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Rate of absorption and optimal amount of the hydrogel products depending on the pH of different water sources

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ABSTRACT

In this article, the process of absorption of various hydrogels and their optimal concentration in distilled, stream, underground (drainage) water at pH 5, 7 and 9 were determined. AQUASORB from France, STOCKOSORB from Germany, Mujiza hydrogel from Uzbekistan were used in the experiment. According to the results, 12.5 g AQUASORB, 15 g STOCKOSORB, and 60 g Mujiza were used in 1 L distilled water with a medium pH of 5 and a gel of 100% volume was formed. When the pH of the distilled water was 7, 15 g AQUASORB, 20 g STOCKOSORB, and 50 g Mujiza were used. Distilled water was alkaline, when pH was 9 and 10 g AQUASORB, 7.5 g STOCKOSORB, and 40 g Mujiza were used. It was determined that the hydrogels' sorption amount was in different concentrations even when the water of the stream and well (drainage) were pH 5, 7 and 9, and a recommendation was given for its use.

Keywords: Sorption, Hydrogel, pH, Distilled water, Waste water, Underground (drainage) water.
Article type: Research Article.

INTRODUCTION

In the conditions of water scarcity, the use of water resources is one of the most urgent problems facing not only our republic, but the entire world community (Morozov 2016). One such innovative raw material is hydrogel granules, a moisture accumulator that collects and retains moisture in the soil. It is also called plant and soil conditioner. A hydrogel is a polymer granule, that's all are superabsorbents (SAP). A superabsorbent can absorb up to 500 times its weight in water (in distilled water) by turning into water-insoluble gels. Since the polymer cannot dissolve due to the covalent crosslinks, water uptakes far in excess of those achievable with hydrophilic linear polymers can be obtained (Robinson & Lee 2009; Jasim & Aljeboree 2021; Radhy & Jasim 2021).

Owing to their high water content, porosity and soft consistency, they intently simulate natural living tissue, more so than any other category of synthetic biomaterials. Hydrogels can either be chemically durable or they may eventually disintegrate and dissolve (Peppas *et al.* 2000). Hydrogels are broadly classified into two categories: Permanent / chemical gel: they are called 'permanent' or 'chemical' gels when they are covalently cross-linked (replacing hydrogen bond by a stronger and stable covalent bonds) networks (Hennink& Nostrum 2002; Ahmed 2015). Hydrogels are also known as 'reversible' or 'physical' gels if molecular entanglements and/or secondary forces such as ionic, hydrogen bonding or hydrophobic forces play the main role in forming the linkage. Physical gels are often rescindable and it is achievable to dissolve them by altering the environmental conditions, such as pH and the ionic strength of solution or temperature (Nho *et al.* 2005; Hoffman 2012). These are similar to conventional hydrogels except these gels may exhibit significant volume changes in response to small changes in pH, temperature, electric field, and light (Jarry *et al.* 2002; Robinson & Lee 2009). Hydrogels may be chemically stable or they may degrade and eventually disintegrate and dissolve (Caló & Khutoryanskiy 2015). When the hydrogel soil dries, the polymer releases 95% of the absorbed water. This process takes place in the soil itself for

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five years. The hydrogel is able to retain a large amount of water and water-soluble fertilizer in recommended amounts for plants. It is known that all agricultural crops are irrigated mainly by streams and well (drainage) waters, and in turn, their pH environments are different. The instructions for use of all hydrogels indicate the amount of consumption only in the case of distilled (pure water with a pH 7). Based on these data, this experiment was conducted in order to determine the rate of consumption of hydrogels for effective use in agriculture, according to different water sources and their pH environments.

MATERIALS AND METHODS

The experiment was conducted at the Khorezm Ma'mun Academy "Laboratory of Soil Fauna and Termites". In determining the sorption process, distilled, ditch, drainage (drainage) waters were used at pH 5, 7 and 9. AQUASORB made in France, Germany STOCKOSORB, and Uzbekistan Mujiza hydrogel were used (Table 1)

Table 1. Experimental design of hydrogels in different water sources and different pH.

