

CHEMICAL CHARACTERISTICS OF SURFACE AND PHREATIC WATER AND THEIR EFFECTS ON THE GROWTH OF *POPULUS EUPHARTICA* OLIV. IN DESERT AREAS OF TARIM NATIONAL NATURE RESERVE, CHINA

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Abstract

Chemical characteristics of surface water and phreatic water and their relationship with the growth of *Populus euphratica* Oliv. were explored. In the study area, hydrochemical types of the surface water were mainly S^{CaM} or Cl^{NaM} (Based on the O. A. Arliekin's classification) and PH value of the surface water was below 8.0. The surface water from various sampling sites has a higher total hardness belonging to hard water and extremely hard water. The contents of sulfates and chlorides in the surface water in the protection zone ranged from 204.1 to 486.3 mg/l and from 70.9 to 239.9 mg/l, respectively. Phreatic water is mainly recharged by the surface water infiltration. In terms of water quality, TDS, total hardness and total alkalinity of phreatic water at W2 sampling point were 17.3, 9.3 and 4.7 times of surface water, respectively. *Populus euphratica* was able to grow normally in the environment of brackish water, where total hardness, total alkalinity, and TDS of overflowing river were in the range of 325.3~769.5, 142.6~290.3 and 782.2~1037.5 mg/l, respectively. The *Populus euphratica* in juvenile phase was a few, and its rejuvenation was confronted with difficulty. The present study can provide a reference for exploring the water quality characteristics of surface and phreatic water and their relationship with the growth of *Populus euphratica*.

Introduction

As the most critical ecological factor in arid and desert areas, water is not only the basis and evidence for the composition, development, and stability of oasis ecosystem, but also determines the ecological evolution process of oasis and desertification (Chen *et al.* 2003). *Populus euphratica* is a representative tree species in oasis ecosystem, its renewal and reproduction are restricted by both water quantity and quality. Tarim Euphrates poplar national nature reserve is located in the middle reaches of Tarim River, which plays a great role in protecting animal and plant resources. However, the population size structure of *Populus euphratica* in this area is inverted pyramid. It is very dry in the Tarim basin. The harsh environment inhibited the germination and survival of the seedlings, and population maintenance was difficult (Wang *et al.* 2016).

Rivers in mountainous areas of Tarim Basin are mostly low-salinity bicarbonate water, which is mostly sulfate water in the middle of plain rivers (Wei 1994). The ions and salinity in the groundwater increase due to the rise of the groundwater level and strong evaporation near the river course of Tarim (Chen *et al.* 2005, Chen *et al.* 2006). The hydraulic relation between surface water and ground water is close (Huo *et al.* 2009a, Huo *et al.* 2009b, Huo *et al.* 2009c, Huo *et al.* 2011). After the construction of the water diversion embankment in the middle reaches of the Tarim River, the desalination belt along the river shrank in a large area, and the negative ecological effect began

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to appear (Chen *et al.* 2009, Li *et al.* 2011). At present, the research focuses on hydrogeology and groundwater chemistry in the Tarim River basin, while the research on surface water and groundwater chemistry in the middle reaches and its influence on the growth of Euphrates poplar forest is less. According to the statistical data of the reserve in 2015, the woodland, open woodland and shrub woodland have decreased by 9.86, 13.67 and 15.05%, respectively in 2006, so the action to save Euphrates poplar forest is urgent.

Taking the Euphrates poplar nature reserve in Tarim as an example the chemical characteristics of surface water and groundwater in the middle reaches of the Tarim River were analyzed, so as to explore the influence of different surface water quality characteristics on the regeneration and succession of Euphrates poplar forests in desertification areas. It will provide theoretical support and scientific basis for the conservation, rejuvenation and regeneration of Euphrates poplar forests.

Materials and Methods

Study area is located in the middle of Tarim River (between Yingbaza in Luntai County and Qiala in Yuli County); and the river is about 398 km long. In the middle reaches of the Tarim River, it crosses the interlaced zone between the alluvial and diluvial plain at the southern foot of the Tianshan Mountains and the northern edge of the Taklamakan desert. The terrain is flat and deposited with silt. During flood season, the river water floods to form ponding swamps. The river channel is bend and often migrated to form a silt plain with a length of 100 km (Wang and Wang 2014). This region is crisscrossed by oases and deserts, and its ecological environment is fragile. From 2000 to 2013, the average annual vegetation coverage was 10.6 ~12.44%, among which the vegetation coverage of farmland was increased significantly (Huo *et al.* 2011, Huo *et al.* 2019, Huo *et al.* 2020). Most of the upstream water was used by farmland, and ecological environment degradation was still the main tone (Guo and Huang 2016). Herbaceous plant is the main component of the plant community in this area, which are reeds, licorice, bougainvillea, and so on. There are still arbor species of *Populus euphratica*, gray leaf populus and shrubs of *Tamarix*, jingle thorn, black fruit medlar, etc. (Zhang and Liang 2016).

