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RUNOFF BEHAVIOUR OF SOIL SEALANTS FOR HARVESTING RAINWATER IN AN ARID ENVIRONMENT

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ABSTRACT

Ten locally available water harvesting sealants were evaluated by simple linear regression analysis of rainfall-runoff data recorded daily over a period of four years (1972-75) at Jodhpur. The runoff efficiency of various treatments, initially in the first year, was in the order : janta emulsion = sodium carbonate > mud plaster, Road Research Laboratory (RRL) > lime concretion > bentonite > stabilization > mud plaster > grass = control > cement plaster. Finally the runoff efficiency was in the order : sodium carbonate > lime concretion = janta emulsion > mud plaster (RRL) > bentonite > mud plaster > cement plaster = stabilization > control > grass in the fourth year. Only sodium carbonate, janta emulsion and lime concretion maintained > 40% runoff efficiency by the end of fourth year.

INTRODUCTION

Harvesting of rain water in the arid regions can be improved by applying suitable surface sealants. Evaluation of such treated water-harvesting catchments implies the field determination of the percentage of runoff (Murthy et al., 1978; 1980). However, this method does not consider threshold rainfall – the minimal rainfall necessary to produce runoff which may constitute a significant proportion of the total potential runoff in the arid environments (Morin and Benyamini, 1977; Sharma et al., 1983). In the present study, the statistical technique of Frasier (1975) was applied to evaluate the water harvesting soil sealants used over a period of four years (1972-75).

MATERIALS AND METHODS

Water harvesting experiments were conducted at Central Research Farm of the Central Arid Zone Research Institute, Jodhpur (26.20°N, 73.03°E). The study area has deep loess soil (Order-Entisol; Group-Camborthid), loamy sand in texture (sand 81%, silt 8%, clay 11%; Bulk density 1.56 g/cm³), undeveloped structure and a profile with a $CaCO_3$ concretionary zone occurring at 75 to 90 cm depth. The monthly mean maximum and minimum temperatures vary from 25°C in January to 42°C in May and 10°C in January to 20°C in June, respectively. Annual potential evapotranspiration is 1850 mm, nearly five times greater than precipitation.

Indigenous soil sealants were tested on plots (2m x 20m) having 0.5% slope and following treatments were there:

1. Control
2. Soil-bentonite (1:4) plaster (1.25 cm thick)
3. Soil-cement cover 1. 25 cm thick (cement 8% by weight)
4. Mud plaster (mixture of soil + husk + cowdung) 1. 25 cm thick.
5. Compacted lime concretion (5 cm layer)
6. Cover of soil and janta emulsion (Esso product) mixed to a thickness of 1. 25 cm.
7. Mechanical stabilization (soil compacted to a depth of 10 cm).
8. Sodium carbonate (100 g/m^2) sprayed and a compacted surface of tank silt 1. 25 cm thick.
9. Mud plaster RRL (recommended by Road Research Laboratory : a mixture of tank silt, janta emulsion and wheat husk).
10. Grass cover : *Lasiurus sindicus* planted at a spacing 25 cm x 25 cm.

The rainfall-runoff data were daily recorded during the study period of 4 years (1972-1975). The runoff water was collected in 2m x 2m x 2m cement concrete tanks. The depth measurements were taken after each storm and rainfall was recorded by standard raingauge installed at the experimental site.

Against the mean annual precipitation of 366 mm, total rainfall received during 1972, 1973, 1974 and 1975 were 363, 642, 244 and 662 mm, respectively. Typical of the desert climate, precipitation pattern and storm size were extremely variable. During these four years only 67 precipitation events produced runoff.

Regression equation of all the treatments for the year 1972 to 1975 were established (Snedecor and Cochran, 1968). Values of correlation coefficient 'r', runoff efficiency 'B' and threshold rainfall P_0 were worked out. Graphs were plotted between rainfall and runoff for all the ten treatments and also for the year and runoff efficiency. For this analysis only those rainfall events which generated runoff were considered.

Theory

Values of annual efficiency of runoff generation and threshold rainfall - minimum rainfall to initiate the runoff, of any water harvesting system is obtained from a simple linear equation of the form –

$$R = A + BP$$

Where R is runoff per storm, P is storm size, A is intercept and B is slope of line.

