Available online at www.sciencedirect.com

ScienceDirect

IERI Procedia 8 (2014) 113 – 118

Procedia IERI

www.elsevier.com/locate/procedia

2014 International Conference on Agricultural and Biosystem Engineering

Impact of Human Activity on the Groundwater Chemical Composition of the South Part of the Poyang Lake Basin

Zhanxue Sun[a], E.A. Soldatova[b]*, N.V. Guseva[b], S.L. Shvartsev[b,c]

[a]East China Institute of Technology, Fuzhou, Jiangxi Province, 344000, China

[b] National Research Tomsk Polytechnic University, Lenina Avenue 30, Tomsk, 634050, Russia

[c]Tomsk Filial of the A.A. Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences, Akademicheskii Avenue 4, Tomsk, 634055, Russia

Abstract

The Poyang Lake basin is one of the main agricultural regions in China with dense population. As a result, groundwater in the research area is exposed to anthropogenic influence. This article considers distinctive features of the groundwater chemical composition. A special attention is paid to main pollutants in the research area. The chemical composition of groundwater was found to have resulted from the complex of natural and anthropogenic factors.

Selection and peer review under responsibility of Information Engineering Research Institute

Keywords: Groundwater; chemical composition; the Poyang Lake basin; pollution

1. Introduction

The Poyang Lake basin is a unique wetland system, which simultaneously is a habitat of rare animal species and an important part of economics. Wide alluvial plains, surrounding Poyang Lake, make the basin one of the main agricultural regions in China. This fact and also dense population with domination of rural

* Corresponding author. Tel.: +7-382-241-9068.
E-mail address: 2a61@mail.ru.

Selection and peer review under responsibility of Information Engineering Research Institute
doi:10.1016/j.ieri.2014.09.019

population lead to increasing the anthropogenic impact, which result, inter alia, in modification of the groundwater chemical composition. The vexed problem of rural regions such as the Poyang Lake basin, where intensive agricultural activity is developed, is groundwater pollution by potassium, phosphate and especially nitrogen compounds (Briling, 1985, Tyutyunova, 1987, Min et al., 2002) with fertilizers, domestic sewage, manure and other livestock waste. Thus it is reasonable to draw special attention to the major pollutants behavior in addition to the complex investigation of the groundwater chemical composition.

2. Materials and Methods

2.1. Study area

The Poyang Lake basin is situated in the south-east China, Jiangxi province. It is one of the main hydrological subsystems of the Yangtze River. The research area refers to the province with subtropical humid climate. The annual mean precipitation is 1400–2400 mm (Wang et al., 2013). An extremely irregular distribution of rainfall during year is resulted from the effect of monsoon. The relief of the Poyang Lake basin is quite various, from mountains of 2200 m height to rolling and alluvial plains (Li and Zhang, 2011).

2.2. Sampling and analytical procedures

The fieldwork in the south part of the Poyang Lake basin was conducted in January and October, 2013. In the study area 27 groundwater samples were collected from wells. The depth of wells in the most cases did not exceed 10 m. The sampling points are confined to the catchment areas of the five major rivers feeding the lake (Fig. 1).

For each sampling point 0,6 L of water was collected using polyethylene bottles to analyze the main ions, N species (NO_3^-, NO_2^-, NH_4^+), PO_4^{2-}, DOC and etc. Electrical conductivity, temperature and pH were measured *in situ.*

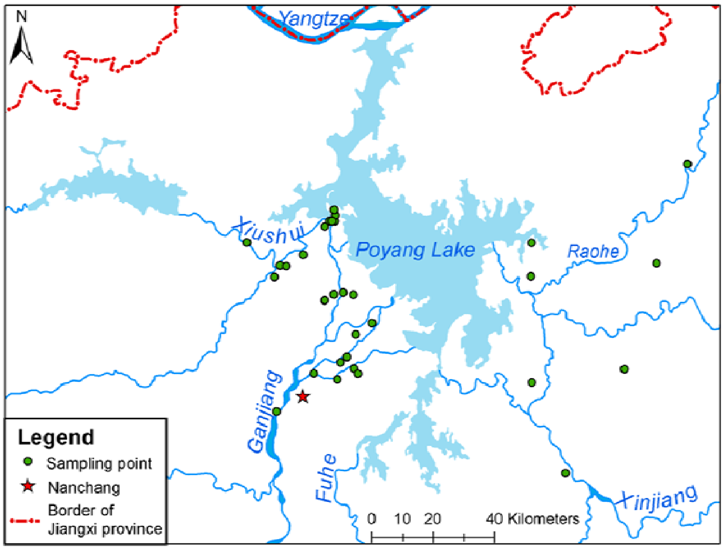

Fig. 1. Scheme of the location of the sampling points in the Poyang Lake basin.

