# Research on water ecological transformation technology of residential district in Lanzhou New Area

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**Abstract**. Water ecological construction is imminent in Lanzhou because it is an arid region with little precipitation. Through the investigation of the natural conditions and construction status of Lanzhou New Area, furthermore analyze the basic condition of water ecological construction in the residential area of Lanzhou new district and explore the application effect of relevant low-impact development technology. This research tried to summarize the "open source" mode suitable for low impact development of water ecological transformation in residential districts of Lanzhou New Area, improve the regional water environment, promote efficiency of utilization of rain to retain the water resource and form a benign circulation system.

## 1. Preface

Water ecological civilization refers to the ethical form of human-water harmony taking the sustainable utilization of water resources, the harmonious development of economy and society and the benign circulation of ecosystem as the main body by implementing the human-water harmony concept, which is a fundamental content of ecological civilization.

The urban water ecosystem functions include landscape recreation, water purification, environmental regulation, hydrological regulation, water supplement and so on. The protection of water ecosystem is of great significance to the improvement of environment and ecological conditions, the balanced development and ecological civilized construction[1]. A good "water ecology" environment is so indispensable for maintaining the healthy and sustainable development of economy and society that it is imperative to promote the construction of water ecological civilized city. In the "Rainwater Utilization of Landscape Design for Residential Space", Wu Weiyao studied the perspective of landscape design. Through the study of new ideas and new theories of current international and domestic rainwater management, he combined the analysis of domestic and foreign practice cases. Explore the way of combining rainwater utilization with landscape design of residential area[2]. Building is an important carrier of urban system and the construction of water ecosystem in it will improve the overall environment and reduce building energy consumption.

## 2. Conditions for water ecological construction in Lanzhou New Area

### *2.1. Features of precipitation and runoff*

*2.1.1. Features of precipitation.* Located in the sub-arid cold temperate zone, Lanzhou New Area has the typical continental climate characteristics with the sufficient sunshine, little precipitation and strong evaporation. The average annual rainfall volume is 245.9 mm, with uneven temporary distribution of mostly concentrating in July and August. And the average annual evaporation volume is 1879.7 mm. The monthly rainfall in Lanzhou New Area is shown on figure 1.

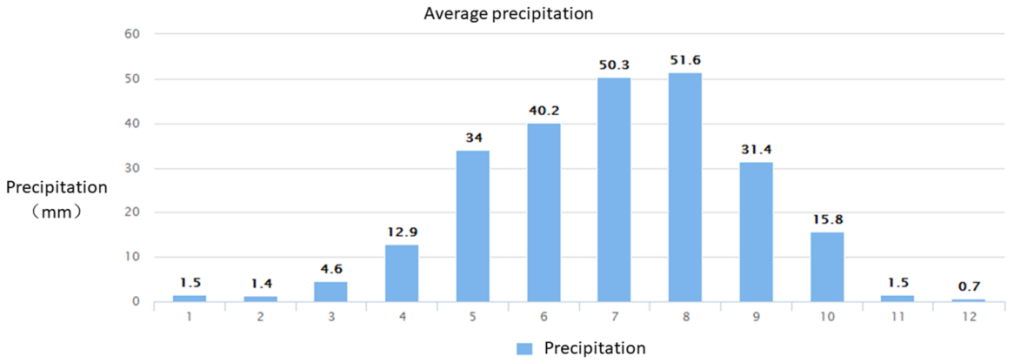


**Figure 1.** Bar chart of monthly mean rainfall in Lanzhou New Area[3].

*2.1.2. Features of runoff.* The volume of precipitation and runoff in Lanzhou New Area is small, with heavy rain falling in July and August mainly. According to the study of rain quality characteristics by collecting runoff in Lanzhou New Area, the chemical values of runoff in roof and cement pavement in 0 min, 5 min, 10 min, 20 min, 30 min, 40 min, 60 min after the beginning of rainfall were measured as follows and the chemicals include pH, turbidity, CODMn (COD for determination of chemical oxidant by potassium permanganate), Ammonia Nitrogen, UV254, total bacteria and total coliform bacteria[4]. Figure 2 shows the photos of rain collection point.