In September 25, 2016, scientific investigation was carried out in the Tarim Euphrates poplar national nature reserve during the flood season in Tarim River watershed. According to the different development of Euphrates poplar forests, surface water samples in ponded swamps were collected in flood overflow areas along the Tarim river trunk stream. The GPS system was used to locate and record the longitude, latitude and altitude of the sampling points. The sample sites were numbered as W1, W2 and W3. The W2 sampling point was excavated until the phreatic water was exposed, and the phreatic water sample was obtained. River samples were taken from the position of the Yuli bridge of the Tarim river trunk stream, and the sampling point was numbered W4. Three parallel samples were taken from each water body for water quality analysis and testing. In order to eliminate the influence of randomness, an average of all the rule results was calculated. Experiments were mainly carried out in the key laboratory of subsurface hydrology and ecological effects in arid region of ministry of education and key laboratory of education ministry on highway engineering of special region (Chang'an University, Xi'an, China).

pH was measured by acidity meter method; Total soluble solid was measured by quality standard method; Total alkalinity, carbonate ions and bicarbonate ions were measured by the method of the double indicator titration and sulfate-EDTA disodium volumetric method; Chloride was measured by method of silver nitrate; Ammonia Nitrogen was measured by Nessler reagent spectrophotometry method; Free carbon dioxide was measured by neutralization method; Calcium, magnesium ions and total alkalinity were measured EDTA disodium complexometric titration.

Results and Discussion

The results of chemical analysis of water samples obtained from various sampling points in the research area are presented in Table 1. The results showed that the surface water from various sampling sites has a higher total hardness which belongs to hard water and extremely hard water.

Table 1. Water quality analysis in different sample plots (mg/l).

Items	Sample location number				
	W1	W2	W2	W3	W4
Water type	Surface water	Surface water	Aquifer water	Surface water	Surface water (Tarim river)
pH value	7.62	7.82	7.32	7.42	7.82
Total hardness (CaCO ₃)	369.1	325.3	3034.3	769.5	300.3
Total alkalinity (CaCO ₃)	165.2	142.6	665.7	290.3	115.1
Total dissolved solids	782.2	838.0	14476.3	1037.5	615.3
Sulfate	252.2	216.1	3452.2	486.3	204.1
Chloride	164.0	239.9	5340.7	70.9	133.0
Calcium	77.7	67.6	438.4	132.8	70.1
Magnesium	42.5	38.0	471.0	106.4	30.4
Ammonia nitrogen (NH ₄ ⁺ -N)	0.20	0	0	0.45	0
Bicarbonate root	201.4	173.9	799.4	353.9	140.3
Carbonic acid root	0	0	0	0	0
Free CO ₂	16.5	6.6	69.3	27.5	4.4

Sampling time was during the high flow season of Tarim River. The main and overflowing river water in the reserve were fresh and brackish water. The TDS of the water sample in the position of the Yuli bridge in the middle reaches of the Tarim River main stream was 615.3 mg/l. According to the hygienic standard of drinking water (GB5749 - 2006), the dissolved solid less than 1000 mg/l can be considered as fresh water. The surface water salinity of W2 sampling point was 838 mg/l. At the digging depth of 65 cm under the Euphrates poplar forest was in the W2 sample plot, the water was exposed, whose salinity reached 14.5 g/l, belonging to the brine (10 - 50 g/l). This indicated that the surface salinity was strong. The TDS of surface water samples in W3 was 1037.5 mg/l, being brackish water. TDS in W3 water sample was 68.6% higher than that in W4 water sample.

The pH value of surface water and phreatic water sample was between 7.32 and 7.82. The water sample of Tarim main stream in the position of Yuli Bridge had the highest pH value (7.82) and the pH value at W2 sampling point was the lowest (7.32). The total alkalinity (CaCO₃) of surface water samples in various places was between 100 and 300mg/l. Compared with other surface water samples, the total alkalinity of water samples at W4 sampling point in the Tarim River trunk stream was the lowest (115.1 mg/l). The water quality of Tarim main stream is better than the overflow river water on both sides of the river in terms of salinity and total hardness (Table 1). This might be due to (a) Water evaporation causes salt enrichment in the surface of both sides of the river, (b) The slow water flow and strong evaporation in the ponding marsh also worsen the water quality, (c) In the main channel, the water supply is relative large and the river water is moving, so the salt in the water is not easy to deposit.

Phreatic water is mainly recharged by the surface water infiltration. In terms of water quality, TDS, total hardness and total alkalinity of phreatic water at W2 sampling point were 17.3, 9.3 and 4.7 times of surface water, respectively. This is because phreatic water dissolves more salts in the soil. The water quality is closely related to the soil environment, which reflects the degree of soil salinity.