Putting $R = 0$

$0 = A + BP$

$$\text{or } P = \frac{-A}{B} \qquad \dots \qquad (2)$$

The threshold value obtained from the P-axis intercept (i. e. $\frac{-A}{B}$) is denoted as P_0, then :

$$A = -BP_0 \qquad \dots \qquad (3)$$

Hence, equation (1) modifies to

$$R = B(P - P_0) \qquad \dots \qquad (4)$$

The coefficient B represents the runoff efficiency after the threshold rainfall has been exceeded.

At ideal conditions, very smooth newly prepared water repellent catchment should yield essentially cent per cent runoff and thus be independent of the vagaries of storm size and intensity, and antecedent moisture. There should be no infiltration of precipitation or no entrapment of water because of surface roughness, nor any wetting of the treated surface. Ideal parameters of the regression equation for such treatments are $A \rightarrow 0$, $P_0 = 0$, and $B = 1$.

RESULTS AND DISCUSSION

The efficiencies, as determined by the ratios of runoff to runoff generating rain fall (total rainfall - threshold rainfall) of janta emulsion and sodium carbonate treat ments were highest (92%) in the first year, 1972 (Fig. 1). But in the fourth year (1975), efficiency of janta emulsion treatment reduced more than that of sodium carbonate treatment. Maximum reductions in efficiencies were observed in the case of mud plaster and mechanical stabilization treatment. Initial efficiency of grass cover treatment was better than that of control and soil cement treatment but in 1975 it became lowest of all. Efficiency of lime concretion in the first year was much lower than that of janta emulsion treatment but in 1975 efficiencies of both the treatments dropped to the same level.

In first year the control, soil-cement and grass cover treatments had efficiencies less 50% and the remaining treatments had more than 60% efficiencies. In the fourth year, efficiency of the sodium carbonate treatment remained about 50%, of janta emulsion and lime concretion about 45% and, less than 25% for the rest of the treatments.

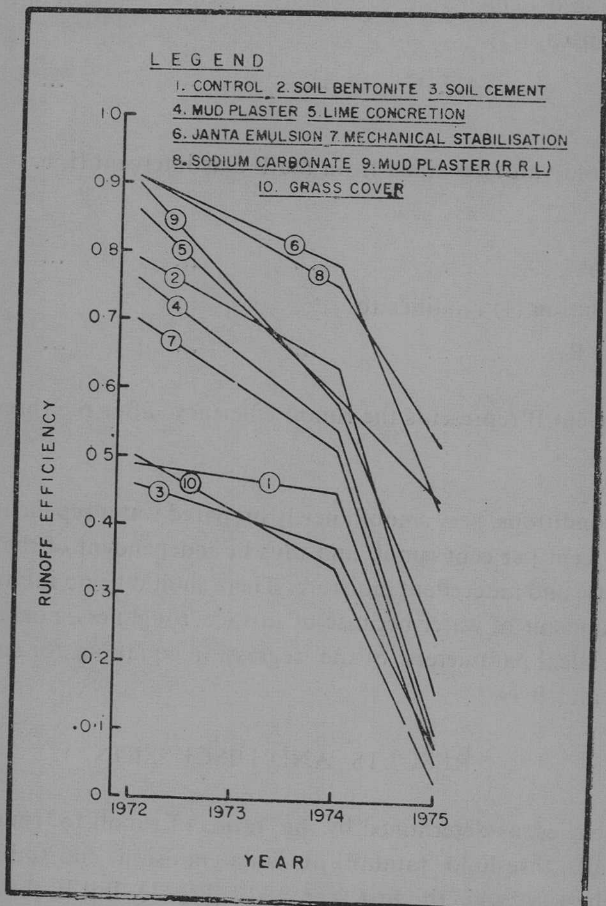

Fig. 1 Effect of time since the application of water harvesting sealants on runoff efficiency

In the first two years, threshold value was minimum in the case of janta emulsion and maximum in the case of control and cement-soil treatments (Fig. 2, and Table 1). In the fourth year, threshold value was maximum in the case of grass-cover treatment and lower in lime concretion in comparison with the janta emulsion and sodium carbonate treatments.

