RAINFALL CHARACTERISTIC AND RAINWATER UTILIZATION MEASURES IN HEBEI PLAIN

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Abstract: Environments are deteriorating because of water resources severe scarcity in Hebei plain, and it has practical significance to make use of rain. The rainfall characteristic in Hebei plain were analyzed, it is characterized by seasonal rain, uneven spatial and temporal distribution, alternative flood and drought. The process of rainfall resourcefulization was studied from the viewpoint of hydrology and the connotation of rainwater utilization was also discussed in the paper. Rainwater in urban region are collected together for household use, Greenland irrigation, public facilities, man-made lake, etc. the main purposes of rainwater utilization in rural region prefer to agriculture irrigation, groundwater recharge, household use, etc. The environment impacts of rainwater utilization were also summarized finally.

Key word: Rainwater exploitation; Hebei plain; utilization pattern

Some metropolises such as Beijing and Tianjin lie in Hebei plain; consequently prosper economy and a large number population is bringing forth huge pressure on land and water resources. Water resources per capita and per land are only 380m³ and 243 m³ respectively in Hebei plain, which account for 10% and 8.5% of national average. Surface water scarcity has caused excess groundwater exploitation to meet with the water demand; More than 6 billion m³ groundwater has been over-exploited in north China. Excess groundwater exploitation results in a series of environment problems such as the groundwater table descent, the ground down sink etc... Water crisis urge people to attach importance to rainwater at the point of sustainable development. Annual mean 535 mm is recorded in Hebei plain. Plenty rainfall in Hebei plain

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gives a good potential of rainwater utilization. Rainwater utilization has a long history in Hebei plain; rain fed agriculture is a kind of rainwater utilization. The 7th international conference of rainwater catchments was held in Beijing in 1995. The conference has promoted the Chinese rainwater utilization wide development. The “121” rainwater catchments engineering solved successfully. Fig. 1

The location of Hebei plain
The problem of the domestic water in Gansu province, at the same time, agricultural irrigation was also developed in some extent. Water cellar, cabinet and pond have been built to collect rainwater for domestic drink in Mancheng county and Yixian county in Taihong Mountain District. According to figure, about 66 207 water cisterns, 469 ponds and 13661 other water rainwater catchments engineering were built in 1949-1998 in the west of Hebei province.

1. Rainfall Characteristic in Hebei Plain

Located in the middle and southeast of Hebei province, Hebei plain covers about 57.2 thousand Km², one of the developed agriculture districts in China. It is continental temperate monsoon climate with vivid four seasons. Annual mean precipitation is about 535mm according to the rainfall series of 1956 to 1997, and the co variation is up to 20%, one of the maximum co-variation in China. Rainfall is concentrated on flood period of June to September and make up for 80% of the whole year. As an important water resource for crop, it has a practical significance to rainwater utilization in Hebei plain. The rainfall characteristics in Hebei plain are summarized as the following:

- Uneven spatial distribution. In general, rainfall is increasing gradually from southeast to northwest. Precipitation distribution is relatively complex due to the natural terrain; sometimes annual precipitation is up to 600 mm in rainstorm center.
- Uneven temporal distribution. So many rainfalls often occur in rainy season, which amount to 65%-75% of the whole precipitation. The least rainfall is only one-tenth in winter and spring.
- Great co variation precipitation among years. As one of the maximum co-variation region, it is up to 20% generally, even 30% in the middle of Hebei plain. Drought and flood often alternatively occurs among years.
- Heavy precipitation and less utilization. Precipitation often shows strong characteristic of monsoon, daily maximum rainfall is recorded to 300mm. heavy
rainfall leads to heavy runoff, it is difficult to collect and store rain in heavy rainfall.

On the one hand rainwater catchments on-site can provide more practicable water to local region; on other hand, rainwater is collected and stored on site to reduce runoff and flood, thus the loss caused by flood will be alleviated in some extent. In addition, the strong economy provides a strong financial foundation to rainwater utilization. So rainwater utilization has good prosperity.

