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THE PRECIPITATION INFILTRATION AND RUNOFF RECHARGING EXPERIMENT OBSERVATION IN THE TAKLIMAKAN DESERT

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ABSTRACT: This is a certain quantity of available groundwater resources in the form of freshwater lens according to the survey and drilling experiment along the oil-transporting highway in the Taklimakan Desert, which is the second largest moving desert in the world, located in the northwest part of China. As the primary freshwater sources, local precipitation in the heartland of Taklimakan Desert, not only forms the runoff on the clayey ground, but also feeds the groundwater. After the analysis of historic records of the rainfall and the formation of clayey sediments, the precipitation infiltration and runoff recharging experiment was conducted, a natural rainfall-runoff process was observed and recorded. The studied area referred to this paper is located in the middle part of the desert, within 6 km wide and 60 km long along the new oil-transporting highway. This paper reveals that in the center of the desert an event of storm (4 mm) can be considered as the critical value of the runoff produced on the clayey ground. The rainfall infiltration coefficients on the sand dunes are over 0.46 for the erosion side, thus, rainstorms and runoffs as main fresh water sources feed the ground water directly.

KEY WORDS: precipitation, infiltration, runoff, Taklimakan Desert

1 INTRODUCTION

The local precipitation is most important available freshwater source in deserts. The Taklimakan Desert belongs to an extreme arid belt. According to a few years' limited observation data, it is estimated that the precipitation should be in the range of 30-50 mm annually. However in the centre of the desert, an event of storm to be up to or exceeding 20 mm may occur occasionally during rainy seasons. The rainstorms usually have a shorter duration and strong intensity. On the thinner layer of dry sand in moving dunes, the rainstorms compensate the underground water and thus form the freshwater lens (Chen, 1965; Kunin, 1962).

At the same time, in the low land between dunes or alluvial plains which are covered by dunes there are large or small parts of clayey ground. Owing to the lowest infiltration rate of the clay, it is easy to form surface flow. The surface water follows natural collecting networks and then penetrates into undersand layer or dunes around through surface soil, forming another kind of freshwater lens (Gao *et al*., 1994). This type of freshwater lens is the main sweet water resources in the desert centre.

The studied area is located in the middle part of the desert with an extension from Tarim Desert Oil-transport Highway K 0 to K 60, the two sides along the road are 6 km wide. According to the statistical data from aerial images the biggest catchment area is about 4 km^2, if including covered alkalisaline soil, poplar and *Tamarix* the area can be 82 km^2, equal to 11% of the studied area. The catchment with a bank form usually has a higher percentage along the sides of fossil rivers. On the flood-alluvial plains of the Tarim River the percentage can even be up to 70.

2 FEATURES OF PRECIPITATION AND VAPOUR

The precipitation record in the desert centre is scarce, there is no rainfall observation network and a few fixed stations observing rainfall have limited recording years. Thus the estimation of the precipitation in the big desert centre is very difficult. Great effort has been made to collect every available rainfall record, even short duration or only one storm. There are four station-years records data at Xiaotang and Mancan. Monthly precipitation in 1988 at Manxi and in 1989 at Tazhong No. 1 was recorded by Li Jiangfeng (1991) (Table 1).

It is practical to begin with a brief climatological analysis of the vapour sources and their channels in the desert. Outside moisture-laden air is the main source. Heavy rain storms are developed from high barie-topography systems. The fact that the humidity in air near bottom is only as much as half of the average at the same latitude indicates the vertical transport of local moisture may be omission.

Upper-air sounding record shows that the relative humidity (RH) in the air layer about 3000–4000 m altitude reaches 40% – 60%. The RH decreases at the lower altitude. At 1500 m it can also attains 30% – 50%. This altitude is about the same as that of the surrounding mountains. The alien-moisture coming into the basin through the vertical transporting induced by the vertical convection current originates storms.