No	Hydrogel type	Variations
1	AQUASORB	In distilled water at pH 5, 7 and 9 In ditch water at pH 5, 7 and 9 In underground (drainage) water at pH 5, 7 and 9
2	STOCKOSORB	In distilled water at pH 5, 7 and 9 In ditch water at pH 5, 7 and 9 Underground (drainage) water at pH 5, 7 and 9
3	Mujiza	In distilled water at pH 5, 7 and 9 In ditch water at pH 5, 7 and 9 Underground (drainage) water at pH 5, 7 and 9

Required equipment: pH meter, analytical balance, laboratory glasses, mixing glass wand, HNO_3 acid, KOH alkali.

Method of the scientific work: Initially distilled, ditch and well (drainage) waters were brought to pH 5, 7 and 9 using KOH (alkali) and HNO_3 (nitric acid) using a pH meter. AQUASORB, STOCKOSORB, Mujiza hydrogels were added to distilled, stream and well (drainage) waters with a pH of 5, 7 and 9 in excess of 0.25 g until the formation of a gel (sorption process) and the optimal amount of sorption was determined.

RESULTS AND DISCUSSION

Option I: AQUASORB hydrogel

In the case of AQUASORB hydrogel, 1, 1.25, 1.5 and 2 g were measured and mixed with 0.1 L distilled water. 90% of gels were formed from 1 g of hydrogel mixture, 130% from 2 g of hydrogel mixture of distilled water with medium pH 5.

Table 1. AQUASORB hydrogel mixture in distilled water at pH 5, 7 and 9.

AQUASORB hydrogel (g)	Distilled water (mL)	Increase hydrogel volume in the result of absorption (%)		
		pH 5	pH 7	pH 9
1	100	90	100	80
1.25	100	100	110	90
1.5	100	110	120	100
2	100	130	130	120

The hydrogel mixture in water formed 100% to 130% gel when the medium pH was 7, and 80% to 120% gels were formed in distilled water at pH 9 (Table 1).

Table 2. AQUASORB hydrogel in drainage water at pH 5, 7 and 9.

AQUASORB hydrogel (g)	Drainage water (mL)	Increase in hydrogel absorbing volume (%)		
		pH 5	pH 7	pH 9
1	100	80	80	80
1.5	100	100	100	100
2	100	120	120	120

Fig. 1: Gels formed from AQUASORB hydrogel mixture in distilled water medium pH 5, 7 and 9, 80% in glass 1 from left; 90% in glass 2; 100% in glass 3; 110% in glass 4; and view of gels at 120% volume in glass 5.

When 1, 1.5 and 2 g AQUASORB were mixed with 0.1 L stream water at pH 5, 80% by 1 g, 100% by 1.5 g, and 120% by 2 g of hydrogel mixture were formed. The consumption of hydrogel did not change even in the case of pH 7 and 9 (Table 2).

Table 3. AQUASORB hydrogel in the well water drainage at pH 5, 7 and 9.

AQUASORB Hydrogel (g)	Well water drainage (mL)	Increase in hydrogel absorbing volume (%)		
		pH 5	pH 7	pH 9
1	100	40	50	60
2	100	60	70	80
2.5	100	70	80	100
3	100	80	100	110
3.5	100	100	110	120

AQUASORB hydrogel to well (drainage) water was added as 1, 2, 2.5, 3 and 3.5 g. The minimum gel volume was 40% when the pH was 5, and 100% sorption was achieved when we added 3.5 g hydrogel to 0.1 L water. When the pH of well (drainage) water was 7, a gel in the form of complete sorption was formed by 3 g hydrogel. The normative gel appearance in water at pH 9 was 2.5 g in 0.1 L water (Table 3).

Option II: STOCKOSORB hydrogel

In the case of STOCKOSORB hydrogel, the mixture was prepared by adding 0.75, 1, 1.5 and 2 g to distilled water. The size of the gels formed ranged from 70% to 120% when the distilled water pH was 5, and the normative sorption process was formed when 1.5 g was added to 0.1 L water. The optimal amount of gel was 0.75 g of hydrogel in the case of pH 7. In water with pH 9, the optimal gel appearance was obtained when 2 g was used (Table 4).

Fig. 2. Gels formed from STOCKOSORB hydrogel mixture in distilled water at pH 5, 7 and 9; 70% in glass 1 from left; 100% in glass 2; 110% in glass 3; 120% volume gels in glass 4.

Table 4. STOCKOSORB hydrogel in distilled water at pH 5, 7 and 9.

STOCKOSORB hydrogel (g)	Distilled water (mL)	Increase in hydrogel absorbing volume (%)		
		pH 5	**pH 7**	**pH 9**
0.75	100	70	100	50
1	100	80	110	60
1.5	100	100	130	80
2	100	120	150	100

Table 5. STOCKOSORB hydrogel in drainage water at pH 5, 7 and 9.

