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HYDROCHEMISTRY AND MAPPING OF THE GROUNDWATER CONTAMINATION INDEX IN CHANGCHUN CITY, CHINA

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Groundwater quality is changing in Changchun City. The Ca-HCO_3 or Ca-Cl facies type tends to be influenced by release of anthropogenic nitrate, calcium, sulfide, and chloride. A scatter analysis shows a strong positive correlation between the ions Ca, Cl and nitrate and a weak negative correlation between the thickness of the unsaturated zone and the Ca, SO_4, Cl and nitrate ions. A mapping of contaminant index based on the Chinese standard for groundwater quality classifies the groundwater of most parts of the city in the worst classes, and reveals a growth of the heavily polluted zone from 1995 to 1998. The groundwater is not suitable for drinking due to the presence of high concentrations of nitrate, nitrite, iron and manganese, but can be used for irrigation.

INTRODUCTION

This study investigates and characterizes the dynamic change in groundwater quality in Changchun City during the past several years. Numerous studies on Changchun City groundwater had shown this change (Mou Shu Qin et al., 1992; Wang Bian and Zhao Yuqi and Wang Bian, 1990) but there has been no reliable demonstration of the cause of these changes. The result of the scatter analysis presented here is evidence that part of the major ions, specifically Ca, Cl, and SO_4 have no natural origin. The results of this study contributes to a better understanding of the hydrochemistry and the evolution of water quality.

SITE CHARACTERIZATION

The study area is the urban area of Changchun City (Figure 1a). It is located between 43° 47´ to 43° 59´ N and 125 °12´ to 125 °26´ E in the central part of the northeast plain of China, and it covers a total area of about 500 km2.

Changchun City, the capital of Jilin province, borders Jilin City on the southeast, Heilongjiang province on the northeast, Siping City on the southwest and Baicheng City on the northwest.

The climate of this part of China is cold with a long winter (October to March) in the year, and a short summer (May to September). The mean annual rainfall in Changchun City ranges from 500-900 mm while mean annual temperature is 4 degrees C.

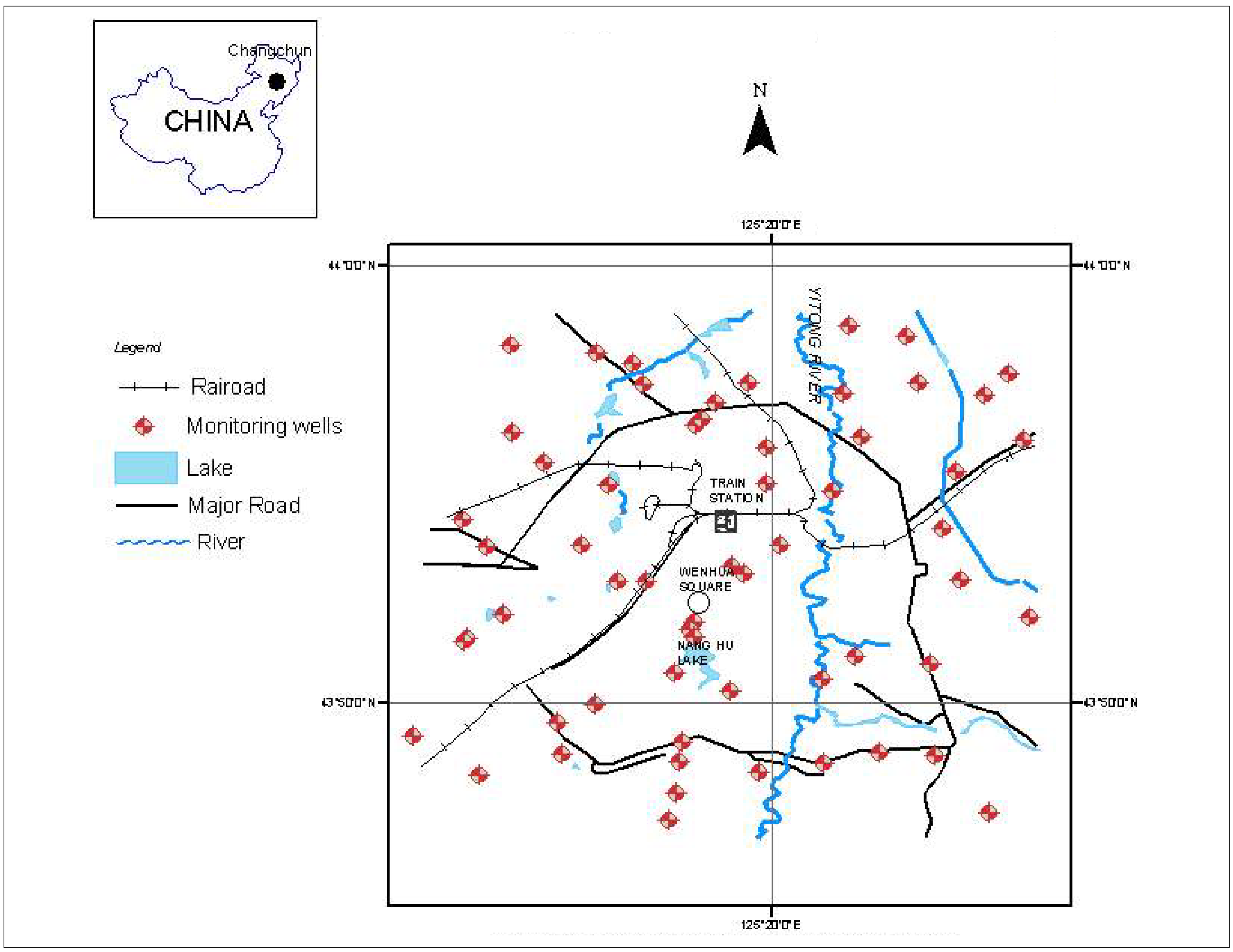

Figure 1. Map of study area.