Table 1 Monthly precipitation at fixed stations (mm)

Station	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Xiaotang	1991								34.0					34.0
	1992	1.6	0.0	0.4	0.0	35.5	6.4	6.5	0.2	1.2	0.9	0.0	0.0	52.7
	1993	0.8	0.0	1.9	0.0	4.5	8.7	13.1	10.4	0.0	0.0	0.1	0.0	39.5
	1994	0.0	0.0	0.0	0.5	0.8	21.7	0.1	32.3	0.3	1.0	0.0	0.0	56.7
Mancan No. 1	1992						1.6	15.8	4.0	0.0	0.0	0.0		
	1993	0.6	0.0	0.5	0.0	13.1								36.0
Manxi	1988	0.0	0.0	5.3	0.1	4.6	14.5	37.0	8.3	15.2	0.0	0.0	0.0	84.7
Tazhong No. 1	1989				0.0		10.4		12.6		0.0		0.0	23.0

The study of probable maximum precipitation (PMP) exhibits that the difference of PMP is only 1.1 mm between the northern and the southern of the Xinjiang Uygur Autonomous Region, while the actual annual precipitation difference reaches 100 mm. Therefore, the less precipitation of the southern is fundamently not due to the moisture but the dynamic and other conditions.

3 THE FORMATION AND EVOLUTION OF THE CLAYEY GROUND ON A SENSE OF CATCHMENT

The clayey layer is originated from the flooding and alluvial accumulation. The wandering stream causes rapid transformation of the landscape on alluviate plain. Once the clayey ground is formed, the runoff will enforce its forming process, which will further strengthen the takyr crust.

Naturally, clayey ground is easily to be covered by sand. As it is bare, the smoothy surface makes sand pass through easily. But if the drifting sand encounters with barrier such as dunes or shrubs, the accumulation begins around it. The deposition improves habitat conditions of shrubs which flourishing again enforce the deposition of sand.

The typical characteristics of clayey ground is its flatness and strong water-insulation. Most of the areas were cut by periodic runoff.

4 MEASURING AND ANALYSIS OF PRECIPITATION-RUNOFF ON THE RUNOFF EXPERIMENT SITES

On the basis of a comprehensive surveying along the oilroad, in order to understand the process of runoff collecting on the clayey ground (China National Petroleum Corporation, 1996), a set of experiment sites was set up at Xiaotang (40°50′N, 83°06′E), located to southwest of Xiaotang Meteorology Station, 200 m away from it, consisted of four runoff flats with square area of 100 m^2 (Fig. 1), 25 m^2, 4 m^2 and 1 m^2 respectively. Different slopes, roughness and degree of nature collection network cutting on soil surface were the mainly consideration factor to decide the actual site. 0.055 and 0.075 slopes of 100 m^2 and 25 m^2 plats not only are typical in the studied area, but also guarantee the natural flow. The flats were situated along one bank side of a natural washout gully (2 m wide, 1 m deep) into where the runoff on two sides areas streams. The gully's bottom is covered by clayey layer (2– 3 cm thick). It is this layer that ensures large amount of water to flow in the gully against infiltrating into the sand. Flats of 4 m^2 and 1 m^2 with the smooth ground serve as check flats. Artificial rainfall from sprinkler was conducted on 1 m^2 flat (Table 2).

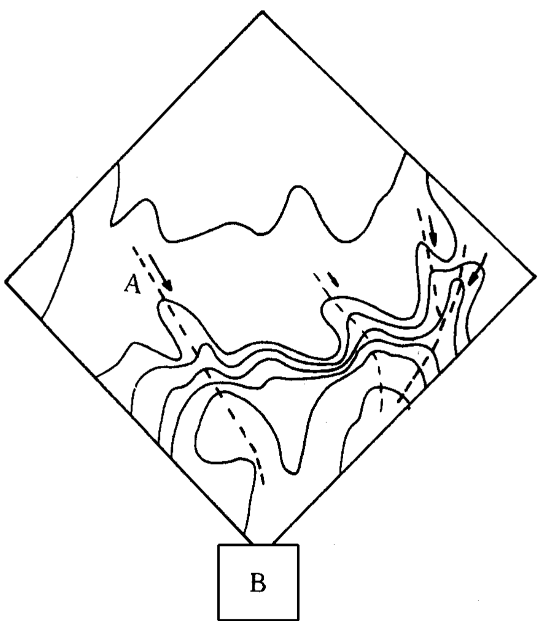

Fig. 1 Topographic map of 100 m^2 catchment (contour interval 5 cm)

