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Effects of Several Environmental Factors on Longevity and Health of the Human Population of Zhongxiang, Hubei, China

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Abstract Increasing human health and longevity is of global interest. Environmental, genetic, and stochastic factors all affect longevity. Among these factors, the environment is extremely important. To investigate the relationship between the environment and longevity, we studied the environment in Zhongxiang (China), where the inhabitants commonly have long life spans. Air was analyzed for negative oxygen ions, SO_2, and inhalable particles, while drinking water and rice were analyzed for macro- and micro-elements. The air quality in this area was determined to be grade I with high negative oxygen ion content and low SO_2 and inhalable particle contents. Apart from Fe, Mn, and F, all tested elements and the pH were within national standards and World Health Organization guidelines. The percentage of long-lived people in the area was closely related to the macro- and micro-element contents of their staple food, rice. The elements in rice could be classified into three categories according to their effect on longevity: Sr, Ca, Al, Mo, and Se, which were positively correlated with longevity; Fe, Mn, Zn, Cr, P, Mg, and K, which had a weak effect on local longevity, and Cu and Ba, which had a negative effect on longevity.

Keywords Longevity · Environment · Air · Water · Rice · Element

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Introduction

Increasing human health and longevity is of global interest. Human longevity is affected by many factors, including genetics, lifestyle, and the environment [1–5]. Among these factors, the environment is extremely important. The close relationship between the environment and human heath has been known for many years. It was noted by the ancient Chinese as long as 3,000 years ago [6], and monographs have found the relationship between topography and lifespan [7]. In 1973, Hamilton et al. reported that the abundance of chemical elements in the human body was similar to that in the earth's crust [5, 8].

Elements are human body's basic constituents. Trace elements cannot be produced in the human body. Their intake has to come from the natural environment. So, trace element contents in the natural environment have significant effect on human health and longevity. Studies have shown that many chronic degenerative diseases, including several cancers, are known to be more common in selenium-deficient societies and individuals [9]. Se deficiency in soil is related to endemic Kashin-Beck and Keshan diseases in China [10–12]. Zn deficiency has been reported to result in growth failure and sexual infantilism, delayed wound healing, and other conditions [13]. Studies have found a close relationship between the available forms of elements such as Se, B, Ni, and Mo in soils and the number of humans living to over 90 years of age [5].

Drinking water can be an important source of rapidly assimilable elements that can benefit health or affect it adversely. Of the 14 trace elements known to be essential for human beings, apparently some are assimilated much more readily from water than from food [14]. Rice is an important source of nutrients and energy for the daily life of many people [15]. So, element contents in rice have great significance to human health.

The negative oxygen ions, SO_2, and inhalable particulates in air impact human health and longevity. Negative oxygen ions are essential for revitalizing the body and improving metabolism. Negative oxygen ions have even been called the elements of longevity because of their close relation to life expectancy.

SO_2 and inhalable particles are important indices for evaluating air quality [16]. SO_2 can reduce visibility and contribute to the formation of acid rain. High SO_2 content in the air affects the respiratory system. Inhalable particles in air also impact longevity. Studies have shown that short-term exposure to fine particulate matter <2.5 μm in diameter ($PM_{2.5}$) increases plasma endothelin in animals [17, 18]. Higher levels of $PM_{2.5}$ in the air may alter the balance between vasodilators and vasoconstrictors and impair endothelium-dependent vasodilation [18]. From health studies, it has been estimated that daily mortality increases by 1% for each 10 $\mu g/m^3$ increase in PM_{10}. Daily respiratory mortality has been estimated to increase by 3.4% for a 10 $\mu g/m^3$ PM_{10} increase, while cardiac mortality increases 1.4%.

Although these studies have explained some relationships between the environment and health, they are limited to individual environmental medium. Few studies have been comprehensively investigated the relationship between the environment and human health and longevity. To investigate the effect of the environment on longevity, the Chinese Gerontological Society began evaluation of longevity counties in China in 2000. Longevity was found to be regional, and most of the longevity counties were in Southeast China. To investigate the geographical clustering of longevity counties in China, we studied Zhongxiang, which historically had many residents with long life spans. A comprehensive environmental study was conducted. Air quality was monitored on the ground, and local drinking water and staple food (rice) samples were collected for analysis.