2. The Process of rainwater resourcefulization and the connotation of rainwater utilization.

Precipitation is the main source of water resources in land, surface water and groundwater all derive from rainwater. Rainwater resource is defined as the rainwater that can be turned directly to practicable water on-site region by technical or engineering measures in the activity of humankind. The process of turning rain to rainwater resources is called rainwater resourcefulization. In broad sense, all those process which precipitation or atmospheric water is utilized indirectly are regarded as wide rainwater resourcefulization. Rainwater resourcefulization can be described as following formula:

\[ QR = P - R_s - R_g - E_0 \]  

(1)

where: QR is rainwater resources, P is precipitation, Rs and Rg are surface runoff and ground runoff caused by rainfall respectively, E_0 is evapotranspiration during rainfall.

Rainwater resources can be written in other expression:

\[ QR = S_n + S_a + \sum_{i=1}^{n} AW_i + G + U \]  

(2)

where: Sn is rainwater stored on natural condition, Sa is rainwater stored on man-made condition, AW is rainwater stored in soil layer, \( \sum_{i=1}^{n} AW_i \) is called also agricultural water resources(according to the definition by FAO), G is rainwater recharge to groundwater, and U is rainwater utilized by mankind during rainfall.
There are two ways of Rainwater resourcefulization, one is natural transformation without mankind activities, and the other is artificial transformation with mankind activities (see the Fig. 1). Each component parts of rainwater resourcefulization interacts each other and have some effectiveness on sequential link. In general, rainfalls and turns into runoff in land, simultaneously infiltrates into soil, then recharge groundwater. More rainwater stored in surface, less recharge to groundwater. On the other side, more rainwater will turn into runoff and loss away if no good catchments facilities.

![Diagram of Rainwater Resourcefulization](attachment:image.png)

**Fig.2 Process of rainwater resourcefulization**

The rainwater resource has some similar basic characteristics with other water resource, such as certain quantity and quality, directly usability, annual renewal etc. At the same time, rainwater resources still show some special characteristics, such as spatial and temporal diversity, distinctly effectiveness, concentrated, abruptness, and strong intensity. These feathers lead to low guarantee of water use.

In tradition, rainwater is often collected and stored in cellar to supply domestic water in freshwater shortage islands, or crop irrigation in arid hilly land. In fact, rainwater can be utilized anywhere there is a rainfall. All factors such as weather, hydrology, topography, and rainwater purpose should be considered to determine the style, scale and technical or engineering in rainwater utilization. In Hebei plain, rainwater utilization has been carrying out in rural and urban region, mainly in agriculture.
3. Rainwater utilization in agriculture in Hebei plain

Because of flat land, deep groundwater level, and advanced agriculture, perfect and integrated field irrigation and drainage engineering, runoff caused by rainfall is little than that on hilly land. The main measures of rainwater exploitation in Hebei plain are as follows:

1) Rainwater utilization in field. The key is the soil capacity of storing rainwater, based on weather forecast, all measures are taken to improve the soil capacity of holding rainwater before rainfall as far as possible, such as heighten ridge of field (scarification) uncover the plastic film to promote infiltration. Simultaneously, fertilizer should be applied with those measures.

2) Rainwater utilization in the field canal. Release gates on canal are shut down before rain to prepare to store runoff in the field and to recharge groundwater under the assurance flood free.

3) Rainwater utilization in household. This is the most popular in Hebei plain. Rainwater can be collected by roof, road surface, and stored in cellar, and discharged by gutters. Rain should be filtrated and sterilized to meet household flush and washing. Fig.3 shows the main form of cellar built in Hebei plain. The specification about rainwater utilization in household has been established to assurance water and safety.