Changchun City, with a population of about 6 million inhabitants, has grown over these last ten years either in urbanization or economically, which has lead to an increase of population, industry, and especially a deficit in water supply. In addition, many environmental problems such as air pollution, solid wastes, sewage effluent management, and seepage of irrigation water into the aquifers are common problems today in Changchun City.

The Yitong River is the main river in the study area, there are several artificial lakes and open reservoirs for water supply and wastewater drains. The water quality in the Yitong River in Changchun City is affected by agricultural, industrial, and municipal wastewater.

The geological structure of the study area consists of Quaternary deposits in the upper part and a Cretaceous and Jurassic bedrock in the lower part. The quaternary substratum is formed by alluvium provided by the river and consists of backfill soil, cohesive soil, and sandy soil with a thickness that varies from 3-20 m.

The Cretaceous formations consist mostly of mudstone and argillaceous sandstone with an average thickness of about 300 m. The bedrock Jurassic formations are of rhyolite and andesite.

The Tectonics are characterized by vertical and horizontal displacements in the Cretaceous and Jurassic formations (Figure 1b). The major faults are generally hidden by the quaternary formations.

Two main types of aquifers characterize the aquifer system:

-The unconsolidated Quaternary formations constitute the upper aquifers; they are exploited by

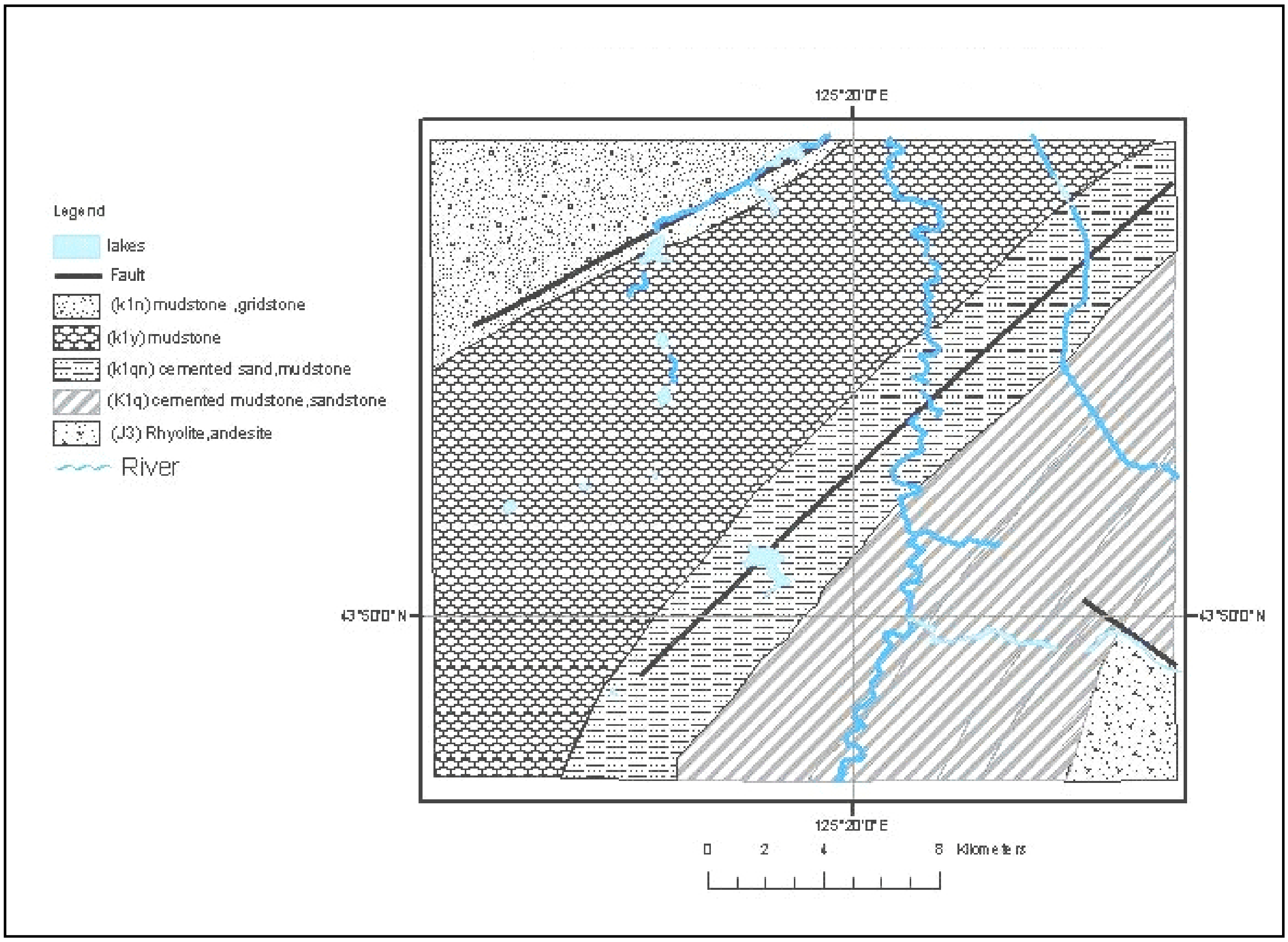

Figure 1b. Geology of the fissured aquifer system.

shallow wells. The thicknesses of these aquifers varies from 5 to 20 m, and their productivity varies from 10 to 1000 m^3/day.