The main ions (SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, K^+) were analyzed by ion chromatography (ICS 1000 and ICS 2000), CO_2, CO_3^{2-}, HCO_3^- by titration. N species (NH_4^+, NO_2^-, NO_3^-) and PO_4^{2-} were measured by fotocolorimetry, DOC by high-temperature catalytic oxidation method at The Research and Education Center "Water" of The Institute of Natural Resources (TPU, Tomsk, Russia). The chemical composition investigation results are given below (Table 1).

Table 1. Chemical composition of the Poyang Lake basin groundwater. TDS=Total Dissolved Solids; - : not determined.

ID	pH	Eh	CO_2	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	NH_4^+	NO_2^-	NO_3^-	PO_4^{3-}	DOC	TDS
		mV							mg/L							
PL-1	6,8	261	8,8	68,3	11,4	19,0	17,9	16,6	14,3	7,08	0,43	0,05	34,8	0,14	1,95	189,5
PL-4	7,1	169	17,6	323,3	111,3	67,8	75,4	55,1	58,2	0,94	0,39	0,01	71,3	0,05	2,99	763,4
PL-5	5,0	297	12,3	2,44	0,89	1,49	1,90	0,85	1,37	0,39	0,14	0,02	6,78	-	1,11	16,1
PL-6	5,0	319	17,6	3,66	7,33	60,9	15,2	4,36	34,7	6,58	0,53	0,04	86,1	0,10	2,27	218,8
PL-7	4,9	217	12,3	2,44	0,16	5,26	3,06	1,03	4,52	1,81	0,12	0,01	15,7	-	1,01	33,9
PL-8	6,9	139	17,6	81,7	7,50	3,01	28,7	3,17	2,89	4,60	0,17	0,02	9,46	0,24	1,87	141,1
PL-9	7,0	167	14,1	98,8	25,7	15,1	53,9	9,19	10,5	2,48	0,14	0,03	55,5	0,02	2,12	271,2
PL-10	4,8	202	28,2	3,66	0,17	11,7	2,95	1,83	9,92	2,56	0,02	0,01	21,9	-	1,03	54,7
PL-11	6,2	123	52,8	104,9	19,4	41,3	22,8	12,6	23,9	2,34	2,15	0,02	0,31	-	2,35	227,6
P2	6,3	-73	88,0	100,0	0,67	17,3	13,8	4,24	7,29	1,4	2,9	-	0,22	-	1,03	144,9
P7	6,7	58	35,2	170,8	38,9	22,1	47,5	6,89	18,3	21,2	-	0,3	15,1	0,61	0,89	340,8
P8	6,1	176	39,6	48,8	8,80	32,5	22,6	3,7	15,1	4,84	-	-	23,1	0,15	0,59	159,4
P9	6,5	16	39,6	109,8	3,50	1,95	13,3	6,37	12,8	0,95	0,86	-	0,15	-	0,75	148,8
P10	5,9	113	26,4	18,3	30,1	20,7	16,7	2,76	13,1	3,3	-	-	24,1	-	0,71	129,1
P11	6,4	53	30,8	91,5	14,5	44,8	28,5	9,6	25,0	3,99	-	-	38,4	-	0,98	256,3
P12	6,1	52	44,0	48,8	5,50	25,4	15,4	5,17	17,7	0,74	1,12	0,07	35,6	-	0,47	154,3
P13	6,6	23	35,2	134,2	70,7	58,9	39,3	7,36	43,4	76,0	-	-	93,9	0,58	1,34	523,7
P14	6,4	-68	88,0	164,7	0,75	1,67	23,8	4,5	7,6	1,2	3,4	-	0,22	-	1,58	204,4
P15	6,5	-78	26,4	54,9	6,10	16,6	10,3	2,86	10,7	4,43	1,95	-	0,2	0,09	1,98	106,1
P16	7,0	-91	17,6	146,4	0,94	3,7	21,8	7,58	8,3	1,65	6,4	-	0,24	-	5,53	190,6
P17	6,5	-85	70,4	134,2	0,72	4,93	14,3	6,14	10,6	1,3	3,3	-	0,2	-	2,00	172,4
P18	5,5	140	140,8	36,6	27,2	55,6	20	5,27	25,3	1,25	0,97	-	20,3	0,05	1,10	191,5
P19	6,5	47	30,8	73,2	34,3	26,7	20,7	9,06	17,9	14,9	0,38	-	26,9	0,23	0,84	223,6
P20	6,0	79	48,4	36,6	111,4	14,7	32,6	9,7	22,9	2,46	-	-	28,8	0,06	0,69	259,1
P21	6,7	16	22,0	97,6	14,0	14,4	15,7	6,78	12,5	4,12	2,28	-	0,9	0,18	0,70	166,0
P22	6,3	4	22,0	30,5	2,40	3,2	2,18	1,18	7,8	0,93	-	-	0,49	0,10	0,41	48,7
P23	6,3	90	30,8	54,9	5,90	1,38	4,42	1,72	11,5	1,28	-	-	0,88	0,11	0,34	82,0