**Figure 2.** Rain collection point of cement pavement (on-the-spot take).

Rain runoff pollution situation in roof and cement pavement is serious at the initial stage in Lanzhou New area. With the increase of rainfall duration, the concentration of pollution in runoff appears to reduce in different degrees. The longer the rainfall duration, the slower the decrease speed of rain runoff pollution concentration, and eventually it falls to a relatively stable range of values. The turbidity of roof and cement pavement runoff has significant positive correlation with Ammonia Nitrogen value, CODMn and UV254, showing that the value of Ammonia Nitrogen, CODMn and UV254 in runoff will increase with the turbidity increasing[5].

### *2.2. Soil conditions*

The soil in Lanzhou New Area is mostly loessial soil with deep layer. The average thickness of the surface soil layer is about 0.5-3 meters, under which is sandy gravel layer. There is sparse natural vegetation and few species in Lanzhou New Area. According to the Map of Highway Collapsible Loess Types in Gansu Province, Lanzhou New Area is located in the Longxi-Loess Plateau area. The soil there, strong collapsibility with grade III strength, belongs to self-collapsible types with fast speed to collapse. Homogeneous content, loose structure and high porosity, collapsible loess is of these special characteristics. When it is unwetted, its strength is high and compressibility is small but its structure will be destroyed rapidly when it is wetted under certain pressure, resulting in soil collapsing with large additional weight and decreasing of strength fast. The physical properties of loess are shown on table 1.

**Table 1.** Physical properties of loess [6].

| Location | Number Of samples | Water content (%) | Bulk density (N/cm$^3$) | dry density (g/cm$^3$) | Density (g/cm3) | void ratio | saturation | liquid limit (%) | Plastic limit (%) | plasticity index | Compressibility | collapsibility coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LinYao | 10 | 9.2 | 1.39 | 1.27 | 2.70 | 1.12 | 23.5 | 26.9 | 20.0 | 6.9 | 0.047 | 0.062 |
| LanZhou | 191 | 7.4 | 1.35 | 1.26 | 2.70 | 1.13 | 17.7 | 25.3 | 16.5 | 8.8 | 0.041 | 0.084 |
| WeiYuan | 4 | 6.4 | 1.33 | 1.28 | 2.72 | 1.17 | 14.9 | 26.8 | 19.0 | 7.8 | - | 0.155 |
| LongXi | 20 | 9.4 | 1.30 | 1.19 | 2.71 | 1.22 | 20.5 | 28.0 | 19.5 | 8.5 | - | 0.155 |
| XiJi | 20 | 15.5 | 1.51 | 1.31 | 2.72 | 1.19 | 36.5 | 30.7 | 19.3 | 11.4 | - | 0.096 |
| DingXi | 76 | 18.6 | 1.40 | 1.18 | 2.70 | 1.28 | 42.3 | 28.6 | 17.5 | 11.1 | 0.105 | 0.074 |

### *2.3. Hydrological characteristics*

Groundwater can be divided into bedrock fissure water, Tertiary pore-fissure water in clastic rock mass and Quaternary pore water in loose rock mass according to the geological and geomorphological conditions of the basin, the lithology of aquifer and the occurrence and embedment features of groundwater. The aquifers of bedrock fissure water are poor in water abundance, mainly distributed in bedrock mountain areas at the northern part of the basin.

## 3. Optimization measures of water ecological facilities of a residential area in Lanzhou New Area

### *3.1. Construction background*

*3.1.1. The urgency of water ecological reconstruction in arid areas of Western China.* The available water resources per capita in Lanzhou is only 720 cubic meters, sharing 33% of the national per capita with 2150 cubic meters. It is a typical arid and water-deficient city in the western part of China. With the continuous increase of urban scale and impervious surface area, the rain absorbed mostly by underground infiltration before is discharged centrally, which not only causes serious water resources waste, but also soil erosion and geological disasters in a larger degree. Lanzhou New Area, the fifth national-level new area, is an important economic growth pole in Northwest China, an important industrial base, an important strategic platform for opening to the west, and an important window and

gateway for Gansu's opening up to the outside world strategy. The construction of sponge city in Lanzhou New Area is a promotion of the overall environment optimization in Qinwangchuan Basin, an innovative attempt of new urbanization construction, a strong demonstration especially in Northwest part of China and will guide the urban development in the future. It is not only the urgent need of urban construction, but also of paramount importance for urban sustainable development to construct a sponge city, a comprehensive ecological water environment management system of "infiltration, stagnation, storage, purification, utilization and drainage" so that rain can be stored and used locally and the attention of rainwater resources utilization in the water-deficient areas in the west can be strengthened. It is imminent and will make a contribution to the construction of low-impact development facilities in surrounding cities at the same time.

