Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2018.22511

121 (2018) 305–310
July

Rhf on water chemistry characteristics and influencing factors of water body in the Inner Mongolia section of Yellow River

Li-e Liang[a,*], Shengbin Li[a], Changyou Li[b], Hongxia Yang[a]

[a]*Architectural Engineering Institute, Yan'an University, Yan'an, China, email: imaulle2008@163.com (L.-e Liang)*
[b]*Water Conservancy and Civil Engineering College, Inner Mongolia Agricultural University, Hohhot, China*

Received 26 February 2018; Accepted 15 May 2018

ABSTRACT

The sampling data from five monitoring sites are used for the study along the reach of Yellow River in Inner Mongolia. The water chemistry characteristics of the Yellow River were analyzed by the methods of the anion and cation triangulation and Gibbs diagram. The results showed that the total dissolved solid and electrical conductivity of the water in Inner Mongolian reach of the Yellow River were increased. The order of the main cation content is $Na^+ > Ca^{2+} > Mg^{2+} > K^+$, and the dominant cation is Na^+. The main anion content order is $SO_4^{2-} > Cl^- > HCO_3^- > CO_3^{2-}$, and the dominant anion is SO_4^{2-}. The total ion content is increasing along the reach. According to Alejan classification of hydrochemical types of surface water classification, Inner Mongolia reach of the Yellow River water chemistry type is [S]NaII type water. The river water is mainly affected by the chemical characteristics of carbonate rock and halite. The factors that are controlling water chemical characteristics were analyzed. The results show that the chemical characteristics of the Yellow River water at Inner Mongolia reach are controlled by precipitation and rock weathering. The contribution of human activity along the Yellow River on the ion content, source and composition of water is also larger.

Keywords: Inner Mongolia Section of the Yellow River; Water Chemistry Type; Rock Weathering; Human Activity

1. Introduction

River is the most active part of the earth's water cycle, and the composition of water depends on the composition of contacting material and solubility as well as physical, chemical and biological interactions between materials. Chemical characteristics of river water can reveal the source of water ion and reflect rock feature of the area through which river flows, soil characteristics and the influence of human activities on the river. At present, many domestic researches have been focused on water chemistry study of some large rivers, such as the Yangtze River [1,2], Yellow River [3,4], and continental river (such as the Heihe [5,6] of Lijiang Basin, Tarim River [7], etc.), mainly involving the analysis of main river hydrochemistry type and influencing factors of ion source. Because of space and time differences owing to each river environment conditions, its chemical composition and different influence factors vary.

In recent years, due to the rapid development of coastal economy and population, sanitary and industrial wastewater are discharged into the Yellow River, causing the Yellow River serious water pollution. According to "river water quality bulletin for Yellow River water of provincial boundary and water resources of key sections" in August 2015, there are 143 key sections set in the Yellow River, among which there are 45 main streams and 98 tributaries. There are 100 cross sections classified as class I–III of water quality, accounting for 69.9%; 20 IV–V water cross section, accounting for 14.0%; 23 water quality worse V sections, accounting for 16.1%. In Inner Mongolia reaches

* Corresponding author.

Presented at the 3rd International Conference on Recent Advancements in Chemical, Environmental and Energy Engineering, 15–16 February, Chennai, India, 2018

of the Yellow River, the industrial city of Baotou is especially heavily polluted, with more than 90% of industrial waste water and sewage discharged into Kundulun River, Sidaosha River, West River and East river then flowing into the Yellow River in Baotou section by four sewer ditches separately. Again in Ordos, sewage of general Drainage Station of Cattle Camp, Husitai River, Dadian Discharge Port, East Willow Ditch drain directly into the Yellow River [8]. At the same time, along with the development of agriculture, irrigated agriculture development affected the process of the Yellow River water salinization [9]. It is mainly because of the increase in Hetao region on irrigation rate and water consumption, which, however, causes the increase of water salinization, mainly as soluble salt in soil ditch again into the Yellow River owing to the irrigation through ditches, rendering higher ions content of the Yellow River. Given the special environment in Inner Mongolia within section of the Yellow River, it is necessary to analyze water chemical characteristics of the segment and its influencing factors and to parse water quality from the angle of geochemistry for Inner Mongolia reaches of the Yellow River, so as to provide hopefully important reference value for the rational utilization and ecological protection of the Yellow River water resources.