Hydrogel (g)	Drainage (mL)	Increase in hydrogel absorbing volume in%		
		pH 5	**pH 7**	**pH 9**
1	100	80	80	70
1.5	100	100	100	90
1.75 _	100	110	110	100
2	100	120	120	110

In the case of stream water in pH 5, 7 and 9, amounts of 1, 1.5, 1.75 and 2 g STOCKOSORB hydrogel were used and gels of 80% to 120% volume were formed. Optimum gels were formed using 1.5 g hydrogel at pH 5 and 7, and 1.75 g hydrogel at pH 9 (Table 5).

Table 6. STOCKOSORB hydrogel in well water at pH 5, 7 and 9.

Hydrogel (g)	Well water (mL)	Increase in hydrogel absorbing volume in%		
		pH 5	**pH 7**	**pH 9**
1	100	60	70	70
1.5	100	80	80	80
1.75	100	90	100	100
2	100	100	110	110

In the case of STOCKOSORB hydrogel in well (drainage) water at pH 5, 7 and 9, a rate of 60% to 110% gels were formed from the hydrogel mixture in 0.1 L water. The complete absorption process was formed when 2 g hydrogel was consumed in 0.1 L water at pH 5, while 1.75 g at pH 7 and 9 (Table 6).

Option III: Hydrogel Mujiza

60% to 120% gels were formed from the Mujiza hydrogel mixture in pH 5, 7 and 9 with 0.1 L distilled water. When 100% gel was used at pH 5, 6 g hydrogel was used. In addition, we used 4 g at pH 7, and 5 g hydrogel at pH 9 (Table 7).

Fig. 3: Gels formed from a Mujiza hydrogel mixture in a distilled water at pH 5, 7 and 9; From right gels of 60% in the 1st glass, 80% in the 2nd glass, 100% in the 3rd glass, and 120% in the 4th glass.

Table 7. Hydrogel Mujiza in distilled water at pH 5, 7 and 9.

Hydrogel Mujiza (g)	Distilled water (mL)	Increase in hydrogel absorbing volume (%)		
		pH 5	pH 7	pH 9
4	100	60	100	80
5	100	80	120	100
6	100	100	140	120

Table 8. Hydrogel Mujiza in drainage water at pH 5, 7 and 9.

Hydrogel Mujiza (g)	Drainage water (mL)	Increase in hydrogel absorbing volume in%		
		pH 5	pH 7	pH 9
2	100	50	50	50
3	100	80	80	80
4	100	90	90	90
5	100	100	100	100

Hydrogel mixtures of 2, 3, 4 and 5 g Mujiza hydrogel were prepared in stream water. When the pH was 5, a total of 50% by 2 g, 80% by 3 g, 90% by 4 g, and 100% by 5 g hydrogel mixture were formed. This indicator did not change in the case of pH 7 and 9 (Table 8).

Table 9. Hydrogel Mujiza in well water at pH 5, 7 and 9.

Hydrogel Mujiza (g)	Well water (L)	Volume increase of hydrogel due to absorption in %		
		pH 5	pH 7	pH 9
5	0.1	50	80	80
5.5	0.1	60	90	90
6	0.1	80	100	100
6.5	0.1	100	110	110

In the case of Mujiza hydrogel in well (drainage) water; 5, 5.5, 6 and 6.5 g were used. In 0.1 L water at pH 5, 50% by 5 g, 60% by 5.5 g, 80% by 6 g, and 100% by 6.5 g hydrogel were formed. The gel volumes formed at pH 7 and 9 were almost identical, ranging from 80% to 110% (Table 9). According to the results, the distilled, stream and well (drainage) water with a pH of 5 was 0.1, 1 and 10. It was determined that how much hydrogel is used for 100 L. If 12.5 g AQUASORB hydrogel is mixed with 1 L distilled water, a gel of 100% volume is formed. In the case of STOCKOSORB, it was 15 g, while once 60 g Mujiza hydrogel was used, a full volume of gel was formed. Consumption of AQUASORB and STOCKOSORB hydrogels in stream water with a pH 5 was uniform, and full volume gels were formed when 15 g were consumed per 1 L water.

Table 10. Application of different hydrogels in the various water sources at pH 5.