3. Results

Groundwater of the Poyang Lake basin is fresh with TDS (Total Dissolve Solids) values mainly below 500 mg/L (Table 1). The value of TDS is above 500 mg/L only in two sampling points (PL-4, P13) having amounts 763,4 and 523,7 mg/L, respectively. The main ions (Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}) make a significant contribution to the TDS value as well as NO_3^{-} и K^{+}. The pH value is ranged from 4,83 to 7,06 (Table 1) with an average 6,22. Relatively low concentrations of DOC (Dissolved Organic Carbon) in groundwater are provided by the high content of CO_2, probably which are the results of organic matter mineralization.

One of the characteristic features of groundwater of the Poyang Lake basin is a variety of the chemical composition (Fig. 2a). Taking in account natural conditions of groundwater chemical composition formation, especially, the fact that territory of the basin corresponds to the province with subtropical humid climate, and absence of salt deposits in upper part of earth crust, one might suppose that the Poyang Lake basin chemical composition groundwater should be HCO_3–Ca and HCO_3–Ca–Mg. However, increased role of chloride and nitrate in anionic composition is registered in groundwater. Their high concentrations lead to dividing of groundwater into specific types with prevalence of those compounds, the content of Cl^{-} and NO_3^{-} reaches 52% (PL-6) and 57% (PL-7) in sum of anions, respectively. At the same time, their total content reaches 94% in sampling point PL-6. In some sampling points rising concentrations of sulfates is observed. The cationic composition also is non-homogenous (Fig. 2a), a significant proportion of sodium is noted and in some points the high content of potassium. Concentrations of phosphates in groundwater of the Poyang Lake basin is low, rarely above 0,2 mg/L (Table 1).

4. Discussion

Significant fluctuations of the chemical composition result from the impact of the complex of natural and anthropogenic factors to its formation. The high nitrates content require particular attention.