-Deep aquifers that are the result of the fractured and fissured Cretaceous and Jurassic formations. The fractured sandstone is a very productive aquifer, while the less fractured mudstone is very poor. The thicknesses vary from 20 to 300 m, and productivity is varies from 100 to 3000 m^3/day.

The main directions of groundwater flow converge towards the Yitong River.

The pH of the groundwater ranges from 7 to 9. The temperature varies from 8° C in the shallow aquifers to 40° C in the deep aquifers. The deep fissure water is very mineralized (0.8-1 g/l) compared to the shallow pore water (0.1-0.3 g/l) when it is not polluted.

METHODOLOGY

The Water Resource office in Changchun City and the College of Environment and Resources at Jilin University have conducted a groundwater quality monitoring program in Changchun City since 1981. The program is based on annual sampling of randomly selected municipal water supply wells from July to September, and was designed to provide data for characterizing groundwater quality in the shallow Quaternary aquifers and deep bedrock aquifers.

Temperature, pH, and conductivity were measured in the field .The concentrations of Ca, Mg, Fe, Cl, HCO_3, and SO_4 were determined by titration, while those of K, Na, NO_3 were determined by atomic absorption.

Some sampling well data from 1983 to 1990 have been used to show the natural water quality considering that they may be less affected by industrialization and the growth of population. Data from sampling wells in 1998 have been used to determine the evolution of the water facies by means of the Piper diagram.

In order to locate the origin of the pollution, regression analyses are conducted to detect relationships between some pairs of ionic species, or between these species and the water level in the monitoring wells (thickness of the vadose zone.)

A mapping using GIS features has been conducted to detect the zones that are most affected by chemical pollution according to the Chinese quality standard for groundwater, and the spatial-temporal evolution of this pollution.

RESULTS

Natural groundwater quality

Table 1 shows the evolution of groundwater type according to the major anions and cations from 1983 to 1990 in different wells. Almost 40 percent of these sampling wells were used for drinking purposes in 1988 while the remaining part where used for agriculture or industries.

The concentrations of major ions are expressed in milliequivalent per liter (meq/l), with the error of ionic balance:

$$e = \frac{\sum cation - \sum anion}{\sum cation + \sum anion} * 100 \leq 5\% \tag{1}$$

Table 1. Evolution in Major Ions in Groundwater from 1983 to 1990
Concentration of Ions in Milliequivalent per Liter (meq/l)