2. Materials and methods

2.1. Introduction of research area

The Yellow River flows through Shizuishan City into the territory of Inner Mongolia, Bayannaoer City, Erdos City, Wuhai City and Baotou, then flows through Hohhot Qingshui River to the territory of Shanxi Province, with length of 840 km within the Inner Mongolia reaches of the Yellow River. River area is 151,267 km^2, which belongs to upstream and middle reaches of the Yellow River [10], where climate is dry and has low rainfall with annual average rainfall of 150–400 mm besides, it is unevenly distributed over years, with about 75% of rainfall concentrated in 7–9 months. Ice regime begins in late November annually, and from middle of December to March of next year is freezing period. While the Yellow River is flowing through the Ulan Buh Desert in Inner Mongolia, ten kongduis and Kubuqi Desert, when there is heavy rain or flood, a large number of sediment is developed into the Yellow River, leading to serious deposition of river sediment and frequent river channel landform evolution. Within the territory of the Yellow River in Inner Mongolia, 97% of river water is used for agricultural irrigation with Yellow River irrigation area of 661.67 million hm^2. This autonomous region of the Yellow River is source of development of the Hetao irrigation district, south irrigation area of Ordos City, Tumed Plain Yellow River irrigation area [11].

2.2. Collection and test of the samples

From July to September in 2017, the Yellow River in Inner Mongolia has carried on the investigation and sampling on sections of Yellow River in Inner Mongolia (Sanshenggong-the Sanhu estuary-Dengkou-Zhangliwenyao-Lama Bay). Three cross sections are set in Sanshenggong and Sanhu estuary with each about 2 km apart; Dengkou, Zhangliwenyao and Horn Bay each is set with six cross sections with a distance of 2 km between each section and a total of 24 collecting water samples the depth of which is at 0.5 m below the surface, the sampling point is shown in Fig. 1. The site is using Mettler (SG8-ELK, SG9-ELK) multiple parameters determination to determine the water's pH value, total dissolved solid (TDS) and electrical conductivity (EC) (measurement accuracy is 1‰). After samples are taken back to the lab, water samples are filtered with circulation use of