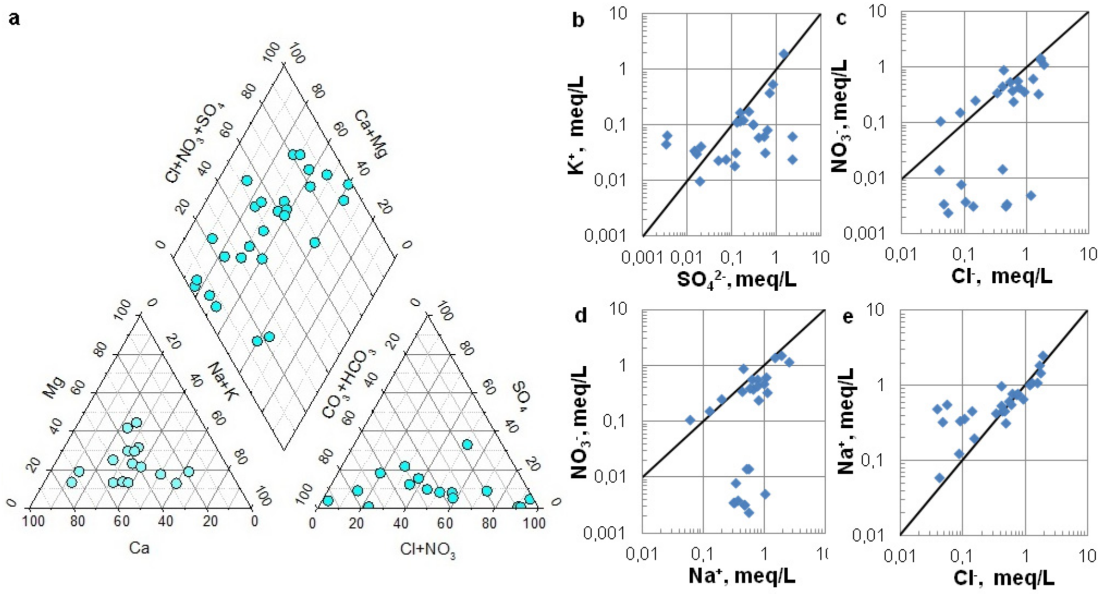

Fig. 2. (a) Piper diagram with the data of the chemical composition of the Poyang Lake basin groundwater; (b) K^{+} concentrations versus SO_4^{2-} concentrations; (c) NO_3^{-} concentrations versus concentrations of Cl^{-}; (d) NO_3^{-} concentrations versus concentrations of Na^{+}; (e) concentrations of Na^{+} versus Cl^{-} concentrations.

One notices a tendency to accumulation of potassium concentrations in groundwater with rising of sulfate concentrations (Fig. 2b). The most likely source of K^+ in groundwater of the Poyang Lake basin is potash fertilizers. In this way, rising of SO_4^{2-} concentrations, as well as K^+, probably is connected with agricultural activity and using of the potash fertilizers, as far as many of them are represented by sulfates with high solubility. Besides it, sulfides may be natural source of high sulfate concentrations in groundwater, however, dependence between reduction-oxidation conditions, pH value and concentrations of sulfate is not observed.

Also probable source of SO_4^{2-} and Cl^- enrichment may be industrial pollution. However, the observed dependence of NO_3^- concentrations from Cl^- and Na^+ (Fig. 2c, d), as well as interdependence between Cl^- and Na^+ (Fig. 2e) likely results from common source of NO_3^-, Cl^- and Na^+ enrichment. Their supposed sources may be mineral and organic fertilizers, which easy to dissolve and are washed out from soil, as well as domestic sewage (Roy et al., 1999, Min et al., 2002, Koh et al., 2010, Nisi et al., 2013). However, correlations between NO_3^-, Cl^- and Na^+ point to predominant contribution of domestic sewage to nitrogen compounds balance in groundwater. According to Roy and Nisi (Roy et al, 1999, Nisi et al., 2013), who described the dependence between ratios Cl/Na and NO_3/Na on the sources of NO_3^- enrichment in natural water, formation of groundwater chemical composition occurs under influence of complex of anthropogenic factors – agricultural component and communal effluent (Fig. 3a). Position of the points on the diagram indicates the dominant influence of domestic sewage to NO_3^-, Cl^- and Na^+ enrichment processes.

Nevertheless, low nitrate concentrations do not mean absence of anthropogenic impact. In this case, the low content of NO_3^- is compensated by rising of NH_4^+, which is generated by nitrates reduction under the low Eh value, on the one hand, and on the other, when NH_4^+ gets directly into reducing conditions, which are formed as a result of using organic fertilizers or decomposition processes of manure or other products of