The contents of sulfates and chlorides in the surface water in the protection zone ranged from 204.1 to 486.3 mg/l and from 70.9 to 239.9 mg/l, respectively. The chloride content of 133 mg/l and the sulfate content of 204.1 mg/l in the river water samples in the position of Yuli bridge of Tarim River are both lower than the corresponding limits in the national drinking water quality and sanitation standards (250 mg/l). The sulfate content of surface water at the sampling point W3 was 486.3 mg/l. This surface water belongs to brackish water. In the surface waters of W1 and W3 sample plots, the ammonia nitrogen content exceeds the national nature reserve Class I standard (≤ 0.15 mg/l) according to the surface water environmental quality standard (GB3838-2002). Correspondingly, the free CO₂ content in water of W1 and W3 sample plots was relatively high which were, 16.5 and 27.5 mg/l, respectively. Large areas of cash crops such as cotton, oil palm, red medlar and melon are planted in the study area, indicating that the surface water in the middle reaches of the Tarim River has been affected by human factors such as agricultural drainage. In conclusion, TDS, total alkalinity and total hardness in the middle reaches of the Tarim River increased in different degrees because the overflowed river water flowed through the surface with serious salt accumulation, and the salt index in the phreatic aquifer was much higher than the surface water in the same area. At the same time, large-scale reclamation on both sides of the river has also had a negative impact on water quality in the middle reaches of the Tarim River.

In the early autumn of 2016, the Euphrates poplar in the desert riparian forest in the middle reaches of the Tarim River had entered the deciduous stage and its leaves began to turn yellow. According to vegetation type, quantity and overall coverage, the habitats of *Populus euphratica* forest community are divided into three regional types: desertification area, transition zone and riverbank radiation area. The results of field investigation showed that the population size of *Populus euphratica* and *Populus pruinosa* in this area are inverted pyramid with few young individuals and little renewal resources. The growth characteristics of *Populus Euphrates* in W1, W2 and W3 plots are shown in Table 2.

Table 2. Growth characteristics of *Populus euphratica* in 3 chosen plots.

Item	Sample number		
	W1	W2	W3
Growth pattern	<i>Populus euphratica</i> - <i>Tamarix chinensis</i>	<i>Populus euphratica</i> - <i>Tamarix chinensis</i> -reed	<i>Populus euphratica</i>
Main species	<i>Tamarix chinensis</i> (dominant species), <i>Populus euphratica</i>	<i>Populus Euphrates</i> , tamarisk, <i>Tamarisk</i> , reed, Camel thorn, salt grass	<i>Populus euphratica</i> , <i>Tamarix chinensis</i>
Total coverage	30~60%	80~100%	80~100%
Breeding way	Root rice breeding	Seeds, root rice breeding	Seeds, root rice breeding

W1 sample plot is located in the terraces on the south bank of the Tarim River, which is a transitional zone with a surface layer of salt crystallization. It is affected by seasonal floods and has a short submergence period. The dominant species is *Tamarix chinensis*, growing in bunches with

the height of 2~4 m and the diameter of 2~6 m, and the height of the sand fixation of 20~40 cm near surface. *Populus euphratica* grows sparsely.

W2 sample plot is a riparian radiation area, where rivers flow through during the flood season. The population structure of *Populus euphratica* is relatively stable in this area. The age of trees is mostly in the middle age and near mature stage. The height of the main *Populus euphratica* is 7 ~ 10 m, with more than 170 trees per hectare. The height of the topmost tree is more than 16m and the height of the young tree layer is 3~5 m, and the number of young trees per hectare is about 320. *Tamarix chinensis* is distributed in clumps or patches, with a height of 2~4m and a coverage rate of 10 ~ 30%. Grass species are reed, salt grass, camel thorn and so on. The TDS value of groundwater in the W2 sample was 14.5 g/l. The groundwater contains 10~20 g/l of dry matter and only the most salt-tolerant tree species can adapt (Huo *et al.* 2009c, Huo *et al.* 2016, Wang *et al.* 2016). Therefore, the vegetation of riparian forest in this area is mainly middle-aged and old-aged *Populus euphratica* and salt-tolerant shrubs.

W3 sample plot is located in the flood plain with patches of *Populus euphratica* forest and few grasses, and the renewal and succession of *Populus euphratica* is relatively easy. The seedlings and root-sucker seedlings of *Populus euphratica*, 15 ~ 30 cm high, can be seen on the new alluvium.. *Populus euphratica* saplings are generally within 10 years old, with a height of 2 ~ 4 m, and about 20 ~ 40 trees per 100 m² area. The saplings have started to differentiate, with a large number of apoptosis and being natural sparse. The associated species of *P. euphratica* community is unstable and the main species is *Tamarix chinensis*.

The results showed that the surface water chemical characteristics changed little and the water quality was stable in the three different growth modes of Euphrates poplar forest, which was basically suitable for the growth of Euphrates poplar forest.

The total hardness, alkalinity and TDS of the overflowing river are higher than those of the main stream. The surface water in the study area is adversely affected by farmland drainage, and the ammonia nitrogen content was 0 - 0.45 mg/l. The surface water in some areas is already brackish water. Overall, the water quality has little difference. *Populus euphratica* can grow normally in brackish water with TDS > 1000 mg/l. The vegetation in the study area is mainly composed of xerophytes and halophytes, which are suitable for *Populus euphratica* growing in sandy soil. The *Populus euphratica* and *Populus pruinosa* in this area had fewer young individuals and lacked regeneration resources, which is a declining species. The harsh environment in the Tarim River basin inhibited the germination and survival of *Populus euphratica* seedlings.

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