The objectives of this study were to determine the spatial distribution of centenarians and people >80 years old and evaluate the air and drinking water quality and trace elements in staple food (rice), and determine their relationship with local longevity.

Materials and Methods

Study Site

Zhongxiang is located in the north of Jingzhou district, which is in the middle reaches of Han River at 112°07′–113°00′E, 30º42′–31º36′N (Fig. 1). The topography in this area is higher in the northeast than that in the southwest. The Han river divides Zhongxiang into east and west sections. Alluvial plains border either side of the river, and hills and mountains extend out from the alluvial plains. The total area of the county is 4,417.8 km^2, among which plain lakes account for 28.65%, hillocks account for 37.16%, mounds 13.76%, and mountainous areas 20.43%. The annual average temperature over the past 40 years was 15.9°C, with extremely high and low temperatures of 39.7°C and –15.3°C, respectively. The average annual rainfall over the same period was 942.9 mm, and 65% of this was concentrated from April to July each year [19].

According to statistics from the Bureau of Civil Affairs and Aging Office, by September 2007, there were 77 centenarians out of a total population of 1.01 million people in the area. The number of over 80-year-olds was 15,507. The ratio of centenarians in this area exceeds the world longevity county standard specified by the United Nations of 75 centenarians/1 million people. Consequently, this county was titled the Longevity County in 2008 by the Chinese Gerontological Society.

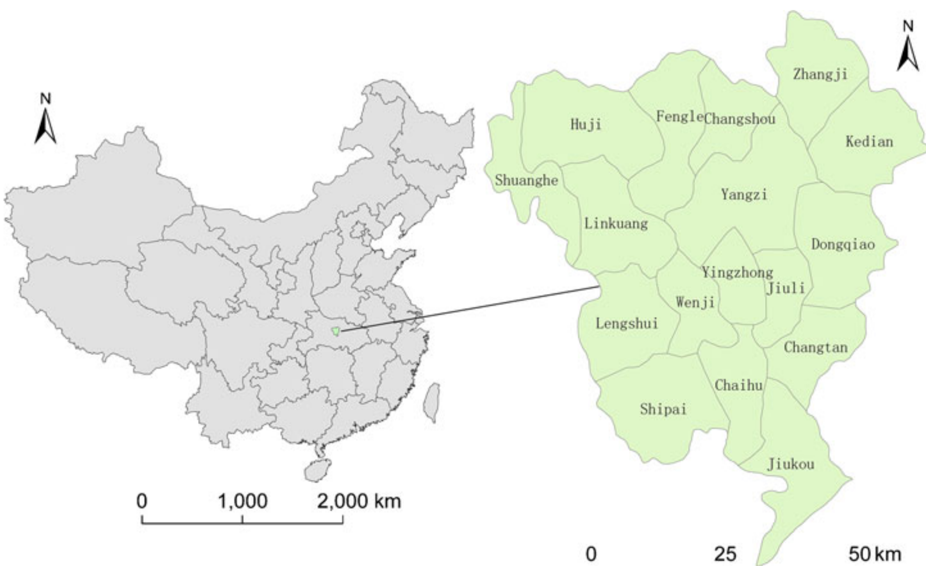

Fig. 1 The location of the study area

Data Collection and Sampling

Statistical data for the centenarian and >80-year-old populations came from the Zhongxiang Bureau of Civil Affairs in 2007. The percentage of the >80-year-olds was calculated on the town basis.

According to the distribution of centenarians in respective towns, towns with different numbers of centenarians were selected. Some of these centenarians in different towns were selected as study objects. To explore the relationship between the environment and longevity, drinking water (n=22) and rice (n=22) were collected from the study participant's homes. Additionally, the number of the negative oxygen ions, SO_2, and inhalable particles were monitored in both indoor (n=10) and outdoor air (n=10) samples. The longitude and latitude of each sampling site were recorded using a handheld global positioning system.