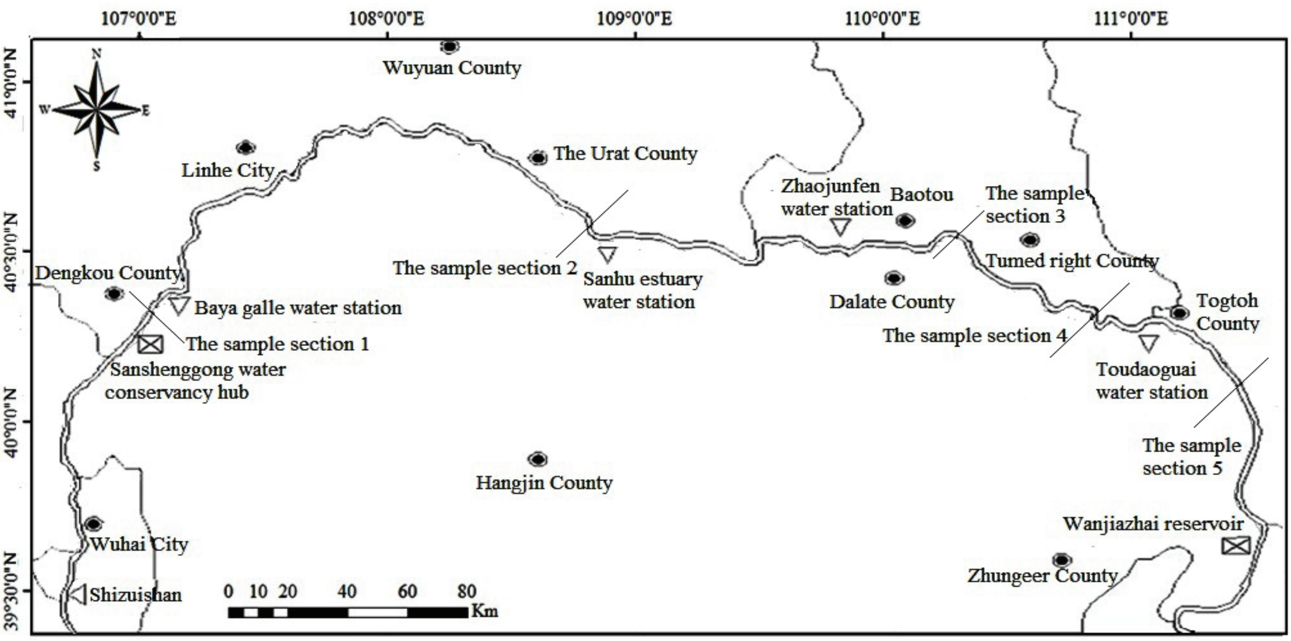

Fig. 1. Sampling sites. Location: location 1 – Sanshenggong; Location 2 – Sanhu estuary; Location 3 – Baotou Dengkou; Location 4 – Zhangliwenyao; Location 5 – Lama bay.

vacuum pump and microporous membrane filter of aperture 0.45 μm and 50 mm diameter. The filtrate after filtration is used for testing anionic (Cl^-, SO_4^{2-}) and cationic (K^+, Na^+, Ca^{2+}, Mg^{2+}) by the ICS-90 ion chromatograph produced in the United States Diane (DIONEX) company. Total hardness (mg $CaCO_3 \cdot L^{-1}$) = 2.497 × Ca (in mg $Ca \cdot L^{-1}$) + 4.118 × Mg (in mg $Mg \cdot L^{-1}$) [10]. Concentration of HCO_3^- and CO_3^{2-} is determined with double indicator titration method.

3. Results and discussion

3.1. Physical and chemical characteristics of Yellow River within section of Inner Mongolia

pH value reflects the acid and alkaline water, plays a certain control effect on the redox reaction of water. The pH of the range is as follows for Inner Mongolia reaches of the Yellow River: 6.74–8.96, and the variation coefficient is 6.25%. The water is in weak acid and alkaline. Water hardness refers to the total water calcium and magnesium ion concentration, the change of Inner Mongolia reaches of the Yellow River water hardness range is: 188.88–270.38 mg L^{-1}, average of 238.08 mg L^{-1} and the variation coefficient is 10.17%, which belongs to hard water (hardness > 180 mg $CaCO_3 \cdot L^{-1}$). Characteristics of pH value and the hardness were analyzed along the reach, as is shown in Fig. 2. The pH of the Yellow River in Inner Mongolia section presents the downward trend along Sanshenggong, Sanhu Estuary-Dengkou-Zhangliwenyao-Lama Bay.

EC depends on the concentration of the ions contained in water. The range of EC in the Yellow River in Inner Mongolia section: 0.73–1.043 ms cm^{-1}, with a mean of 0.97 ms cm^{-1}, coefficient of variation is 11.57%; TDS range: 363.33–521.33 mg L^{-1}, with a mean of 481.98 mg L^{-1}, coefficient of variation is 11.81%. TDS reflects the total solids in water of the concentration of ions. TDS includes the ions in the water of the river and complex, and its main source: atmospheric input of sea salt; silicate, weathering and dissolution of carbonate rocks and evaporates and input of human activity [10]. The data show that the two groups have significant difference, being statistically significant. pH and frictional characteristics of hardness were analyzed, as is shown in Fig. 2, where EC and TDS all show increasing trend. EC and TDS present positive correlation in water body of the Yellow River in Inner Mongolia section. The main reason is that Yellow River flows through the important industrial city of Baotou and the Hetao irrigation district; industrial and agricultural waste water carry large amounts of salt into the Yellow River, resulting in EC and TDS along the reach.

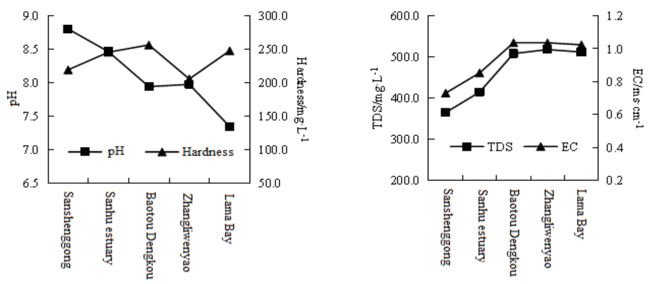

Fig. 2. Characteristics of physical and chemical parameters.

