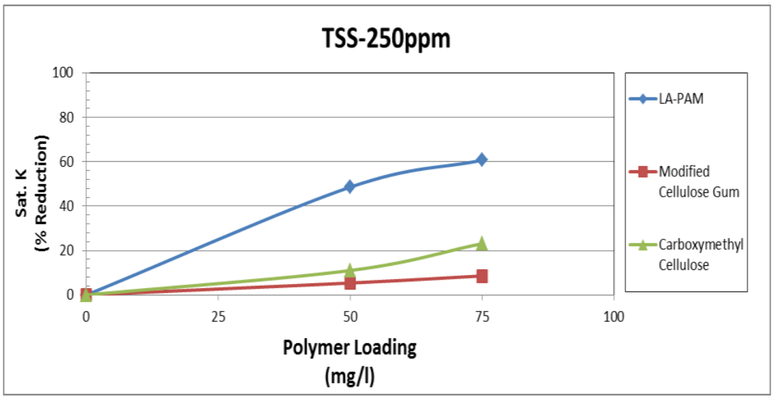

Fig. 2: % reduction in K_{sat} at TSS of 250ppm

Graphs in fig.2 show the percentage (%) reduction in saturated hydraulic conductivities of different polymers at suspended sediment content of 250mg/l. The reduction increases with the increase in polymer content. The maximum reduction of

60.73% was found in LA-PAM at 75mg/l polymer loading. The maximum reductions in MCG and CMC were only 8.56% and 23.11%, respectively.

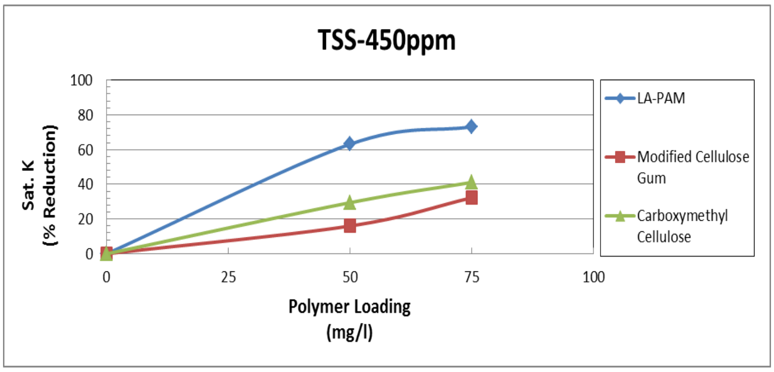

Fig. 3: % reduction in K_{sat} at TSS of 450ppm

Graphs in fig.3 show the percentage (%) reduction in saturated hydraulic conductivities of different polymers at suspended sediment content of 450mg/l. The reduction increases with the increase in polymer content. The maximum reduction of 73.16% was found in LA-PAM at 75mg/l polymer loading. The maximum reductions in MCG and CMC were 32.28% and 41.19%, respectively.

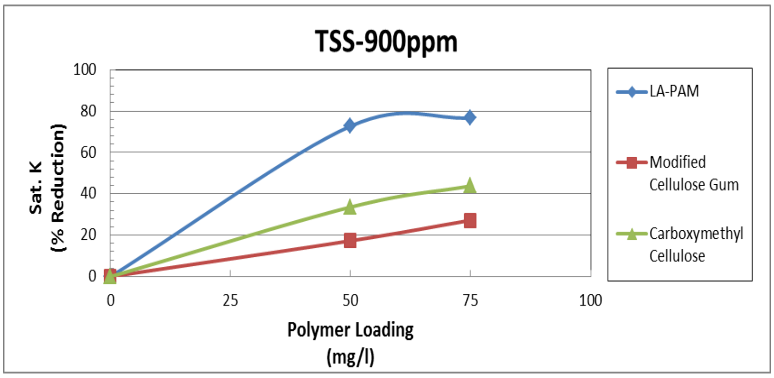

Fig. 4: % reduction in K_{sat} at TSS of 900ppm

Graphs in fig.4 show the percentage (%) reduction in saturated hydraulic conductivities of different polymers at suspended sediment content of 900mg/l. The reduction increases with the increase in polymer content. The maximum reduction of 76.07% is found in LA-PAM at 75mg/l polymer loading. The maximum reductions in MCG and CMC are 27.22% and 43.86%, respectively.