Lithology	Well ID	Water Chemistry 1983	1984	1985	1986	1987	1988	1989	1990
Pore Water	A072	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$Cl>HCO_3>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Mg>Na	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$NO_3>Cl>SO_4$ Ca>Na>Mg	$Cl>SO_4>HCO_3$ Ca>Na>Mg	$Cl>SO_4>HCO_3$ Ca>Na>Mg	$Cl>SO_4>HCO_3>NO_3$ Ca>Na>Mg
Q4	A064	$SO_4>HCO_3>Cl$ Ca>Mg>Na	$SO_4>HCO_3>Cl$ Ca>Na>Mg	$SO_4>HCO_3>Cl$ Ca>Mg>Na	$HCO_3>SO_4>Cl$ Ca>Na>Mg	$SO_4>HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>NO_3>SO_4$ Ca>Na>Mg
	A028	$Cl>SO_4>HCO_3$ Ca>Na>Mg	$Cl>SO_4>HCO_3$ Ca>Na>Mg	$Cl>SO_4>HCO_3$ Ca>Na>Mg	$SO_4>Cl>HCO_3$ Ca>Na>Mg	$SO_4>Cl>HCO_3$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$SO_4>Cl>HCO_3$ Ca>Na>Mg	$Cl>SO_4>HCO_3$ Ca>Na>Mg
	A092	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$Cl>HCO_3>SO_4$ Ca>Na>Mg	$NO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>SO_4>Cl$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$SO_4>Cl>HCO_3$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Na>Ca>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg
Pore Water	A001	$Cl>HCO_3>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$Cl>HCO_3>SO_4$ Ca>Na>Mg	$Cl>HCO_3>SO_4$ Ca>Na>Mg	$Cl>HCO_3>SO_4$ Ca>Mg>Na
Q3	A106	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$Cl>HCO_3>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>NO_3>SO_4$ Ca>Na>Mg
	A212	$Cl>NO_3>HCO_3$ Ca>Mg>Na	$Cl>NO_3>HCO_3$ Ca>Mg>Na	$Cl>NO_3>SO_4$ Ca>Mg>Na	$Cl>NO_3>SO_4$ Ca>Na>Mg	$Cl>SO_4>HCO_3$ Ca>Na>Mg	$Cl>NO_3>SO_4$ Ca>Mg>Na	$SO_4>Cl>HCO_3$ Ca>Mg>Na	$Cl>NO_3>HCO_3$ Ca>Mg>Na
	A097	$Cl>NO_3>SO_4$ Ca>Na>Mg	$Cl>NO_3$ Ca>Mg>Na	$Cl>NO_3> HCO_3$ Ca>Mg>Na	$Cl>NO_3>SO_4$ Ca>Na>Mg	$Cl>NO_3>SO_4$ Ca>Na>Mg	$Cl>NO_3>HCO_3$ Ca>Na>Mg	$Cl>SO_4>HCO_3$ Ca>Mg>Na	$Cl>NO_3>SO_4$ Ca>Mg>Na
	A099	$Cl>NO_3>HCO_3$ Ca>Mg>Na	$NO_3>Cl>HCO_3$ Ca>Na>Mg	$NO_3>Cl>SO_4$ Ca>Na>Mg	$NO_3>Cl>SO_4$ Ca>Na>Mg	$NO_3>Cl>SO_4$ Ca>Na>Mg	$NO_3>Cl>HCO_3$ Ca>Na>Mg	$NO_3>Cl>SO_4$ Ca>Mg>Na	$Cl>HCO_3>SO_4$ Ca>Na>Mg
Pore Water	A045	$NO_3>HCO_3>Cl$ Ca>Mg>Na	$HCO_3>NO_3>Cl$ Ca>Mg>Na	$NO_3>HCO_3>Cl$ Ca>Na>Mg	$NO_3>Cl$ Ca>Na	$NO_3>Cl>HCO_3$ Ca>Mg>Na	$NO_3>Cl>HCO_3$ Ca>Na>Mg	$NO_3>Cl>HCO_3$ Ca>Na>Mg	$NO_3>Cl>HCO_3$ Ca>Na>Mg
Q2	A120	$HCO_3>Cl>SO_4$ Ca>Mg>Na	$Cl>NO_3$ Ca>Mg>Na	$Cl>NO_3>HCO_3$ Ca>Na>Mg		$NO_3>Cl$ Ca>Mg	$Cl>NO_3$ Ca>Mg	$Cl>NO_3$ Ca>Mg	$Cl>NO_3$ Ca>Mg
	A037	$Cl>NO_3>HCO_3$ Ca>Mg>Na	$Cl>NO_3>HCO_3$ Ca>Mg>Na	$Cl>NO_3>HCO_3$ Ca>Mg>Na	$Cl>NO_3>HCO_3$ Ca>Mg>Na	$Cl>NO_3>SO_4$ Ca>Mg>Na	$Cl>NO_3>SO_4$ Ca>Mg>Na	$Cl>NO_3>SO_4$ Ca>Mg	$Cl>NO_3>SO_4$ Ca>Mg
	A087			$Cl>NO_3>SO_4$ Ca>Na>Mg	$NO_3>Cl>SO_4$ Ca>Na>Mg	$NO_3>Cl>SO_4$ Ca>Na>Mg	$NO_3>Cl>HCO_3$ Ca>Na>Mg	$NO_3>SO_4>Cl$ Ca>Na>Mg	$NO_3>Cl>SO_4$ Ca>Na>Mg
	A016	$Cl>SO_4>NO_3$ Ca>Mg>Na	$Cl>NO_3>HCO_3$ Ca>Na>Mg	$Cl>SO_4>NO_3$ Ca>Mg>Na	$NO_3>Cl>SO_4$ Ca>Na>Mg	$Cl>NO_3>SO_4$ Ca>Mg>Na	$Cl> SO_4$ Ca>Mg>Na	$SO_4>HCO_3>Cl$ Ca>Na>Mg	$NO_3>Cl$ Ca>Mg>Na
	A218	$SO_4>NO_3>HCO_3$ Ca>Na>Mg	$Cl>HCO_3>SO_4$ Ca>Na>Mg	$NO_4>SO_4>HCO_3$ Ca>Na>Mg	$NO_4>SO_4>HCO_3$ Ca>Na>Mg	$NO_4>SO_4>Cl$ Ca>Na>Mg	$NO_4>SO_4>Cl$ Ca>Na>Mg	$NO_3>HCO_3>Cl$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Na>Mg
Fissure water	A074	$HCO_3>Cl$ Na>Ca>Mg	HCO_3 Na>Ca>Mg	HCO_3 Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg	HCO_3 Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl$ Na>Ca>Mg	$HCO_3>Cl$ Ca>Na>Mg
	A073	$HCO_3>Cl>SO_4$ Na>Ca>Mg	$HCO_3>Cl$ Ca>Mg>Na	HCO_3 Na>Ca>Mg		$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg
	A115	$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>SO_4$ Ca>Na>Mg	$HCO_3>NO_3$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>NO_3>SO_4$ Ca>Na>Mg	$HCO_3>SO_4>Cl$ Ca>Na>Mg	HCO_3 Ca>Na>Mg	HCO_3 Ca>Na>Mg
	A208	$HCO_3>Cl>NO_3$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$HCO_3>Cl>NO_3$ Ca>Mg>Na	$HCO_3>Cl>SO_4$ Ca>Mg>Na	$HCO_3>Cl$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na
	A203	$HCO_3>Cl>NO_3$ Ca>Na>Mg	$HCO_3>Cl>NO_3$ Ca>Mg>Na	$HCO_3>Cl>NO_3$ Ca>Mg>Na	$HCO_3>Cl>NO_3$ Ca>Mg>Na	$HCO_3>Cl>NO_3$ Ca>Mg>Na	$HCO_3>Cl>SO_4$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$HCO_3>Cl>NO_3$ Ca>Mg>Na
	A214	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$HCO_3>Cl>NO_3$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$HCO_3>Cl>NO_3$ Ca>Mg>Na
	A020				$Cl>HCO_3>NO_3$ Ca>Mg	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na	$Cl>HCO_3>SO_4$ Ca>Mg>Na	$Cl>HCO_3>NO_3$ Ca>Mg>Na
	A210	$HCO_3>Cl$ Ca>Mg>Na	$HCO_3>Cl>SO_4$ Ca>Mg>Na	$HCO_3>Cl>SO_4$ Ca>Mg>Na	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg
	A005	$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl>NO_3$ Ca>Na>Mg	$HCO_3>Cl>NO_3$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>NO_3$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg
	A015	$HCO_3 >SO_4$ Ca>Mg>Na	$HCO_3>SO_4>Cl$ Ca>Mg>Na	$HCO_3>SO_4>Cl$ Ca>Mg>Na	$HCO_3>Cl>SO_4$ Ca >Na	$HCO_3>Cl>SO_4$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Mg>Na	$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl$ Ca>Na>Mg
	A030					$HCO_3>Cl$ Ca>Na>Mg	$HCO_3>Cl>SO_4$ Ca>Mg>Na	$HCO_3>Cl$ Ca>Na>Mg	HCO_3 Na>Ca>Mg
	A232				HCO_3 Na>Ca	HCO_3 Na>Ca	$HCO_3>Cl$ Ca>Na	HCO_3 Na>Ca	HCO_3 Na