The contents of negative oxygen ions, SO_2, and inhalable particles in the air were monitored on site with an Air Ion Counter AIC-1000 (American ALPhaLab Inc), Interscan 4240 digital portable SO_2 analyzer (American Interscan Corporation), and P-5L2C portable digital dust analyzer (Beijing Institute of New Technology Applications), respectively.

Because local economy and industry are underdeveloped, tap water is not common, and well water is the main drinking water for residents. There is usually a well for each home. Well water samples were collected at each centenarian's home using a mineral water bottle using standard sampling protocol [20, 21]. All sampled tubewells were purged by vigorous pumping for 10 min immediately before sample collection. The pH was immediately determined using a portable pH meter at the end of each day's sampling. About 10 drops of 1:1 HNO_3 were immediately added to the samples to prevent adsorption of dissolved metals to the interior walls of the storage bottle and minimize post-sampling microbial activity. All water samples were kept in a refrigerator at 0°C to 4°C and sent to the laboratory after sampling until analysis.

Rice is the most important staple food grown in the local area. Rice samples were also collected at each centenarian's home. The rice grains were washed with tap water and deionized water, dried in an oven at 60°C for 24 h, and then grounded with a stainless-steel grinder to <0.15-mm particle size for chemical analysis.

Chemical Analysis

The water samples were brought out of the refrigerator and allowed to defrost before analysis. Concentrated HNO_3 (12 mL) and perchloric acid $HClO_4$ (1 mL) were added to 1 g of the rice sample, and the mixture was left at room temperature overnight. The sample was then evaporated to near-dryness on a hot plate at about 130°C. The resulting clear solution was diluted to 15 mL with deionized water. Then, the Al, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Mo, P, Sr, and Zn contents were determined by inductively coupled plasma-mass spectrometry. The Se content was determined by ICP optical emission spectrometry. The concentration of F was determined with a fluoride ion-selective electrode method.

To examine the accuracy of the data, some samples were analyzed in duplicate in parallel. The results showed good reproducibility. For calibration, three blank samples and three standard samples were measured in each set of samples. The recovery rates of all measured samples were between 80% and 109% with reference to GBW (E) 080684.

Data Processing

Statistical data from the Bureau of Civil Affairs and Aging Office was used to calculate the number of centenarians per 1 million people and the percentage of the >80-year-olds to the total population in each town. SPSS was used to conduct basic statistical analysis, correlation analysis, and the principal component analysis.

Results

Ratio of >80 and 100-Year-Old Residents in Each Town

According to the 2007 statistical data provided by the Bureau of Civil Affairs of Zhongxiang city, the ratio of centenarians was, on average, 88/million. The average ratio of the >80-year-olds was 1,621/100,000. These ratios differed from town to town (Table 1). The highest percentages of residents >80 years old were 2.84%, 2.23%, and 2.22% in the towns of Wenji, Shipai, and Shuanghe, respectively. The towns of Dongqiao and Yingzhong had the lowest percentage of residents >80 years old at 1.19% and 1.33%, respectively. The highest centenarian/million was 185.83 in Changshou, whereas the lowest centenarian/million was zero in Zhangji.

Air Quality

The air quality data are summarized in Table 2 and the environmental quality standard GB 3095–1996 is listed in Table 3. The range of negative ions in indoor air was 342–798 ions/

Table 1 Ratios of centenarians and the >80-year-olds to total residents in the townships examined