3.2. Chemical characteristics of the Yellow River in Inner Mongolia section of the river water

Inner Mongolia reaches of the Yellow River main cationic content order: $Na^+ > Ca^{2+} > Mg^{2+} > K^+$, with ions of Na^+ as dominant, followed by Ca^{2+}, accounting for, respectively, 53.39% and 28.26% of the total number of cation. Main content of anion order: $SO_4^{2-} > Cl^- > HCO_3^-$, with ions of SO_4^{2-}as dominant, Cl^- as second, accounting for 52.86% and 37.30% of the total number of anion respectively. According to the type of hydrochemistry classification method of O·A Alejan classification of hydrochemical types of surface water classification [12], hydrochemical type of Inner Mongolia reaches of the Yellow River water is [S]Na II type water. II type in the Yellow River water is in larger amount, and its characteristic is that hardness is greater than the basicity. Concerning the origin, this type is associated with all kinds of sedimentary rock, mostly belongs to the low salinity and the salinity of the water. The Yellow River hydrochemistry type mostly belongs to major carbonate. Parts of regions, such as Gansu province in the northeast, central and southern Ningxia Hui Autonomous Region, Inner Mongolia Autonomous Region, in the north of Shanxi Province and Shaanxi province, chemical types are mostly sulfate or chloride and water quality is poorer, which accord with the results of the study.

Cationic and anionic triangle chart show changes of the main ions in the water as a reflection of the chemical composition characteristics of water body, so as to identify its control end yuan [13] and reveal the relative contribution the different rock weathering on total composition of solute in water. Ion of Yin and Yang triangle of the Yellow River in Inner Mongolia section of the river water diagram is shown in Fig. 3. As can be seen from the figure, the anion is mainly distributed in the SO_4^{2-}–Cl^-–HCO_3^- line. Cation is mainly distributed in line of Na^++K^+–Ca^{2+}, so you can infer that the Yellow River in Inner Mongolia section is affected by carbonate rocks and water evaporation.

3.3. Discussion

Gibbs [14] and Li et al. [15] found that the process control of surface water chemical composition includes mainly three categories, namely, atmospheric circulation, circulation of sea salt, rock weathering and evaporation crystallization, after studying chemistry control mechanism through rivers, lakes,

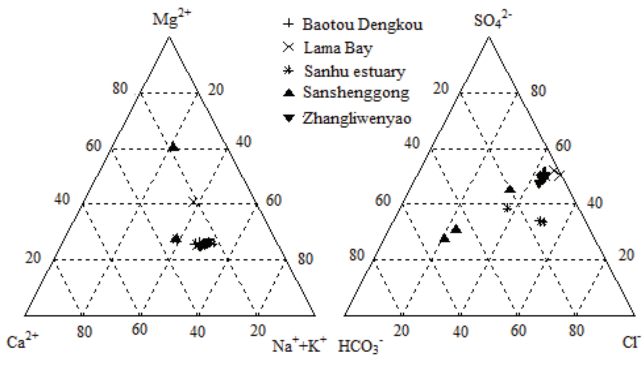

Fig. 3. Piper diagram of Inner Mongolia section of the Yellow River.

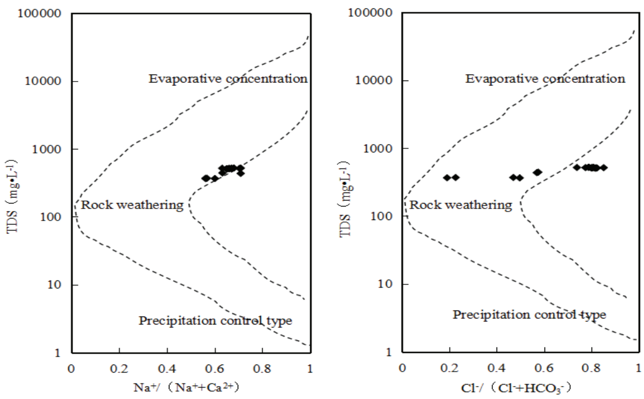

Fig. 4. Gibbs diagram of Inner Mongolia section of the Yellow River.

reservoirs and other water in most of the world. In order to demonstrate an intuitive comparison of surface water chemical composition, forming reason, and the relationship between each other, semilog coordinate diagram is made, with the diagram of ordinate for logarithmic coordinates on behalf of the TDS content in surface water, abscissa for common coordinates on behalf of the cationic $Na^+/(Na^+ + Ca^{2+})$ or $Cl^-/(Cl^- + HCO_3^-)$ ratio, as shown in Fig. 4. Rock weathering products are the main ion in water source, polluted from human activities and at the same time it is also a source of surface water in ion composition [16].