Calcium, magnesium and bicarbonate are the dominant ions in most of the samples; chlorides and nitrates are dominant ions in many samples in the shallow aquifer systems.

The analysis using the Piper diagram (Piper, 1944) for the 59 samples in the 1998 data set confirms in large part these water types (Figure 2).

There are two dominant facies according to the major anions both rich in Ca and Mg:

- Bicarbonate facies: about 40 percent of the sampled water

- Chloride facies: about 50 percent of samples

- Four samples are classified as carbonate (CO3-Na+K)

There is no significant cation exchange between Ca and Na, and the values of sodium adsorption ratio (SAR) are very low with only 3 among the 59 samples in 1998 presenting a SAR greater than 10.

Statistical analysis

Scatter analyses based on Pearson correlation by means of SPSS 11 (SPSS, 2002) indicate

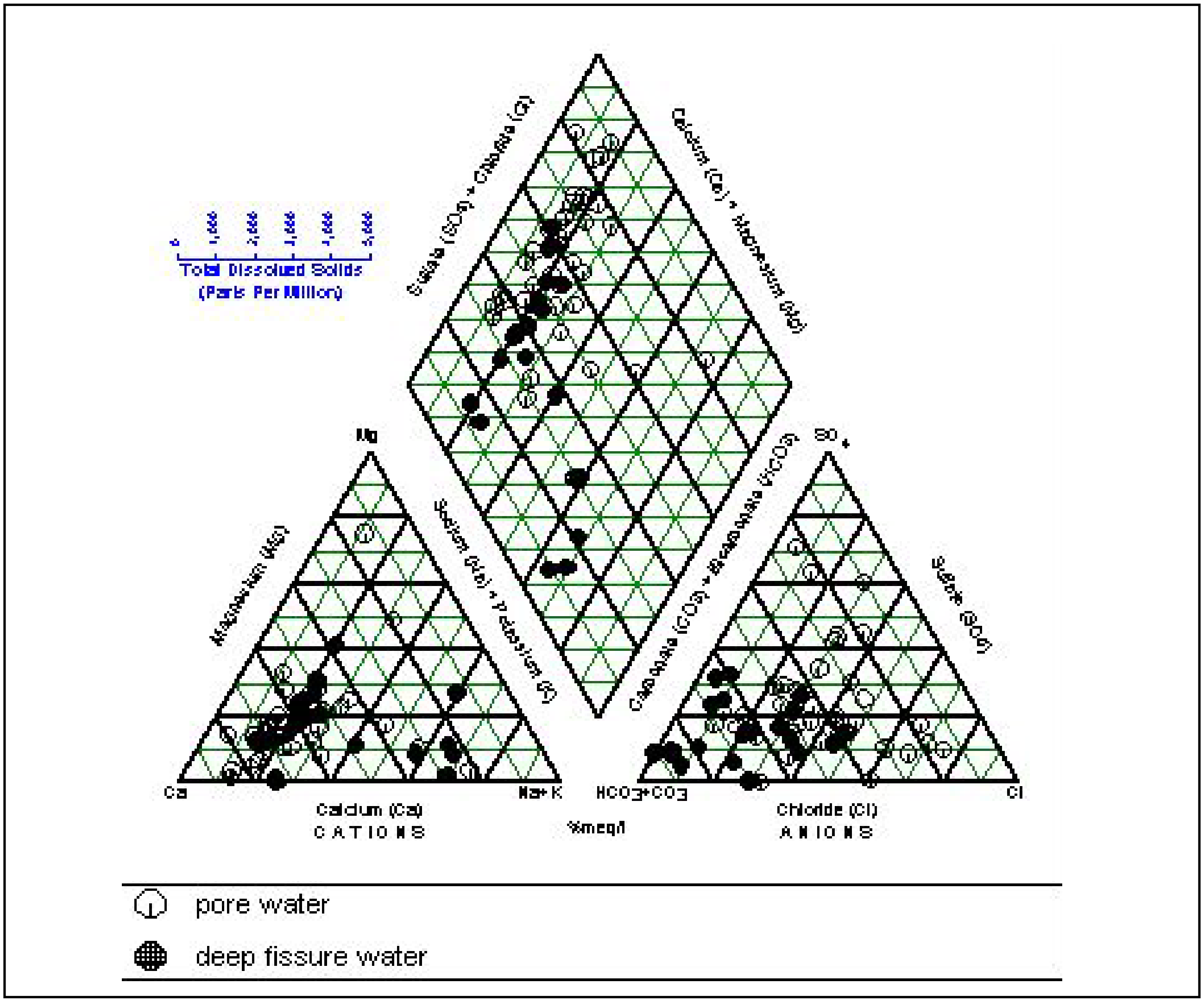

Figure 2. Piper Diagram, Changchun City 1998.

correlations between pairs of some ionic species, and between ionic species and depth of the water table in 1995 and 1998 (Table 2).