Town	TP	>80	Centenarian	>80%[a]	C/million
Yangzi	56,823	857	7	1.51	123.19
Changshou	26,906	468	5	1.74	185.83
Fengle	75,182	1,128	10	1.50	133.01
Huji	115,484	1,737	7	1.50	60.61
Shuanghe	47,659	1,057	1	2.22	20.98
Linkuang	40,567	520	6	1.28	147.90
Wenji	44,805	1,273	5	2.84	111.59
Lengshui	50,262	754	9	1.50	179.06
Kedian	14,675	220	2	1.50	136.29
Jiukou	104,202	1,563	3	1.50	28.79
Changtan	19,468	272	1	1.40	51.37
Zhangji	23,061	346	0	1.50	0
Jiuli	12,704	184	1	1.45	78.72
Shipai	84,942	1,890	4	2.23	47.09
Chaihu	103,142	1,460	3	1.42	29.09
Dongqiao	23,161	276	1	1.19	43.18
Yingzhong	158,052	2,104	7	1.33	44.29
Guanzhuanghu, Luohansi	31,744	398	5	1.25	157.51
Max	1,017,900	15,507	77	2.84	185.83
Min	12,704	184	0	1.19	0
Mean	107,934	1,685	8	1.60	87.06

TP total population, *C/million* the number of centenarians per million residents

[a] >80%: the percentage of people aged over 80 years

cm^3 (mean 595 ions/cm^3) and that in outdoor air was 318–660 ions/cm^3 (mean 463 ions/cm^3). These values are all much greater than those typically present in an urban enclosed housing area (40–50 ions/cm^3). It is believed that the air with a positive to negative ion ratio of 1–3 and minor gaseous negative ion content >300 ion/cm^3 has a relatively good balance. All the negative ions contents in the selected sites were >300 ion/cm^3, and almost all the positive to negative ion ratios were between 1 and 3. The mean positive to negative ion ratios indoors and outdoors were 1.62 and 1.65, respectively. These ratios are also above that specified by Chinese clean air standards (1:1.2).

The SO_2 content indoors was 0.004–0.011 mg/m^3 (mean 0.007 mg/m^3) (Table 1). This is two orders of magnitude lower than that provided by the indoor air quality standard GB/T 18883-2002 (0.5 mg/m^3). The inhalable particle content indoors was 0.07–0.116 mg/m^3 (mean 0.088 mg/m^3), which is well below the indoor air quality standard GB/T 18883-2002 (0.15 mg/m^3). Outdoors the SO_2 and inhalable particle contents were 0.004–0.010 mg/m^3 (mean 0.006 mg/m^3) and 0.061–0.112 mg/m^3 (mean 0.080 mg/m^3), respectively. These are again well below the ambient air quality standard GB 3095-1996. From these results, the air quality can be classed as grade I.

Drinking Water Quality

Drinking water may make an important contribution to total dietary intake of required macro- and micro-elements essential for human health and may affect the desirable balance of these elements [14]. In this study, the pH and Na, Fe, Ba, Cd, Cr, Cu, Mn, Mo, Ni, Pb, Se, Zn, and F concentrations of the collected water samples were determined (Table 4). The data were compared with the standards for Drinking Water Quality GB 5749-2006 and World Health Organization (WHO) guidelines [22], which are also included in Table 4. Many of the samples had Fe, Mn, and F concentrations equal to or exceeding the national standards and the WHO guideline values, with 90.91%, 72.73%, and 95.45% of the samples reaching Fe, Mn, and F guidelines. Except Fe, Mn, and F, all other tested elements and pH are up to the national standards and the WHO guideline value.

All the water samples had pH>7 and were classed as weakly alkaline. Studies show that weak alkaline spring water is beneficial to longevity. Cu concentrations in all the samples were two orders of magnitude lower than the recommended values.

The samples were further classified as either surface water or groundwater samples and again compared with environmental standards for quality of surface- and groundwater

Table 2 The air quality monitoring results

Indoor	SO_2, mg/m^3	Inhalable particles, mg/m^3	Negative ions, ions/cm^3	Positive ion, ions/cm^3	Negative ion/ positive ion
Max	0.011	0.116	798	608	2.93
Min	0.004	0.07	342	244	0.95
Mean	0.007	0.088	595	385	1.62
Indoor air quality standard	0.5	0.15			
Outdoor					
Max	0.010	0.112	660	634	2.61
Min	0.004	0.061	318	190	0.66
Mean	0.006	0.080	463	340	1.65