3.3.1. Atmospheric circulation precipitation

Inner Mongolia reaches of the Yellow River belongs to the continental arid and semi-arid monsoon climate zone, with rainfall concentrating in the 7th, 8th, 9th months of year, annual rainfall of about 150–450 mm, 70% of annual rainfall, annual evaporation of 1,200–2,000 mm, evaporation for four to eight times of rainfall. Meanwhile, Inner Mongolia section of the Yellow River is more dominated by the west and north westerly continental monsoon winds, so ocean monsoon of Inner Mongolia reaches of the Yellow River will not produce certain effect. As it can be seen from the Gibbs graph, sample point is away from the atmospheric precipitation, and controlled area shows that atmospheric precipitation has no effect on regional water chemical characteristics basically. According to the research of the Chen et al. [9], faint Yellow River estuaries of the Bo sea tide has an impact on river and estuarine only of more than 20–50 km. By calculating the average Cl/Na values which is 1.11 and less than the world average water ratio (Cl/Na = 1.15) [17]. At the same time, the study area is away from the ocean, thus less affected by the atmospheric circulation. So it is believed that the main source of ions is not controlled by atmospheric precipitation for Inner Mongolia reaches of the Yellow River water.

3.3.2. Rock weathering

As can be seen from Fig. 5 of the Gibbs diagram, in Inner Mongolia the chemistry in the water of the Yellow River is mainly controlled by rock weathering. TDS is less than 1,000 mg/L, rho (Na^+)/[rho (Na^+) + rho (Ca^{2+})] ratio is 0.56–0.71, rho (Cl^-)/[rho (Cl^-) + rho (HCO_3^-)] ratio is 0.19–0.85, the effect of river water by the weathering of rocks is relatively strong. Existing research shows that the K^+, Na^+ ions are from evaporite or silicate weathering products; Ca^{2+}, Mg^{2+} mainly comes from carbonate, evaporite or silicate; Cl^- and SO_4^{2-} mainly come from evaporation of karst; HCO_3^- mainly comes from carbonate [13]. Analysis of each ion proportion relations can be seen in Fig. 5. In Fig. 5(a), the data points fall under 1:1 contour and deviates from the contour distant, it means that evaporation is greater than the carbonate source rock. By calculation of rock weathering intensity $(Ca^{2+} + Mg^{2+})/(K^+ + Na^+)$ ratio, the average is 0.82 (ranged from 0.67 to 1.19), is far lower than the world level by 2.2 [18], mainly controlled by karst solution evaporation. Widespread evaporation salt mine are found in Inner Mongolia section of the Yellow River, such as gypsum and anhydrite, distributing in the surface layer of rock and soil. In the arid climate condition, weathering, evaporation crystallization is gradually developed, thus affecting the ion of the river. In Fig. 5(b), the data point distribution characteristics is similar to Fig. 5(a), and is far away from and deviates from contour, which shows that carbonate weathering cannot fully explain the water source of Ca^{2+} and Mg^{2+}. The ratio of Cl^- and $K^+ + Na^+$ diagram is shown in Fig. 5(c), data points are near the 1:1 contour, suggesting that evaporite (NaCl, KCl) Cl^- is the main source of K^+ and Na^+ ions. In Fig. 5(d), data points are near the 1:1 contour, meaning that sulfate salt rocks weathering dissolution is the important source of Na^+ in water. Fig. 5(e) presents the ratio of HCO_3^- and Na^+ diagram where data points are located under away from the contour, which explains that the source of the Na^+ is not controlled by weathering of carbonate dissolution. Fig. 5(f) is the SO_4^{2-} $(Ca^{2+} + Mg^{2+})$ and the ratio of the diagram where data points are situated near the 1:1 contour, close to the contour, which suggests that $Ca^{2+} + Mg^{2+}$ in the water may be derived from the weathering dissolved sulfate salt rocks.