Each flat erects barrier to prevent input or output of the local runoff. At one vertex angle in each of the flats digs a storage basin in which the cyclinder bucket collects water.

June 28, 1994 observed an event of rainstorm, the precipitation was recorded by automatic siphon gauge (DJS2). Artificial and siphon correction were conducted. The daily evaporation was 6.2 mm (Table 3). According to time weight distribution, during runoff producing period it evaporated 2.3 mm. precipitation of 3.8 mm in June 16 l as ted 20 minutes, it produced no flow, while the depressions in the flats collected water. So, amount of rainfall over 4.0 mm and intensity of 0.2 mm/min can be considered as the critical value of the runoff producing.

Table 2 Experiment result of artificial sprinkling on 1 m^2 catchment

Experiment number	Duration (min)	Sprinkling depth (mm)	Runoff depth (mm)	Coefficient	Sprinkling intensity (mm/min)
I	5	8.87	1.02	0.11	1.77
II	15	8.87	3.90	0.44	0.59
III	17	8.87	4.98	0.56	0.52
IV	18.5	8.87	2.81	0.32	0.48

Table 3 Meteorological factor on June 27 and 28

Date	Evaporation (mm)	Humidity (%)	Temperature (℃)
June 27	12.1	38	22.8
June 28	6.2	78	19.1

With the increase of the flat's area, the runoff coefficient rises absurdly. The fact reveals that on a certain range of areas, larger catchment enables the yield and confluence of basin to be of extreme uniformity which induces the trend in a direction favorable to the yield. Here the slope is not the main factor affecting the coefficient. Comparing to the experiment with sprinkler, it is suitable to adopt 0. 27 as runoff coefficient (Table 4).

Table 4 Characteristic values of runoff on stations on June 28

	Flat area (m^2)			
	100	25	4	1
Runoff volume (dm^3)	359. 4	62. 6	8. 02	1. 72
Runoff depth (mm)	3. 59	2. 48	2. 01	1. 72
Coefficient	0. 27	0. 18	0. 14	0. 12
Slope	0. 055	0. 074	0	0

The maximum flood peak is 6. 88 dm^3/min. This value is equal to collecting one bucket of water (bucket volume 17. 2 dm^3) in 2. 5 min. Considering the flood cross sectional area to be 0. 02 dm^2, the flow velocity is 0. 6 m/s. The velocity is high enough to bring up certain amount of suspended sediment, and to wash out ditches (Fig. 2).