Table 3 Environmental air quality standard

Pollutant	Data collection concentration limit, mg/cm^3			
		Grade I	Grade II	Grade III
SO_2	Annual mean	0.02	0.06	0.1
	Daily average	0.05	0.15	0.25
	Hourly average	0.15	0.5	0.7
Inhalable particulates	Annual mean	0.04	0.1	0.15
	Daily average	0.05	0.15	0.25

(Table 5). Cd, Cr, and Mo were not detected in the groundwater samples, and Cd and Cr were not detected in the surface water samples. The results for the pH and Cd, Cr, Pb, and Se concentrations in the surface- and groundwater indicate it is class I. The Co, Mo, Zn, and F results in the groundwater samples also indicated it was class I. The other tested elements mostly satisfied the class I quality standard. All these results show that the local water is clean and free from pollution, and this is a contributing factor to local longevity.

Rice Analysis Results

The collected rice samples were analyzed for Al, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Mo, P, Sr, Zn, and Se, and the data (Table 6) were compared with that from the suburbs of Jinan city (China) [23] and the average element content in crops [24]. Compared with rice samples from the suburbs of Jinan, Al, Fe, K, Mg, Mn, Mo, and Zn contents were higher in the rice samples from Zhongxiang, whereas the Cd and Pb contents were lower in the Zhongxiang samples. The Ca, Cu, Fe, Mg, Mn, Mo, and Zn contents were all within the range of average crop contents. The ratio of Ca/Cd was much higher in the Zhongxiang rice samples than in those from the suburbs of Jinan. It is known that the incidence of coronary heart disease is inversely proportional to the ratio of Ca/Cd. In addition, Mn and Zn are known as anti-aging elements. Therefore, the high contents of Mn and Zn and the high ratio of Ca/Cd may contribute to local longevity.

Correlation analysis was performed on the 14 tested elements and the percentages of residents in the centenarian and >80 year old age groups (Table 7). Significant positive correlations were found between the percentage of centenarians and the contents of Al, Ca, and Sr in rice ($p<0.01$), and the correlation coefficients were 0.38, 0.348, and 0.483, respectively. Significant positive correlations were also found between the percentage of the >80-year-olds and the contents of Cu, Mo, Sr, Zn, Se in rice ($p<0.01$), and the correlation coefficients were 0.238, 0.391, 0.135, 0.156, and 0.715, respectively. In contrast, significant negative correlations were found between the percentage of centenarians and the contents of Ba, Cr, and Cu in rice and between the percentage of >80-year-olds and the contents of Al, Ba, and Cr.

Correlations between elements were also significant. Because the elements interact in a synergistic or antagonistic manner, it is difficult to determine the elements that dominantly influence longevity. Principal component analysis was conducted on the 14 elements and the percentages of long-lived people in order to find the main element or element group influencing longevity.

The results of the principal component analysis are shown in Table 8. Five principal components were obtained, which accounted for 91.15% of the variance. The first principal

Table 4 Element concentrations of surface water and groundwater

	pH	Na[a]	Fe[a]	Ba[a]	Cd[a]	Cr[a]	Cu[a]	Mn[a]	Mo[a]	Ni[a]	Pb[a]	Se[b]	Zn[a]	F[a]
Max	8.30	127.7	0.77	0.303	0	0	0.025	5.314	0.003	0.006	0.005	3.731	0.091	2.52
Min	7.00	4.04	0	0.022	0	0	0.011	0	0	0.002	0	0.231	0	0.044
Mean	7.52	52.79	0.11	0.135	0	0	0.017	0.535	0.00014	0.003	0.0007	0.958	0.018	0.325
NS	6.5–8.5	200	0.3	0.7			1	0.1		0.02	0.01	10		
WHO GV	6.5–8.5	200	2	0.7	0.003	0.05	2	0.4	0.07	0.07	0.01	10	0.01(0.05)	1.5
RN	100%	100%	90.91%	100%			100%	72.73%		100%	100%	100%		
RWHO	100%	100%	100%	100%	100%	100%	100%	72.73%	100%	100%	100%	100%	100%	95.45%