There are strong correlations between the ions Ca, Cl, and NO_3 in 1995 and 1998 (Figure 3). In 1998 the correlation is strong either in the shallow pore water or in the deep fissure water.

Weak negative correlations exist between depth of water table (thickness of the unsaturated zone) and Ca, SO_4, and NO_3 ions; these correlations are visible only fissure water, not in the pore water.

Contamination index mapping

The mapping of pollution areas is made according to Chinese quality standard for groundwater (GB/T 14848-1993). Table 3 shows standard classes for groundwater.

Table 4 shows a given index value, F_i according to the class value for each element or ion.

The contamination index is:

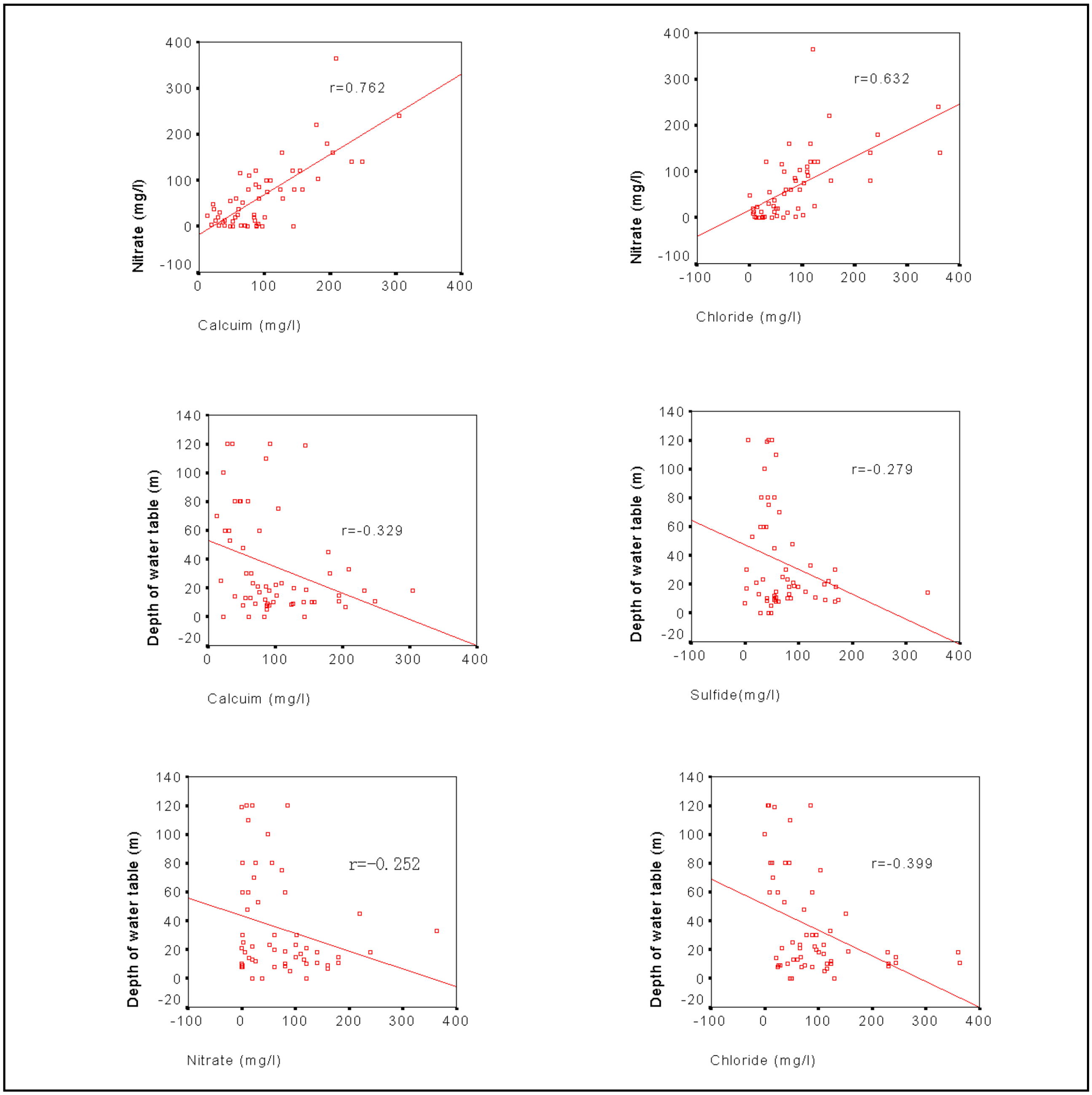

Figure 3. Correlation between ions and parameters.

$$F=\sqrt{\frac{\overline{F}^2+F_{max}^2}{2}} \tag{2}$$

Where = $$\overline{F}=\frac{1}{n}\sum_{i=l}^{n}F_i \tag{3}$$

F_{max}= the highest index values.