*3.1.2. Importance of water ecological facilities construction in residential districts.* Building and residential districts are the sources of urban rainfall drainage system, so they are the subject of urban sponge transformation project, and the important node of urban space in turn. The construction of water ecological facilities in residential districts is an essential measure to reduce emissions at source. End treatment was adopted basically in urban construction in the past, however, it was not accord with the actual national conditions in China as a traditional method, including high population density and the low finance of government. Therefore, it is necessary to turn to reducing emissions at the source, that is, controlling runoff from the beginning to relieve the pressure of end treatment effectively. The construction and transformation of water ecology in residential districts is an important part in the construction of sponge cities and the key for the Western water-deficient and arid cities to begin the construction of sponge cities.

### *3.2. Suggestions on optimization of water ecological facilities*

Water ecological facilities are built on the base of rainfall, soil and hydrology features in Lanzhou New Area. In order to guarantees the safe utilization of low-impact water ecological development facilities, permeable pavement and other low-impact development facilities such as rainwater infiltration are used for demonstration effect rather than the major measures for water ecological transformation considering soil collapsibility in residential area of Lanzhou New Area. Focusing on three aspects of rainwater, storage, purification and utilization, the reconstruction of water ecological facilities in residential areas selects small-scale facilities that are suitable for local conditions, economical, effective, safe and convenient to achieve the maximum utilization of rainwater.

The total rainfall in Lanzhou New Area is in small volume, so roof rainwater should be fully collected and utilized. The rain from both residential building roof and pavement can be gathered and introduced to the greenbelt by organized confluence and transfer and then be retained and utilized to reduce the water consumption of the greenbelt irrigation in the rainy period. Therefore, low-impact development measures such as rain bucket, rain pipe disconnection and sunken green space are chosen to reshape the water ecology and improve the utilization efficiency of rainwater in residential areas of Lanzhou New Area.

*3.2.1. Reservoir.* Reservoir refers to the professional facility to store, use rain and reduce peak flow to a certain extent. The construction of reservoir should consider the soil and terrain conditions in Lanzhou New Area, where reinforced concrete and bricks can be chosen as materials for the ground or underground construction. Residential districts with rain reuse requirements can be installed with reservoir and use the rain for toilets cleaning, green space irrigation and waterscape.

Rain barrel or water regulating tank is a necessary rain management and regulation facility. It should be arranged in the place with low utilization rate of the site, as shown on figure 3.

**Figure 3.** Added rain barrel[7].

**Figure 4.** Roof rain pipe[8].

*3.2.2. Rain pipe disconnection.* Rain pipe disconnection refers to the actions of cutting off the rain runoff discharge channel, assisting the rain runoff with ecological control and resource utilization to make it circulate in a natural way. By cutting off the roof rain pipeline properly and then connecting it reasonably with the green facilities of rain control and utilization, the grey facilities will be naturally transited to the green facilities, as a result of which the "grey + green" sponge city construction facilities will be used to improve the efficiency of regional rain utilization. The figure 4 shows three types of roof rain pipe. Roof rain pipelines are installed in all buildings in the residential district to introduce rain to the green space nearby and the ones without this function will be transformed. Figure 5 shows a building that needs roof rain pipe.

**Figure 5.** The building need roof rain pipe (on-the-spot take).

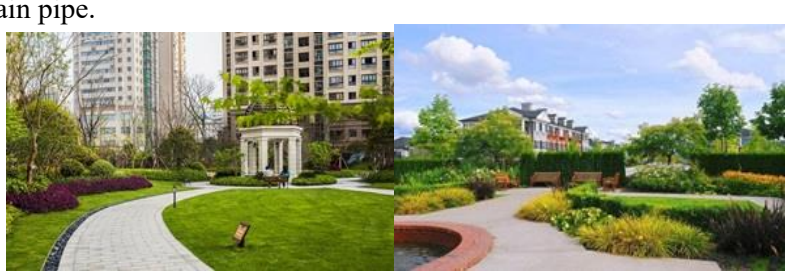

**Figure 6.** Green space optimization (on-the-spot take).

*3.2.3. Sunken green space.* Sunken green space, also called concave-down green space, low-lying green space, refers to the green space whose elevation is lower than the surrounding road surface or paved hardened ground within about 20 cm. Two kinds of green space optimization are shown on figure 6. The sunken green space can be used for planting directly because Lanzhou New Area belongs to the collapsible loess area, where the soil has the large permeability coefficient and can quickly absorb rain runoff. The sunken green space should be kept between 5cm and 15cm in depth according to the requirement of annual runoff control rate in the new area. Rain inlet is set up there to collect overflowing rain and its elevation should be higher than that of the sunken green space.