4) Rainwater used to recharge groundwater. Main engineering measures include: Surface earth infiltration, pond storage seepage, field infiltration, canal leach and well recharge (see Fig.4). Fig.4 show a style of well and pond combination to recharge groundwater.
According to rainwater resourcefulization, rainwater utilization includes mainly three parts: control before rainfall, storage in rain-time, and utilization after rain. Three parts interact each other, match with mutually, and make up a system of rainwater utilization to make use of rainwater; good preparation is made for rainwater storage by controlling before rainfall. Main measures include weather forecast, heighten ridge of field-scarification-uncover the plastic film etc. Rainwater utilization after rainfall embodies directly rainwater resourcefulization. Advanced irrigation technique should be applied to make full use of the rainwater stored in cellar or pond, Such as the court drip irrigation, percolation irrigation, hole irrigation, drip irrigation under film etc.

4. Rainwater utilization in urban

Rainwater utilization can not only increase practicable water or recharge groundwater to alleviate water shortage, but also reduce flood and make environment better. There are so much waterproof grounds to collect rainwater, such as road, roof; square etc. the natural superiority is no other finance request to support this engineering. But there is some deficiency of no storage and expensive to built them. So there is a huge potential for rainwater utilization in urban.

There are some ways in rainwater utilization in urban:
1) Greenbelt irrigation;
2) Water renewal of river, pond, artificial lake etc in urban;
3) Agriculture irrigation of urban facilities or tourism;
4) Household washes and flushes;
5) Water for cleaning the city public facility;
6) Climate and environment improvement.

The rainwater utilization can be divided into five parts according to the process of rainwater resourcefulization: rainwater catchments, bi-system of rainwater and sewerage, storage system, recharge groundwater system and water use system. Figure 5 shows that make up of the whole system in urban. In fact, the whole system also can be summarized into three words: collection, storage, and use. Collection refers to these facilities includes the roof, road, waterproof ground, and pipes of rainwater and sewerage. Storage refers to these facilities pond, man-made like, water chamber, river. Use refers to household flush and wash, irrigation, etc.

The waterproof ground should be reduced more and more or be taking place by Greenbelt to promote recharge groundwater.

Fig.5 The make up of rainwater utilization system in urban
5. The environmental impacts of rainwater utilization

From the viewpoint of local dimension, rainwater utilization is the process of rainfall catchments on site to reduce runoff. It also is regarded as rain redistribution in time and space. Rainwater utilization has its own characteristics and potential other than surface or groundwater resources, rainwater can be used wherever there is rainfall. And less investment and environment impact without limit of scale and techniques. But rainwater utilization is dominated by spatial and temporal rainfall, obvious effectiveness, low water use guarantee, and unsteady water quality. The environment impacts by rainwater
utilization are as follows:

- Improve ecosystem environment in water scarcity region. Rainwater is collected for agriculture, Greenbelt, public sanitary facilities. Most rainwater is stored in river, man-made lake, and pond, which improve the ecosystem environment in Hebei plain.
- Rainwater stored to cut flood peak and to alleviate flood disease. All measures have been taken to store rainwater on site to reduce runoff and relief storm flood control.
- Recharge groundwater to improve groundwater condition. Rainwater is stored to recharge groundwater and heighten groundwater table.
- Practicable water resources. Rainwater is used with combination of surface water and groundwater water to add practicable water resources quantity.
- Contamination caused by impertinent rainwater utilization. Some fertilizer and pesticide will enter surface and groundwater while rainwater is collected to recharge groundwater.
- Soil erosion caused by impertinent rainwater utilization. As the heaviest soil erosion region, about 367 km² lands is suffering soil erosion, and covers 38.2% of gross area.

The water quality problem in domestic water.

Other problems also exist, incorrectness rainwater catchments will lead to flood and some risk will be born. Rain collected on site will reduce water quantity and runoff in the sequent region.

6. Conclusions

Rainwater utilization is developing widely and quickly in China. Its application is expanding gradually from hilly land to agriculture and urban, especially in water crisis Hebei plain. Rain utilization can improve local water resources and alleviate groundwater sink, and improve environment, to realize water sustainable utilization. The style and measures should be considered synthetically on the condition of all kinds of restricts and demand. The rainwater utilization system should be built to turn the limited rainwater to agriculture irrigation and recharge groundwater to improve practicable water resources. At the same time, water saving techniques are combined with agricultural techniques to make full use of rainwater and make the maximum benefits for society.
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