A nomenclature is given for water quality according to the contamination index value:

The samples of elements and ionic species with high concentration levels such as total iron NH_4, NO_3, NO_2, total hardness, and Mn have been classified using Chinese quality standard for groundwater expressed above.

Table 3. Classification of Water Quality According to Concentration of Some Ionic Species

Ions/mg/l	Standards Class Values				
	I	II	III	IV	V
Total Fe	≤0.1	≤0.2	≤0.3	≤1.5	>1.5
Mn	≤0.05	≤0.05	≤0.1	≤1	>1
TH	≤150	≤300	≤450	≤550	>550
NO_3	≤2	≤5	≤20	≤30	>30
NO_2	≤0.00	≤0.1	≤1	≤2	>2
NH_4	≤0.02	≤0.02	≤0.2	≤0.5	>0.5

Table 4. Index Values According to Class Value: Reference GB/T 14848-1993

Class	I	II	III	IV	V
Index F_i	0	1	3	6	10

Table 5. Nomenclature according to Index Value: Reference GB/T 14848-1993

Water Quality	Very Good	Good	Moderate	Bad	Very Bad
F	<0.8	0.8~<2.5	2.5~<4.25	4.25~<7.20	>7.20

Tables 6 and 7 show the classification of groundwater samples in 1995 and 1998.

Model Builder, extension of ArcView spatial analysis and ArcGIS Geostatistical Analyst (ESRI, 2000) has been used for the mapping.

Database tables were created for each element or ion. Concentration maps based on the GB/14848-93 classification are constructed for each element and ion cited above by the kriging method using ArcGIS statistical analysis's tools (ESRI , 2001) .The predicted surface areas for each map class are generated with an error of less that 5 percent. The contamination index maps shown in Figure 4 are the results of arithmetic overlay of all concentration maps by the means of the Model Builder.

The contaminations maps show a progression of the class V surface (poorest quality groundwater) from 1995 to 1998. Class I best quality water is nonexistent .The class IV surface is the largest one in the study area in 1995 and again in the 1998. There is an appearance of class III in the northwest part of the city in 1998.

CONCLUSION

The groundwater in Changchun City has been affected by pollutants and the quality has deteriorated in recent years. The natural major ions are calcium and bicarbonate. Anthropogenic Cl,