NS national standards, WHO GV WHO guideline value, RN rate up to the national standards, RWHO rate up to the WHO guideline value

[a] Elements with units in milligrams per liter

[b] Se units are micrograms per liter

Table 5 Concentrations of elements in the collected water samples

GW		pH	Ca	Fe	Ba	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Se	Zn	F
GW	Max	8.3	303.6	0.77	0.30	0	0.003	0	0.025	5.314	0	0.006	0.005	0.0023	0.048	0.578
	Min	7	10.99	0	0.02	0	0	0	0.011	0	0	0.002	0	0.0002	0.000	0.044
	Mean	7.4	138.5	0.14	0.15	0	0.0005	0	0.016	0.731	0	0.003	0.001	0.0009	0.012	0.24
GWS	I	6.5–8.5	150	0.1	0.01	0.0001	0.005	0.005	0.01	0.05	0.001	0.005	0.005	0.01	0.05	1.0
	II		300	0.2	0.1	0.001	0.05	0.01	0.05	0.05	0.01	0.05	0.01	0.01	0.5	1.0
	II		450	0.3	1.0	0.01	0.05	0.05	1.0	0.1	0.1	0.05	0.05	0.01	1.0	1.0
	IV	5.5–6.5, 8.5–9	550	1.5	4.0	0.01	1.0	0.1	1.5	1.0	0.5	0.1	0.1	0.1	5.0	2.0
	V	<5.5, >9	>550	>1.5	>4.0	>0.01	>1.0	>0.1	>1.5	>1.0	>0.5	>0.1	>0.1	>0.1	>5.0	>2.0
ARG	I%	100%	69%	68.75%	0	100%	100%	100%	0%	62.5%	100%	93.75%	100%	100%	100%	100%
	II%		25%	12.50%	31.25%				100%	0%		6.25%				
	III%		7%	6.25%	68.75%					0%						
	IV%			1.25%						18.75%						
	V%									18.75%						
SW																
SW	Max	8.26	101.4	0.08	0.13	0	0.001	0	0.024	0.074	0.003	0.004	0.002	0.0037	0.091	2.522
	Min	7.60	41.07	0	0.04	0	0	0	0.016	0	0	0.002	0	0.0004	0.013	0.136
	Aver	7.98	62.02	0.04	0.10	0	0.0002	0	0.020	0.015	0.0005	0.003	0.0007	0.001	0.033	0.552
SWS	I	6–9				0.001		0.01	0.01				0.01	0.01	0.05	1.0
	II					0.005		0.05	1.0				0.01	0.01	1.0	1.0
	III					0.005		0.05	1.0				0.05	0.01	1.0	1.0
	IV					0.05		0.05	1.0				0.05	0.02	2.0	1.5
	V					>0.01		>0.1	>1.0				>0.1	>0.02	>2.0	>1.5
ARS	I%	100%				100%		100%	0%				100%	100%	77.78%	83.33%
	II%								100%						22.22%	0%
	V%															16.67%

Units in milligrams per liter

GW ground water, *GWS* ground water standard, *SW* surface water, *SWS* surface water standard, *ARG* ground water achievement ratio, *ARS* surface water achievement ratio

Table 6 Comparison of trace elements in rice crops from different areas

	Al	Ca	Cd	Cu	Fe	K	Mg	Mn	Mo	Zn	Pb	Ca/Cd
ZX	5.16	84.89	–	1.89	10.2	950	356	9.89	0.49	14.58	–	–
JNS	–	53	0.03	1.7	–	567	64	4.3	0.05	8.71	0.66	1767
Crop	–	49.3	–	0.8–10	10–120	–	334	4–45	3.8–8.6	12–40	–	–