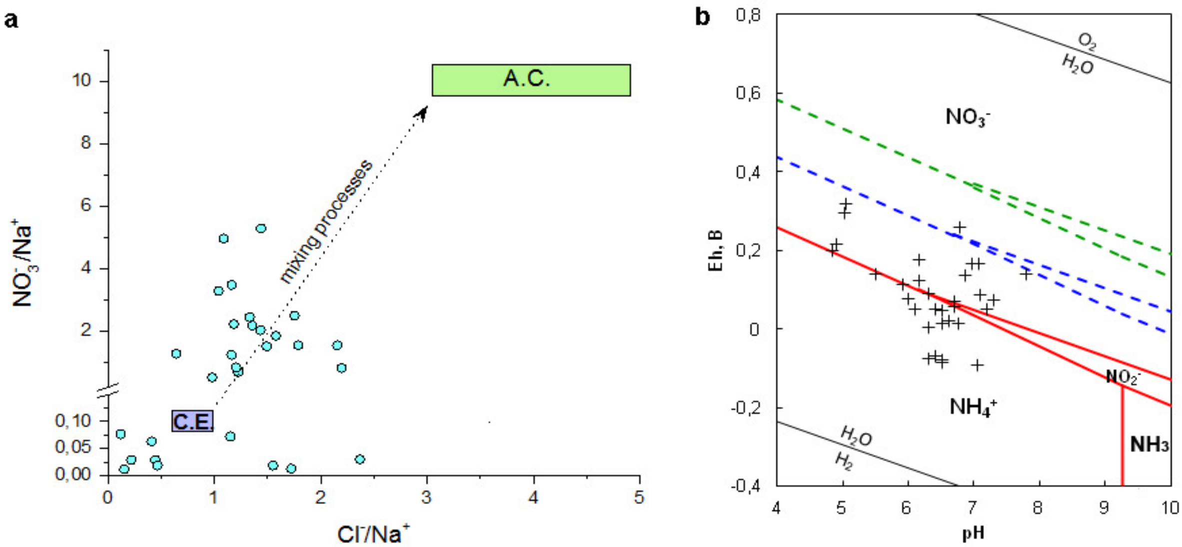

Fig. 3. (a) Diagram of NO_3^-/Na^+ versus Cl^-/Na^+ for the Poyang Lake basin groundwater. A.C. – agricultural component, C.E. – communal effluent (Roy et al., 1999, Nisi et al., 2013). (b) Diagram of dissolved nitrogen compounds stability for the Poyang Lake basin groundwater. Fields of nitrogen compounds stability, plotted on the base of the chemical composition of the Poyang Lake basin groundwater, are restricted by red lines. Fields of stability, plotted using factual data of the chemical composition of nitrogen polluted groundwater (Krainov et al., 1991), are restricted by dotted blue lines. Theoretical fields of nitrogen compounds stability (Krainov et al., 1991) are restricted by dotted green lines.

animal husbandry (Krainov et al., 1991) and domestic waste. Based on the factual sampling data, the diagram of stability of the main dissolved nitrogen compounds (Fig. 3b) differs from theoretical and practical plotting described by Krainov (Krainov et al., 1991). In particular one may notice decreasing the Eh value of transformation oxidized nitrogen forms to reduced forms. One of a probable explanation of this fact is high activity of nitrifying bacteria under suitable temperature conditions of subtropical humid climate.

5. Summary and Conclusion

In the most cases, except main pollutant mentioned below, the chemical composition of groundwater corresponds with the average concentration of chemical elements in groundwater of the province of subtropical humid climate (Shvartsev, 2008). High concentrations of NO_3^-, Cl^-, SO_4^{2-}, K^+, Na^+ are caused by the complex of natural and anthropogenic factors to formation of groundwater chemical composition. Among the anthropogenic factors, agricultural activities and influence of domestic sewage are probably prevailed. Low concentration of NO_3^- in the most cases is compensated by rising of NH_4^+. One can conclude that human activity and dense population in the Poyang Lake basin have a significant influence to formation of the groundwater chemical composition.

Acknowledgements

The investigations were supported by The Russian Foundation for Basic Research (Project No 14-05-31267) and the Russian government assignment "Nauka" TPU.

References

[1] Briling IA. Groundwater contamination by nitrate fertilizer. Water Resources 1985;4:101-107 (in Russian).
[2] Tyutyunova FI. Hydrogeochemistry of technogenesis. Moscow: Nauka; 1987 (in Russian).
[3] Min JH, Yun ST, Kim K, Kim HS, Hahn J, Lee KS. Nitrate contamination of alluvial groundwaters in the Nakdong River basin, Korea. Geosciences J 2002;6(1):35-46.
[4] Wang Q, Riemann D, Vogt S, Glaser R. Impacts of land cover changes on climate trends in Jiangxi province China. Int J Biometeorol 2013.
[5] Li X, Zhang Q. Estimating the potential evapotranspiration of Poyang Lake basin using remote sense data and Shuttleworth-Wallace model. Procedia Environmental Sciences 2011;10:1575-1582.
[6] Roy S, Gaillardet J, Allegre CJ. Geochemistry of dissolved and suspended loads of the Sein river, France. Anthropogenic impact, carbonate and silicate weathering. Geochim Cosmocim Acta 1999; 63:1277-1292.
[7] Koh DC, Mayer b, Lee KS, Ko KS. Land-use controls on sources and fate of nitrate in shallow groundwater of an agricaltural area revealed by multiple environmental tracers. J of Contaminant Hydrology 2010;118:62-78.
[8] Nisi B, Vaselli O., Delgado Huertas A, Tassi F. Dissolved nitrates in the groundwater of the Cecina Plain (Tuscany Central-Western Italy):Clues from the isotopic signature of NO_3^-. Applied Geochem 2013;34:38-52.
[9] Krainov SR, Solomin GA, Zakutin VP. Oxidation-reduction conditions of nitrogen compound transformation in groundwater (for geochemistry-ecological problem solving). Geochemistry 1991;6:822-831 (in Russian).
[10] Shvartsev S.L. Geochemistry of Fresh Groundwater in the Main Landscape Zones of the Earth / Geochemistry International. – USA: Pleiades Publishing, Ltd, 2008 – V. 46. – № 3. – P. 128–1398.