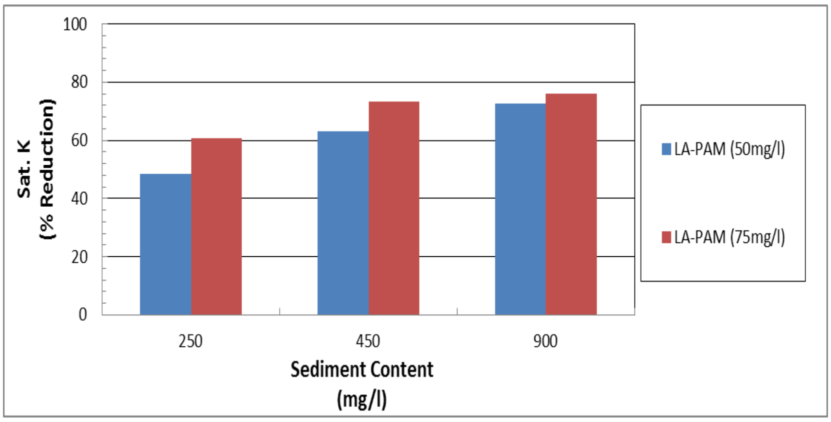

Fig. 5: % reduction in K_{sat} by LA-PAM

Columns shown in fig.5 show the % reduction in saturated hydraulic conductivities of LA-PAM under different suspended sediment contents. It can be seen that the reduction increases with the increase in suspended sediment content. The maximum reduction of 76.07% is found at the sediment content of 900mg/l with LA-PAM loading of 75mg/l.

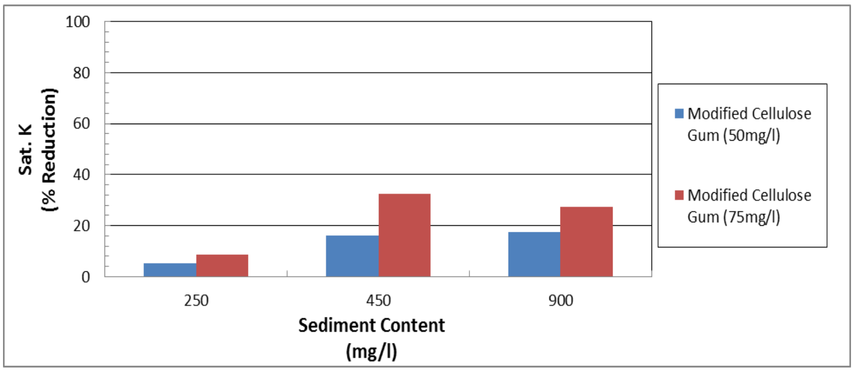

Fig. 6: % reduction in K_{sat} by MCG

Columns shown in fig.6 show the % reduction in saturated hydraulic conductivities of Modified Cellulose Gum (MCG) under different suspended sediment contents. It can be seen that the reduction increases with the increase in suspended sediment content. The maximum reduction of 32.28% is found at the sediment content of 900mg/l with MCG loading of 75mg/l.

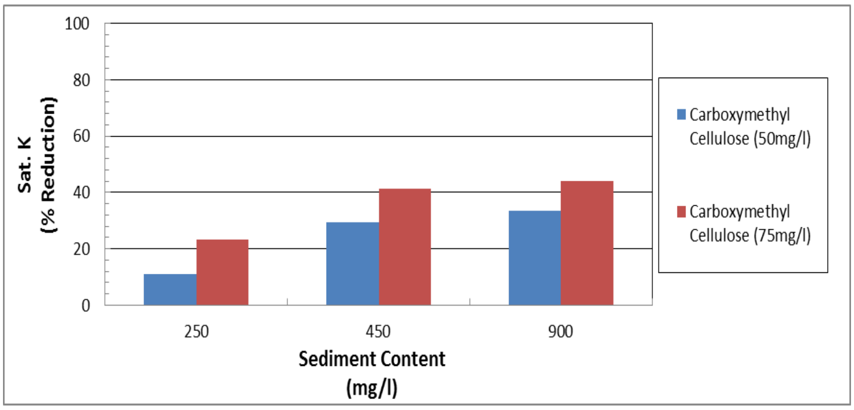

Fig. 07: % reduction in K_{sat} by CMC

Columns shown in fig.07 show the % reduction in saturated hydraulic conductivities of Carboxymethyl Cellulose (CMC) under different suspended sediment contents. It can be seen that the reduction increases with the increase in suspended sediment content. The maximum reduction of 43.86% is found at the sediment content of 900mg/l with MCG loading of 75mg/l.

IV. CONCLUSIONS

The research collates three types of polymers: Linear Anionic Polyacrylamide (LA-PAM), Carboxymethyl Cellulose (CMC), and Modified Cellulose Gum (MCG). The results encapsulate that the LA-PAM is found to be more effective than CMC and MCG in reducing K_{sat} of the soil. Moreover, the reduction was further promoted with the addition of suspended sediments. The best results (i.e., 76.07% reduction in K_{sat} as compared with control) achieved in LA-PAM concentration of 75mg/l at suspended sediment content of 900ppm.

V. RECOMMENDATIONS

The research evaluates the effectiveness of various polymers in reducing K_{sat} of the soil. This study also defines the relationship of polymers' effectiveness with different sediment load concentration and polymer dosage. The outcomes of the study show that the LA-PAM can be used in earthen irrigation channels to control the seepage through the soil. It is recommended that LA-PAM should be applied in real fields for witnessing its feasibility, durability, and practicality. The better understanding of seepage reduction by LA-PAM under different scenarios is likely to facilitate its use by the real field conditions in different areas of the country.

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