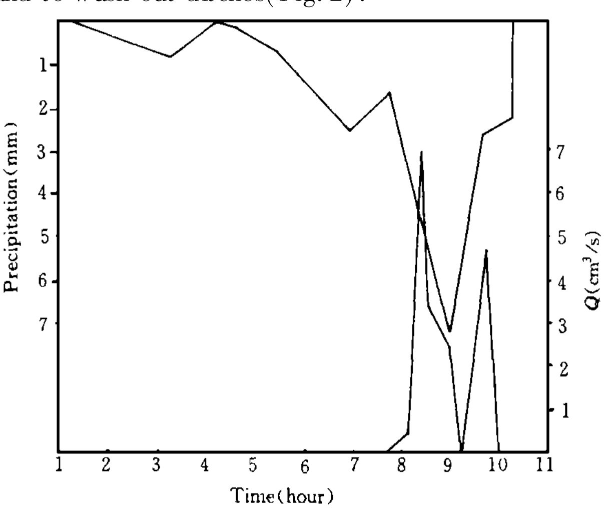

Fig. 2 Precipitation-runoff process on June 28

Recent years practice of desert surveying and sweetwater searching confirmed the existence of fresh water lens (Gao *et al*., 1994), undoubtedly local precipitation is the final source. What puzzles most is the effective rainfall amount and its ensurement. According to the records at Xiaotang and Mancan stations, runoff produced every year on clayey ground from 1992 to 1994 (Table 5). The minimum daily precipitation was 5. 3 mm in 1993 at Xiaotang. There was an antecedent influence rainstorm. A runoff was produced. This is the minimum value selected from all record years.

Table 5 Days of precipitation more than 4 mm at fixed stations

Station	Year	Days
Xiaotang	1992	3
	1993	2
	1994	2
Mancan	1992 (June– Dec.)	2
	1993 (Jan. – June)	1
Xingquman	1988	9
	1989	5
Manxi	1988	3

From all above, a conclusion can be made that in the studied region, the annual effective precipitation is regarded as 24 mm (statistical data adding up the recording rainfall more than 4 mm), runoff coefficient 0. 27, thus calculating the annual amount of runoff of 1. 36 million m^3.

5 DESERT INFILTRATION OF RAINFALL

Comparing with the freshwater lens around clayey ground borderline, the freshwater lens under the joint-together moving dunes and great composite longitudinal sand hills have a extensive distribution and no much water.

Due to the groundwater of 3– 5 g/L under the Taklimakan Desert most lack of adequate data about the later freshwater lens, only infiltration on dunes at one event of rainfall was recorded (Fig. 3).

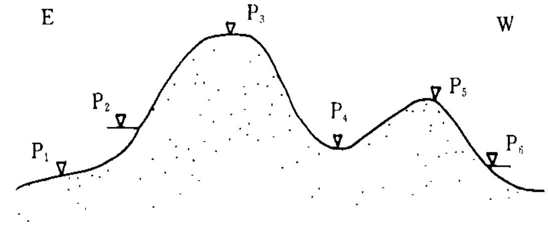

Fig. 3 Cross section of a dune

Few hours after the rainstorm (June 28), average depth of wet sand is 12.8 cm (wetting front in clayey ground is 4 mm depth, stable). The infiltration rate decreases even after, there is already no obvious wet surface in the dunes in July. At the thinner layer depressions between higher dunes, the rainstorms compensate the underground water rapidly (Table 6).

Table 6 Time-space distribution of infiltration depth on dune cross section (cm)

Location	28 June 13:00	June 28 18:00	June 28 21:00	July 29 11:00	June 30 10:00	July 1 22:00	July 2 21:00	July 4 11:00	July 5 11:30
P_1	12.7	15.0	12.0	13.0	18.0	17.0	21.0	19.0	24.0
P_2	12.4	14.5	17.0	20.0	23.0	19.0	17.0	20.0	21.0
P_3	15.0	15.0	14.0	16.5	20.0	21.0	22.0	24.0	26.0
P_4	12.7	∞	12.1	21.5	26.0	∞	∞	∞	∞
P_5	11.0	15.0	14.0	15.5	16.0	18.0	26.0	18.0	21.0
P_6	13.0	12.5	12.0	∞	16.0	20.0	24.0	22.0	27.0

The infiltration listed above is the observing result one month after the rain storm by using the collecting bottles at the different depth locations under ground. The effective depth of the evaporation reaches 30 cm at least. The rainfall infiltration coefficients on the dunes are 0.46 and 0.40 respectively for the erosion side and leeward slope, especially more at the erosion side because of the thin layers of drought sand (Table 7).

Table 7 Infiltration at different sites

Location	Depth (cm)	Infiltration (mm)	Infiltration rate
Erosion	10	0	
	20	8.3	0.46
	30	8.3	0.46
	55	8.9	0.50
Leeward	5	0	
	20	0.3	0.02
	30	6.6	0.37
	45	8.3	0.46

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