Table. 1. Correlation coefficients (r) between rainfall - runoff and threshold rainfall (P_0) for experimental water harvesting sealants in the years 1972-1975

S.No.	Treatment	1972		1973		1974		1975	
		r	P_0	r	P_0	r	P_0	r	P_0
1.	Control	0.783	7.7	0.824	7.6	0.975	6.1	0.580	3.2
2.	Soil-bentonite	0.930	2.6	0.906	4.1	0.986	4.8	0.786	4.8
3.	Soil-cement	0.889	7.7	0.919	5.9	0.985	10.1	0.620	3.5
4.	Mud plaster	0.912	4.5	0.917	4.8	0.980	7.6	0.560	6.1
5.	Lime concretion	0.983	5.6	0.983	5.6	0.976	5.1	0.820	4.3
6.	Janta emulsion	0.984	1.5	0.981	1.5	0.990	4.1	0.880	7.4
7.	Mechanical stabilization	0.946	6.1	0.953	5.8	0.990	11.9	0.660	10.0
8.	Sodium carbonate	0.981	3.1	0.983	3.5	0.990	4.0	0.860	7.9
9.	Mud plaster (RRL)	0.980	5.6	0.979	5.6	0.970	4.2	0.640	3.7
10.	Grass cover	0.747	7.6	0.877	3.8	0.990	8.9	0.600	10.3

Maximum initial runoff of 94.0% by janta emulsion treatment decreased to 29.2% in the fourth year (Table 2). Runoff percentage of sodium carbonate treatment, lower than janta emulsion treatment in the first year imporved in the subsequent years. Runoff percentage of lime concretion was lower than that of sodium carbonate and janta emulsion in 1972 but in fourth year it gave highest runoff among all treatments.

Table 2. Runoff-rainfall ratio over time for the water harvesting sealants

S.No	Treatment	Runoff percentage in the year			
		1972	1973	1974	1975
1.	Control	57.4	22.1	31.3	6.6
2.	Soil-bentonite	87.5	62.7	51.3	12.8
3.	Soil-cement	41.1	28.5	22.7	6.8
4.	Mud plaster	82.0	52.0	38.2	12.6
5.	Lime concretion	74.5	65.0	47.9	39.7
6.	Janta emulsion	94.0	82.4	66.2	29.2
7.	Mechanical stabilization	65.0	48.2	27.7	7.7
8.	Sodium carbonate	91.7	75.0	63.5	34.4
9.	Mud plaster (RRL)	78.7	67.6	48.8	20.3
10.	Grass cover	63.1	18.91	22.6	4.3

Over the period of time the surface sealing property of the sealants deteriorates due to weathering, alternate cycle of wetting and drying, and burrowing actions of animals as ants, rodents, etc. It resulted in the increase of threshold rainfall from 1.5 to 10.3 mm for the various sealants and decrease in the runoff efficiency from 0.9 to