3.3.3. Human activity

In Gibbs diagram, part of the cross section sample point fall in the Gibbs model diagram, suggesting that the Yellow River in Inner Mongolia section of the river may be the interfered of human activities. Sanshenggong section ion content is lower than those of several other sections, the main reason for which is that the coast has almost no polluting enterprises. Ca^{2+} and HCO_3^- and CO_3^{2-} ions content is higher, which is mainly caused by carbonate weathering; Wuliangsuhai Lake is located nearby lakes estuary section whose retreat drains directly into the Yellow River, while Wuliangsuhai Lake mainly accepts Hetao irrigation area of farmland irrigation water, the water quality of which is poor. According to statistics, in 2014, the amount of Wuliangsuhai Lake pollutants COD, TP, TN into the lake is, respectively, 36,254 tons, 182 tons, 36,254 tons. Average concentration of TP, TN and COD in outfall in is, respectively, 2.207, 35.858 and 0.056 mg L^{-1}, making poor water quality. Estimation is done to calculate the amount of in-lake and mainly drained ion in Wuliangsuhai Lake in 2017, as shown in Table 1. The concentration is high for all ion in Wuliangsuhai Lake, especially the drained ones, with concentration of each ion concentration 4–12 times of Wuliangsuhai Lake. Ion concentration of Wuliangsu Lake is very high when compared with Inner Mongolia reaches of the Yellow River water body. In addition to the Ca^{2+}, other