Element unit in milligrams per kilogram

ZX Zhongxiang, *JNS* Jinan city

component included Sr, Ca, Al, and Cu and the percentage of centenarians. Sr, Ca, and Al and the percentage of centenarians had positive loadings (>0.7), while Cu had a negative loading (>0.7). This indicates that Sr, Ca, Al, and Cu are main elements influencing longevity, and Sr, Ca, and Al have a positive effect while Cu has a negative effect. P, Mg, and K had high positive loadings (>0.9) on the second principal component, which indicates these three elements can be grouped together with regards to their influence on longevity. The percentage of >80-year-olds and the contents of Mo and Se had high positive loadings (>0.7) on the third principal component. This indicates that Mo and Se also influence local longevity. The contents of Cr, Fe, and the contents of Zn and Mn had high positive loadings on the fourth and the fifth principal components, respectively, which may have weak effects on local longevity. The positive and negative loadings on the first and the third principal component may occur because of synergistic or antagonistic interactions between the elements.

In summary, the elements in rice were grouped into three categories according to their effect on longevity. The first category includes Sr, Ca, Al, Mo, and Se, which were positively correlated with longevity. The second category includes Fe, Mn, Zn, Cr, P, Mg, and K, which had a weak effect on local longevity. Finally, the third category includes Cu and Ba, which had a negative effect on longevity.

Discussion

Air, water, and food are the interactive media of human with the environment. Consequently, the quality of these environmental media can influence human health and longevity.

Air is the basic environmental element for human survival. Good air quality is conducive to human health and longevity. The SO_2 and the inhalable particulate levels in the air of Zhongxiang were within the grade I air quality standard. Negative ions indoors and outdoors were present at much higher levels than in urban enclosed housing areas.

These results are consistent with earlier studies. Many studies have found that air polluted with SO_2 and inhalable particulate particles can harm human health and lead to many diseases. Air polluted with SO_2 can lead to cardiovascular diseases [25–29], ischemic heart disease [30], and pulmonary heart disease [31]. Particulate matter in air is related to human health to a certain degree. Many epidemiological studies have found that increases in particulate pollution can lead to the occurrence of respiratory symptoms, pulmonary dysfunction, and excessive incidence of heart and lung diseases, even at levels within the air quality standard [32, 33]. Therefore, extremely low particulate matter levels in the air are beneficial to the health of local residents. The beneficial effect of negative ions on human

Table 7 Correlation coefficients between the element contents of locally grown rice and the percentage of longevous people

	Al	Ba	Ca	Cr	Cu	Fe	K	Mg	Mn	Mo	P	Sr	Zn	Se	CPM	EPT
Al	1															
Ba	0.250	1														
Ca	0.857	0.360	1													
Cr	0.183	0.181	0.099	1												
Cu	0.651	0.267	0.609	0.169	1											
Fe	0.689	0.108	0.504	0.745	0.282	1										
K	0.346	0.430	0.057	0.197	0.094	0.414	1									
Mg	0.532	0.415	0.207	0.335	0.302	0.477	0.889	1								
Mn	0.590	0.182	0.400	0.173	0.030	0.379	0.626	0.534	1							
Mo	0.136	0.348	0.273	0.419	0.222	0.317	0.268	0.155	0.293	1						
P	0.484	0.388	0.091	0.291	0.252	0.454	0.929	0.978	0.550	0.195	1					
Sr	0.594	0.573	0.856	0.091	0.568	0.342	0.327	0.037	0.049	0.026	0.177	1				
Zn	0.413	0.040	0.261	0.191	0.025	0.555	0.420	0.305	0.753	0.070	0.376	0.071	1			
Se	0.149	0.226	0.311	0.381	0.502	0.116	0.458	0.143	0.333	0.512	0.246	0.283	0.274	1		
CPM	0.380	0.578	0.348	0.416	0.394	0.003	0.259	0.224	0.095	0.151	0.227	0.483	0.232	0.049	1	
EPT	0.229	0.413	0.062	0.337	0.238	0.264	0.033	0.114	0.063	0.391	0.093	0.135	0.156	0.715	0.139	1

CPM number of centenarians per million people, EPT the number of residents per 100,000 aged >80 years