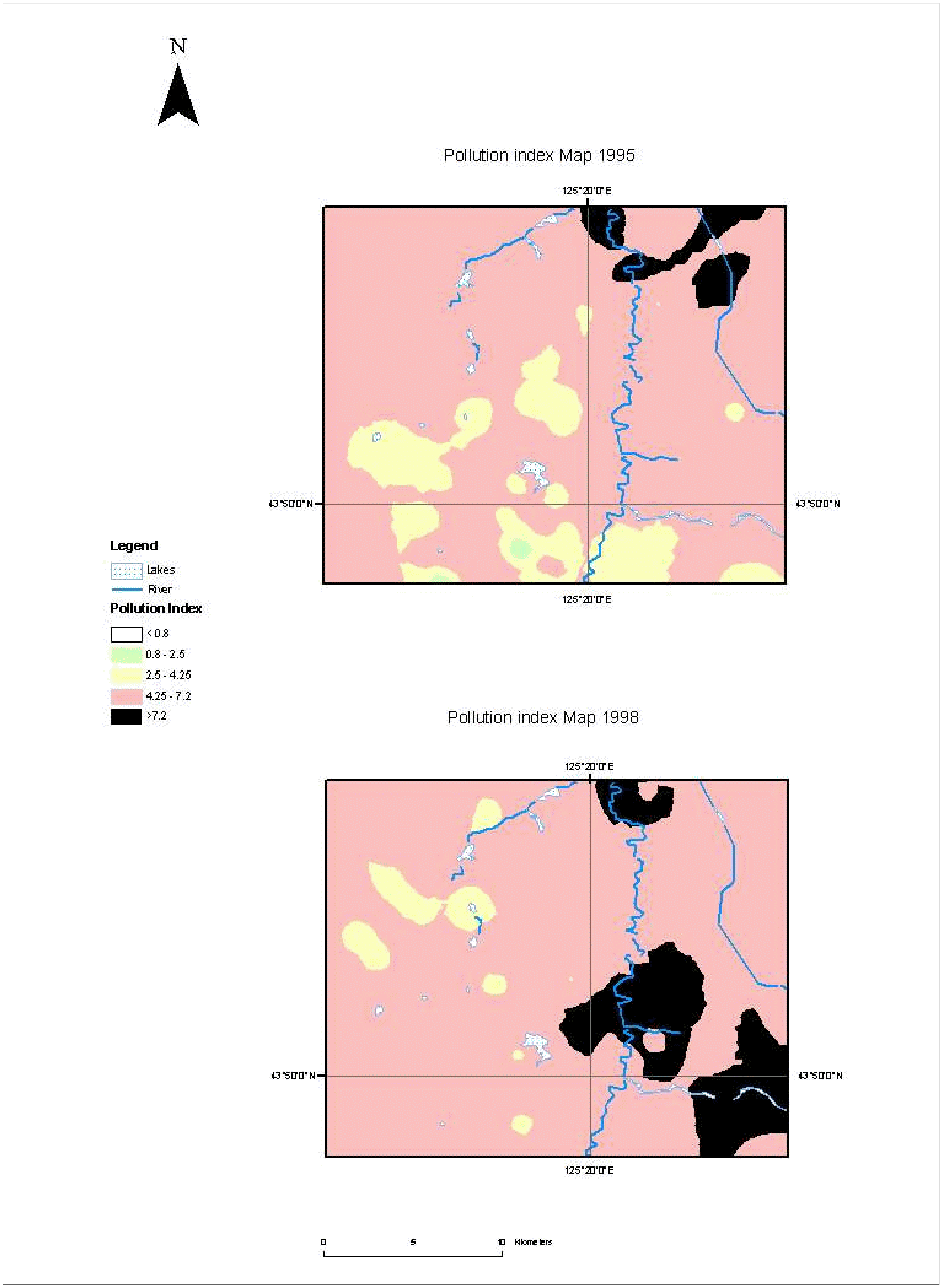

Figure 4. Groundwater contamination index maps.

Table 5. Nomenclature According to Index Value: Reference GB/T 14848-1993

Water quality	Very Good	Good	Moderate	Bad	Very Bad
F	<0.8	0.8~<2.5	2.5~<4.25	4.25~<7.20	>7.20

Table 6. Classification of Samples in 1995 According to GB/14848-93

Elements mg/l	Total Samples	% Samples Class I	% Samples Class II	% Samples Class III	% Samples Class IV	% Samples Class V
Total Iron	79	32	18	4	26	20
Manganese	79	52	6		32	10
TH($CaCO_3$)	79	28	20	16	8	7
Nitrate	79	29	6	11	3	51
Nitrite	79	47	14	9	19	11
NH_4	79	59	32		6	3

Table 7. Classification of Samples in 1998 According to GB/14848-93

Elements mg/l	Total Samples	% Samples Class I	% Samples Class II	% Samples Class III	% Samples Class IV	% Samples Class V
Total Iron	59	19	8	12	41	20
Manganese	59	46		21	21	12
TH($CaCO_3$)	59	10	24	12	6	7
Nitrate	59	18	3	15	8	56
Nitrite	59	3	34	10	31	22
NH_4	59	34	25		16	25

SO_4, Ca and nitrate have caused the deterioration in quality.

The statistical analysis shows relationships between Cl, NO_3, and Ca and between the thickness of the unsaturated zone and some major ions. The correlation between NO_3 and Ca seems to be very strange and explains that a part of groundwater has an anthropogenic origin because nitrate generally comes from agriculture or other anthropogenic processes. Fertilizer such as calcium nitrate are commonly used in China in parks for landscaping. They can release both Ca_2^+ and NO_3^- ions.

The correlation between nitrate and Cl suggests that Cl is not naturally occurring. The weak negative correlation between the depth of the water table and some majors ions (Ca, SO_4, Cl, NO_3) suggests that some of these ions are loaded from the ground surface. The correlation in the deep-fissured media tends to explain the influence of fractures or fissure the dynamics of the contamination. Environmental isotope studies will be necessary to confirm these hypotheses.

There is an increase in the concentrations of most of ionic species from 1995 to 1998. Nitrate is the most widely recognized contaminant in the study area with 51 percent of the samples in 1995 and 56 percent in 1998 falling in the worst class (class V). The nitrite concentrations in the two worst classes (class IV and class V) increased from 30 to 50 percent from 1995 to 1998. Infant methemoglobinemia that only affects children under age of one is the primary health concern related to nitrate. High nitrite concentrations may also be a cause of cancer in China. (Nianfeng et al., 2000).

The concentration of ammonium ions in the two worst classes increased from 9 to 41 percent from 1995 to 1998.

Intensive agriculture during the past 30 years, inadequate waste disposal systems, septic tanks, and the use of fertilizer are the likely causes of today's higher concentrations of nitrate, nitrites and ammonium.

The manganese concentrations in class IV and class V (concentrations > 0.5 mg/l) decreased from 42 to 32 percent in 1998. The concentration of manganese in this class can lead to a disease which can affect the nervous system. The manganese may come from seepage from landfills, or from industrial wastewater.

Total iron in the two worst classes increased from 46 to 61 percent from 1995 to 1998. The iron may derive from the lithology (for example mudstone), but may also be released from industrial or domestic wastes.

Water samples classified as hard increased from 70 to 90 percent. The high concentration of iron and the hardness in groundwater can lead to unacceptable taste or color and the abandonment of the water for drinking purposes. Fluoride concentrations are low; only 2 samples in 1995 and 3 in 1998 (among the 79 samples in 1995 and the 59 samples in 1998) exceed 1 mg/l, which is contrary to fluoride trends in many parts in China where fluoride high concentrations in groundwater are a major environmental problem. (Nianfeng et al., 2000).

In brief, among the 79 1995 water samples and the 59 1998 samples none satisfy the Chinese standard for drinking water. This is a great risk considering that this water may still be used by part of the population in Changchun City for drinking purposes. However, the water can be used for irrigation as the values of the SAR for 95 percent of the samples are lower than 10.

The mapping of groundwater reveals an increase in the areas mapped as class V from 1995 to 1998, located around the Yitong Rivers basin. This shows the influence of the river on the groundwater quality. The best class I area is absent. The class IV area is the largest one during the two years that monitoring was conducted .The mapping process takes into account six ionic species and their range of higher concentrations in the groundwater samples.

For further studies the mapping can consider some other trace elements, oil, volatile etc. This study, which is based on a monitoring of a large number of ionic species, may be useful for environmentalist and decision makers.

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