*3.3. Optimization effect of water ecological facilities*

The project is located in the core development area of Lanzhou New Area, with Weithirteen Road on its north, Huancheng Road on its south, Jingshi Road on its east. It will be the administrative, cultural and commercial center of the New District in the future, with supporting facilities such as hospital, commerce, entertainment functions and so on. The total planning area of the urban garden project is 13789.07 $m^2$, and the total building area is 255001.2 $m^2$, of which 2267.98 m2 on the ground and 323.22 m2 underground. The Plot Ratio is 1.61, the building density 25%, and the green space rate 34.66%. The total residential area of the project is 197863 $m^2$, the commercial area 6590 $m^2$, and the total number of residences 1559 sets. The aerial view of a project is shown on figure 7.

The rainwater utilization is merely green space infiltration retention at present. According to the green space rate, the area of green space in residential areas is 13789.07m$^2$, and the annual volume of natural infiltration rainwater is 10577.69 m$^3$, so the non-drainage outside rate of rain is 31.17%. The water ecological facilities in the residential areas are optimized and transformed by adding rain barrels around the low-storey buildings, collecting rain from the roof of low-storey buildings for green space irrigation. At the same time, the rainwater pipes of the multi-storey and high-storey buildings are disconnected to introduce roof rain into the surrounding green space. The greening methods of road and public green space are altered to decrease the elevation of the green space, to increase the storage space and to conserve the underground water source in the residential areas.

**Figure 7.** Aerial view of a project.


**Figure 8.** sketch for using of rain barrel in building area (on-the-spot take).

According to the planning of residential areas, there are 146 low-storey residential units with a floor area of 39492.44m$^2$, whose estimated roof area is 24149m$^2$ and annual total water storage capacity of rain barrels 4750.76 m$^3$, so 73 rain barrels should be added. The sketch for using of rain barrel is shown on figure 8.

According to the planning, there are 45 multi-storey residential units with floor area of 6266.86m$^2$ and 1368 high-story residential units with floor area of 164455.42m$^2$. Rainwater pipes are retrofitted on 23 multi-story and high-storey residential buildings to introduce rainwater into surrounding greenbelt. The roof area of multi-storey and high-storey residential buildings is estimated 10349.93m$^2$, and the rain water infiltration can be increased by 2036.04 m$^3$ annually after disconnection of rainwater pipes. Schematic diagram of roof rain pipe is shown below in Figure 9.


**Figure 9.** schematic diagram of roof rain pipe (on-the-spot take).

The public and road green space in residential areas is optimized and transformed in the assumption of the sinking depth of 5 cm. The total area of the green space transformed is 137899.07m$^2$, which can increase the rainwater storage capacity by 5876.50 m$^3$. Therefore, the volume of non-drainage outside rainwater in residential areas is 16454.19 m$^3$ in control. The schematic diagram of green space optimization shows below in Figure 10.

Rain storage capacity is increased by 12663.90 m$^3$ and the non-drainage outside rate of rain is 68.49%. Table 2 shows the list of water ecological improvement facilities for renovation project. Transformation of the original underlying surface can increase the rain storage, alleviate high-quality

water and retain rain as much as possible. The water saved can play an important role in improving the water environment, increasing the water sources in the residential area and realizing the "open source" water ecological construction in residential districts.


**Figure 10.** schematic diagram of green space optimization Aerial view of the project (on-the-spot take).

**Table 2.** List of water ecological improvement facilities for renovation projects.

| Transformation project | Modified scale | Volume of Water storage($m^3$) |
|---|---|---|
| rain barrel | 73 | 4750.76 |
| Rain pipe disconnection | 23 | 2036.04 |
| Sunken green space | 13.79ha | 5876.5 |
| Total | - | 12663.29 |

## 4. Summary

This paper studies the optimization effect of water ecological facilities in Lanzhou new area through the reconstruction method of the above cases. Beginning with residential districts, the water ecological environment of Lanzhou New Area can be improved by adding feasible water ecological sponge facilities, as rain barrel, roof rain pipe, green space optimization. Through ways of exploring rain water resources, that increasing rainwater storage to alleviate water shortage situation at the source and reduce local water resources burden.

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