Table 8 Results of the principle component analysis

	Component				
	1	2	3	4	5
Sr	0.883	0.217	0.051	0.139	0.032
Ca	0.850	0.007	0.156	0.103	0.378
Al	0.788	0.418	0.136	0.130	0.369
Cu	0.765	0.198	0.339	0.060	0.151
The rate of centenarians	0.700	0.100	0.055	0.431	0.181
Ba	0.640	0.402	0.579	0.019	0.112
P	0.015	0.968	0.003	0.157	0.145
Mg	0.093	0.948	0.073	0.188	0.124
K	0.177	0.927	0.140	0.103	0.244
Se	0.247	0.283	0.874	0.236	0.171
The rate of >80-year-olds	0.044	0.134	0.839	0.146	0.129
Mo	0.080	0.184	0.712	0.556	0.360
Cr	0.006	0.150	0.217	0.958	0.033
Fe	0.393	0.319	0.025	0.732	0.366
Zn	0.004	0.197	0.136	0.222	0.897
Mn	0.169	0.503	0.041	0.233	0.796

health has been verified by many studies [34–36]. Thus, the high negative ion levels in the air in this area of China are beneficial to the health and longevity of local residents.

The trace elements in water have an important effect on human health [37]. Most of the trace elements tested in the water samples in the study area were within the Chinese National Standards and the WHO guidelines. Most of the tested elements reached class I water quality standards. All the water samples had weakly alkaline pH (>7), which can boost blood circulation and cell metabolism, reduce the generation of acidic material, neutralize gastric acid, eliminate acidosis, and reduce the pH of gastric acid to meet the body's normal needs. Therefore, the weak alkaline water in this area is conducive to human health.

Research has also shown that water with appropriate mineral element contents is an important factor for promoting human health. The imbalance of elements in drinking water can lead to some diseases [38–41]. Consequently, the balance of macro- and micro-elements in the drinking water in this area is also a factor of local longevity.

By correlation analysis and principal component analysis, we divided the elements in rice into three types according to their relationship with longevity. Sr, Ca, Al, Mo, and Se in rice were positively related to longevity. Fe, Mn, Zn, Cr, P, Mg, and K in rice had a weak effect on local longevity, whereas Cu and Ba in rice had a negative effect on longevity.

Trace elements play fundamental roles in human metabolism [42]. Essential trace elements are necessary for optimal function of growth, healing, and metabolic activity in mammalian organisms and for life itself. Consequently, they probably influence longevity. For humans, the typical sources of trace elements are food, drink, and the ambient air. In this study region, rice is the staple food and has been locally produced for a long time. Therefore, the element content in rice is closely associated with element intake of local residents.

The relationship between trace element levels in the diet and the occurrence of certain diseases has been reported previously [43]. In humans, Mn, Fe, Cu, Zn, and Se accomplish many functions to maintain human health. Deficiency in any of these trace elements leads to undesirable pathological conditions [44]. Se has an antiproliferative and cancer protecting effect [45], while Ca is the main component of bones and teeth. Ca also regulates the activity of many enzymes. The positive relationship of Se and Ca in rice with the percentage of long-lived residents shows that higher Se and Ca contents in rice are favorable factors for local longevity. We concluded that Cu in rice had a negative effect on human health, which is consistent with earlier research. Copper toxicity is the major cause of mild cognitive impairment and Alzheimer's disease in aging populations [46]. Therefore, low Cu content in rice is conducive to human health.

Conclusions

A close relationship was observed between the natural environment and longevity in Zhongxiang, China. Residents in this area live in a relatively unpolluted natural environment, with clean air, higher negative oxygen ions, and low SO_2 and inhalable particles. They eat a healthy diet that is rich in mineral content and drink water that is also rich in minerals and weakly alkaline. The elements in their staple food (rice) can be classified into three categories according to their effect on longevity: Sr, Ca, Al, Mo, and Se, which are positively correlated with longevity; Fe, Mn, Zn, Cr, P, Mg, and K, which have a weak effect on local longevity; and Cu, Ba, which have a negative effect on longevity.

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