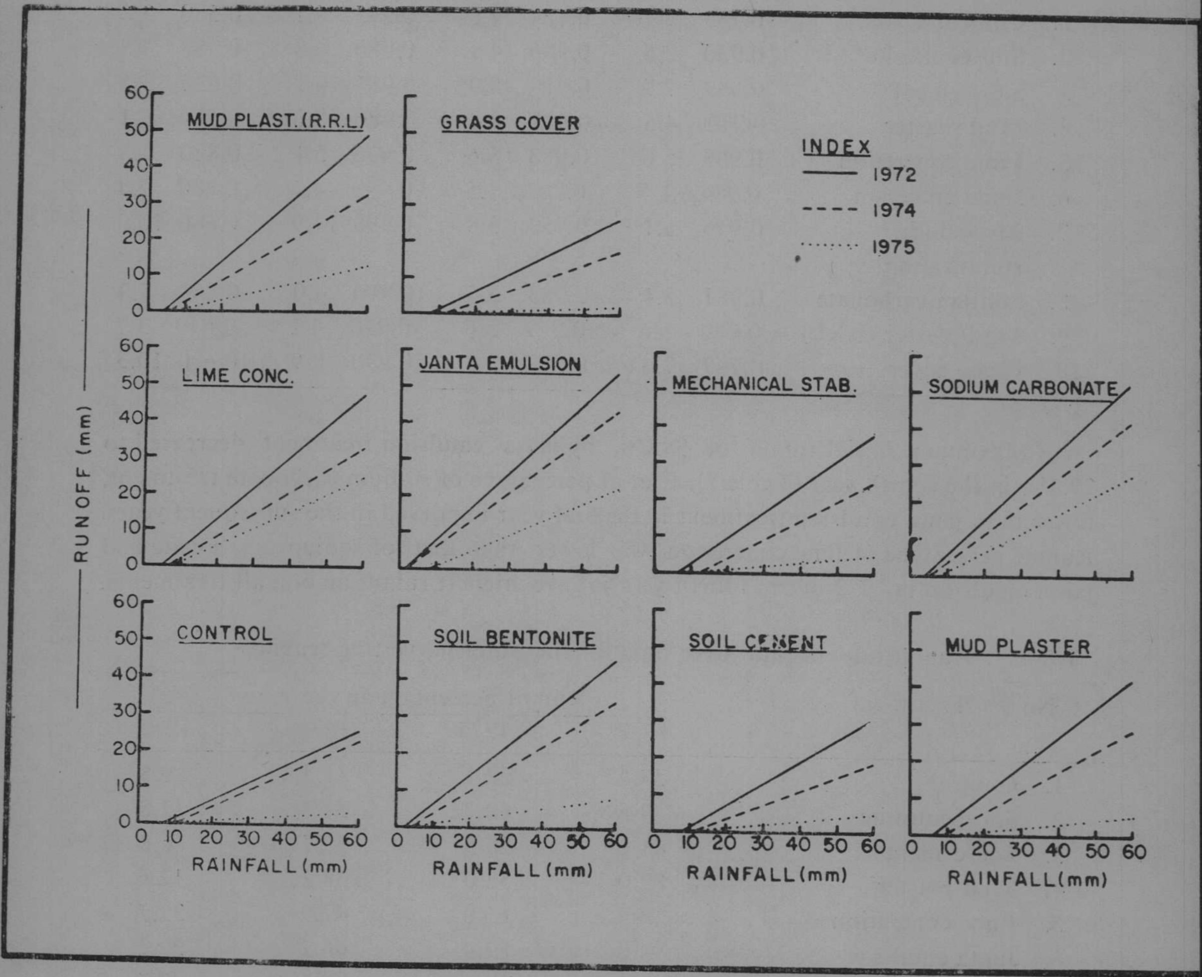

Fig. 2 Annual rainfall-runoff relationships of water harvesting sealants.

0.05. However, the degree of these processes depends on the nature of the sealants. The cracking of bentonite and soil cement caused much infiltration of rainfall into the ground. Murthy et al. (1982) also faced similar problem with the soil cement treatment. Mud plaster and janta amulsion generated the highest runoff initially but deteriorated due to the termite attack and excessive weed growth after the third year. Mechanical stabilisation failed due to the impact of rain drops and burrowing action of the animals.

Lime concretion and sodium carbonate spray were the best among all the treatments tried. They maintained nearly 50% runoff efficiency even at the end of fourth year. Sodium carbonate had been a widely used sealant material in the USA (Anonymous, 1981). Lime concretion swelled and reduced voids during rain. Also sodium presented in the sodium carbonate replaced calcium present in the soil resulting the clay to swell and plug the voids. Grass cover failed completely as a water harvesting material since it created favourable soil structure for the rain water infiltration.

Contrary to the deteriorating behaviour of the soil sealants over time, threshold rainfall decreased from 7.5 to 3.2 mm over a period of four years for the control, which was due to the formation of surface crust. Morin and Benyamini (1977) and Sharma (1986) reported that the hydraulic conductivity of crust reduced by a factor of 200 to 2000 times than the original soil. This resulted in more runoff, low surface retention and increased runoff efficiency over time.

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