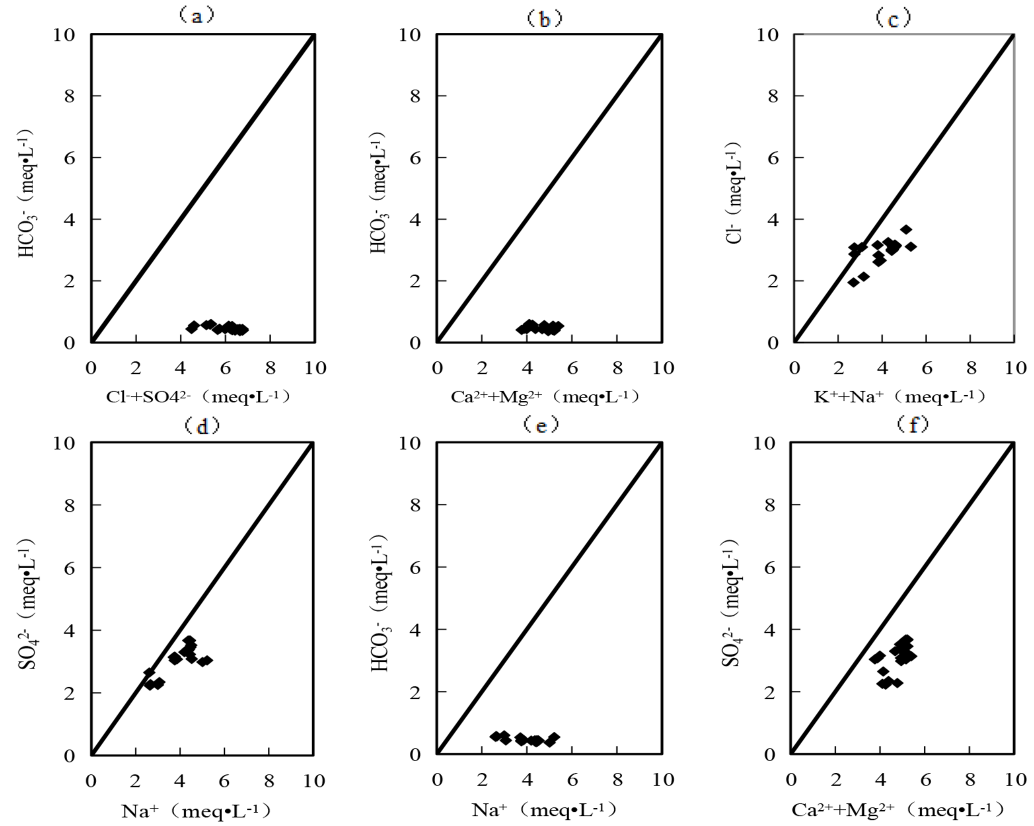

Fig. 5. Proportion relationship between major ions. (a) Ratio between HCO_3^- and $Cl^- + SO_4^{2-}$, (b) ratio between HCO_3^- and $Ca^{2+} + Mg^{2+}$, (c) ratio between Cl^- and $K^+ + Na^+$, (d) ratio between SO_4^{2-} and Na^+, (e) ratio between HCO_3^- and Na^+, (f) ratio between SO_4^{2-} and $Ca^{2+} + Mg^{2+}$.

Table 1
Content of major ions in Wuliangsuhai in August 2017

		Na^+	K^+	Mg^{2+}	Ga^{2+}	Cl^-	SO_4^{2-}	HCO_3^-
	Maximum	617.31	12.58	124.83	64.60	894.20	553.62	243.97
In-lake	Minimum	203.22	6.37	47.21	25.88	288.93	191.31	38.67
	Mean	398.06	8.99	83.57	39.54	564.44	357.60	116.22
Drained	Eight drained	374.15	4.53	83.28	45.90	503.79	329.80	–
	Nine drained	1,202.70	6.97	242.89	120.00	2,098.63	809.71	–
	Ten drained	3,633.90	90.73	375.63	273.56	6,709.90	1,626.37	–
	Total drained	474.46	14.89	81.90	73.04	702.30	407.37	–

ions concentration can reach two to five times of the Yellow River water. Therefore, Wuliangsu water body water quality has a great influence on Inner Mongolia reaches of the Yellow River. At the same time, many small and medium such as paper mills, tomato plants and other high polluting enterprises are located along with the general drainage. Once these enterprises shut down treatment facilities or have no treatment facilities, a large number of sewer will flow directly into the Yellow River, causing the increase of ion in Sanhu estuary; before the Yellow River flows Hetao irrigation area, TDS through Sanshenggong section is 365.67 mg L^{-1}, before going to section of Lama Bay then through the Hetao irrigation district, the TDS increases to 511.78 mg L^{-1}. This fully demonstrates that high salt–water irrigation area has had a huge impact on the Yellow River water quality. Dengkou section is located in heavy industrial city of Baotou, with the segment of the Yellow River coast lined with metallurgy, machinery, coal chemical industry and other enterprises, industrial wastewater emissions increase year by year. More than 90% of the domestic sewage and industrial wastewater by Xisha River, Xi River, Kundulun River, East river directly are discharged into the Yellow River in Baotou section [11]. Lama bay section is near the Lama and Haishengbula Village, with its sewage directly discharged into the river. At the same time, Lama Bay Town is with rich mineral resources such as iron, copper, lead, zinc, so the local government has promoted the introduction of many polluting enterprises for the economic development in recent years, leading to industrial wastewater emissions increase year by year and increased nutrient salt and ions content in this segment of the Yellow

River. From Sanshenggong section to Lama Bay section, TDS and conductivity of EC is increased (Fig. 2), showing that the ion content increases gradually, which fully confirmed the influence of human activities on the river water chemistry.

4. Conclusion

pH value decreases along the reach within Inner Mongolia reaches of the Yellow River, and the hardness and pH shows opposite regularity, while TDS and EC are on the rise; Water main content of cationic order: $Na^+ > Ca^{2+} > Mg^{2+} > K^+$, with Na^+ as the dominant; The main content of anion order: $SO_4^{2-} > Cl^- > HCO_3^- > CO_3^{2-}$, with SO_4^{2-} as the dominant. According to the type of hydrochemistry classification method of O·A Alejan classification of hydrochemical types of surface water classification, hydrochemical type Inner Mongolia reaches of the Yellow River water is [S]Na II type water.

The result of water ion of piper diagram is that the river water of Yellow River in Inner Mongolia section is affected by chemical combination of carbonate rocks and evaporation salt. Through the analysis of the factors of controlling water chemical characteristics, the results show that the water is not controlled by the atmospheric precipitation, but mainly controlled by rock weathering, and human activities along Yellow river also makes a bigger contribution on ion content, source and composition of the Yellow River water.