The water volume (L)	Distilled water			Drain water			Well (drainage) water		
	AQUASORB (g)	STOCKOSORB (g)	Mujiza (g)	AQUASORB (g)	STOCKOSORB (g)	Mujiza (g)	AQUASORB (g)	STOCKOSORB (g)	Mujiza (g)
0.1	1.25	1.5	6	1.5	1.5	5	3.5	2	7
1	12.5	15	60	15	15	50	35	20	70
10	125	150	600	150	150	500	350	200	700
100	1250	1500	6000	1500	1500	5000	3500	2000	7000

In Mujiza hydrogel, this indicator was 50 g per 1 L water, that is, 3 times more than AQUASORB and STOCKOSORB hydrogels. The consumption of hydrogel in well (drainage) water is more than other water contents, the expected result was achieved when using 35 g AQUASORB hydrogel, 20 g STOCKOSORB hydrogel, and 70 g of Mujiza hydrogel in 1 L water (Table 10).

Table 11. Application of different hydrogels in the various water sources at pH 7.

The water volume (L)	Distilled water			Drain water			Well water (drainage)		
	AQUASORB (g)	STOCKOSORB (g)	Mujiza (g)	AQUASORB (g)	STOCKOSORB (g)	Mujiza (g)	AQUASORB (g)	STOCKOSORB (g)	Mujiza (g)
0.1	1	0.75	4	1.5	1.5	5	3	1.75	6
1	10	7.5	40	15	15	50	30	17.5	60
10	100	75	400	150	150	500	300	175	600
100	1000	750	4000	1500	1500	5000	3000	1750	6000

Distilled, stream, well (drainage) waters exhibited the same reaction to pH 7. The consumption of 0.1, 1 and 10 gr hydrogel in the amount of 100 L was determined. When 10 g AQUASORB hydrogel was used in 1 L distilled water, a gel of 100% volume was formed, while this indicator displayed the full absorption volume when 7.5 g STOCKOSORB hydrogel and 40 g Mujiza hydrogel were used. The expected result was achieved when 15 g AQUASORB and STOCKOSORB were used in clean water. In well (drainage) water, this indicator was different, so that, by adding 30 g AQUASORB, 17.5 g STOCKOSORB and 60 g Mujiza hydrogel to 1 L water, 100% of gels were formed (Table 11).

Table 12. Application of different hydrogels in the various water sources at pH 5.

The water volume (L)	Distilled water			Drain water			Well water (drainage)		
	AQUASORB (g)	STOCKOSORB (g)	Mujiza (g)	AQUASORB (g)	STOCKOSORB (g)	Mujiza (g)	AQUASORB (g)	STOCKOSORB (g)	Mujiza (g)
0.1	1.5	2	5	1.5	1.75	5	2.5	1.75	6
1	15	20	50	15	17.5	50	25	17.5	60
10	150	200	500	150	175	500	250	175	600
100	1500	2000	5000	1500	1750	5000	2250	1750	6000

15 g AQUASORB, 20 g STOCKOSORB, and 50 g Mujiza hydrogel were formed in 1 L distilled water in pH 9 and 100% gels were formed. In the case of stream water, 15g AQUASORB, 17.5 g STOCKOSORB and 50 g Mujiza hydrogel was needed . In the well (drainage) water, the optimal amounts of gel for 1 L water were obtained when adding 25 g AQUASORB, 17.5 g STOCKOSORB, and 60 g Mujiza (Table 12).

CONCLUSION

The expected absorption process was observed when the lowest amount of distilled water was used in all pH with the French AQUASORB hydrogel (12.5 g was used at pH 5, 10 g at pH 7, and 15 g at pH 9). The expected absorption process in well (drainage) waters was determined when the German STOCKOSORB hydrogel was used in the lowest amount (20 g at pH 5, 17.5 g at pH 7and 17.5 g at pH 9 per 1 L water). In stream water at pH 5, 7 and 9, French AQUASORB and German STOCKOSORB hydrogels were used in the same amounts (15 g per 1 L water, 17.5 g STOCKOSORB at pH 9). In conclusion, it was found that the absorption process of hydrogels depends on the pH environment of water sources. Recommendations have been developed for the correct amounts using France AQUASORB, Germany STOCKOSORB, Uzbekistan's Mujiza hydrogels, produced in different companies, in conditions of pH 5, 7 and 9 in distilled from water sources, streams and wells (drainage).

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