Acknowledgment

The authors would like to acknowledge the Special Fund Projects of High-level University Construction in Shaanxi Province (2015SXTS03).

References

[1] Y.N. Zhang, Y.Q. Gan, X.Q. Li, Y. Liu, K. Yu, B. Zhang, Water chemical characteristics and controlling factors of the Yangtze River in the wet season, Resour. Environ., Yangtze Basin, 25 (2016) 645–654.
[2] Y.P. Wang, L. Wang, C.X. Xu, Z. Yang, J. Ji, X. Xia, Z. An, J. Yuan, The geochemical characteristics of the Changjiang River system and the chemical origin of the main ions, Geol. Bull. China, 29 (2010) 446–456.
[3] G.X. Shen, X.Y. Song, D. Zhang, Hydrochemistry characteristics of the Qin River (Henan section) in winter, J. Water Resour. Water Eng., 23 (2012) 43–46.
[4] J.R. Cao, X.J. Xu, H.J. Yu, C. Huang, Research on the variation and evolution of groundwater chemistry in the Yellow River Delta, Marine Sci., 38 (2014) 78–85.
[5] Y.L. Gao, J.F. Chen, C.C. Zhang, Y. Yan, Hydrochemical characteristics of the irrigation area in the middle reaches of the Heihe River Basin, Arid Land Geogr., 34 (2011) 575–583.
[6] T. Pu, Y.Q. He, G.F. Zhu, W. Zhang, W. Cao, L. Chang, C. Wang, Geochemistry of Surface and Ground Water in the Lijiang Basin, Northwest Yunnan, Environ. Sci., 3 (2012) 48–54.
[7] J.Y. Xiao, P. Zhao, W.H. Li, Spatial characteristic and controlling factors of surface water hydrochemistry in the Tarim River Basin, Arid Land Geogr., 39 (2016) 201633–201640.
[8] Y. Tian, C.Y. Li, S.N. Zhao, Y. Li, L. Zhang, S. Zhao, Assessment of water environmental quality in Inner Mongolia section of Yellow River based on fuzzy mathematics, Bull. Soil Water Conserv., 36 (2016) 162–166.
[9] J.S. Chen, F.Y. Wang, D.W. He, Geochemistry of water quality of the Yellow River Basin, Earth Sci. Front., 13 (2006) 58–73.
[10] F.J. Xiao, Y.H. Ou, Ecosystem health and its evolution indicator and method, J. Nat. Resour., 17 (2002) 204–209.
[11] S.Z. Zhao, P.D. Wang, F.J. Kong, X. Wang, J. Zhao, S. Li, Q. Zhang, Evaluation of ecosystem health status of Inner Mongolia section of Yellow River, Geoscience, 22 (2008) 1023–1024.
[12] J. Li, M.H. Li, X.M. Fang, F. Wu, Q. Meng, Z. Zhang, X. Liu, Hydrochemical characteristics of the Hurleg Lake, Arid Land Geogr., 38 (2015) 43–51.
[13] J.S. Chen, F.Y. Wang, X.H. Xia, L. Zhang, Major element chemistry of the Changjiang(Yangtze River), Chem. Geol., 187 (2002) 231–255.
[14] R.J. Gibbs, Mechanisms controlling world water chemistry, Science, 170 (1970) 1088–1090.
[15] C.D. Li, S.C. Kang, Y.Q. Liu, J. Hou, J. Guo, X. Liu, Z. Cong, Q. Zhang, Distribution of major ions in waters and their response to regional climatic change in Tibetan lakes, J. Lake Sci., 26 (2016) 743–754.
[16] R.J. Wang, Three-line Diagram and Hydrogeological Interpretation, Geotechnical Investigation and Surveying, 1983, pp. 6–11.
[17] R.J. Gibbs, Water chemistry of the Amazon River, Geochim. Cosmochim. Acta, 1 (1972) 1061–1066.
[18] T. Ahmad, P.P. Khanna, G.J. Chakrapani, S. Balakrishnan, Geochemical characteristics of water and sediment of the Indus river, Trans-Himalaya, India: constrains on weathering and erosion, J. Asian Earth Sci., 16 (1998) 333–346.