Wavelet Analysis of CODMn and NH_3-N in Panzhihua, Upper Yangtze River

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***Abstract*—The 1-D continuous wavelet transform of Morlet was used to investigate the characteristics of water quality at Longdong monitoring station, upper Yangtze River of Panzhihua. The consistence of CODMn and NH_3-N were chosen as main monitoring indicators, produced by Longdong monitoring station by weekly monitoring from 2004 to 2010. The result shows that consistence of CODMn changes between -8 and 8 with roughly 42 weeks mainly cycle, 10 weeks and 21 weeks for the second cycle. Consistence of NH_3-N changes between -0.3 and 0.3, and the largest value appears on 5th week of 2004, a larger value at 35th, 70th and 110th weeks. Except the mentioned weeks above consistence of NH_3-N changes smoothly. There is a small fluctuation from 1 to 15 weeks at the curve of NH_3-N consistence wavelet coefficient variance, and a relatively large fluctuation in 15-50 weeks, while after that that curve showing a rising trend. Overall, CODMn changes by rainfall while NH_3-N by agricultural production habits. In wet season, soil erosion was strengthened with much more mud and sand draining to the river, resulting in a declining of water quality.**

***Index Terms*—Component, formatting, style, styling, insert.** *(key words)*

I. Introduction

Water pollution has become a major obstacle of constraining and puzzling sustainable development in China [1]. Analysis on water quality monitoring information has been carried out in succession in domestic main rivers and lakes, for that can reflect the quality of water environment and the current situation of pollution sources accurately and comprehensively without delay. Analysis on water quality monitoring information has been the premise and foundation to formulate feasible pollution prevention planning and to protect the water environment, and has been an important means and necessary step of energy conservation and emission reduction work. Those works have been done presently in China mainly embodied in evaluation the following ones, PH, chemical oxygen demand (COD), BOD, NH_3-N, total phosphorus, permanganate index, copper, lead, zinc and so on [2]. The upper Yangtze River region is the famous natural resource-rich region, with the wealthiest hydropower, water resources, mineral and biological resources. It is the region with great potential in china’s future economic development, while it is also an ecologically fragile zone. In the future, it will be the crucial areas which should organically combine the two different issues of Environment and Development to implement the National Ecological and Environmental Planning [3]. Currently study on Yangtze River water quality monitoring mainly focuses on the evaluation safety of water quality [4], regional water pollution characteristics [5] and related models [6-8]. However research on the sequential variation of the Yangtze River water quality is rarely seen [9]. Panzhihua city is an important industrial one at the region of upper Yangtze River, and it will be significant to analysis the temporal water quality monitoring indicators of Panzhihua Longdong Monitoring Station. The most frequently used methods on temporal series data are DFA [10], wavelet [11] and rank correlation coefficient analysis [9], among which the wavelet analysis proposed by Morlet has gradually become an international research hotspot. Along with the formation and development of wavelet theory and technologies, it has been gradually accepted in the fields of hydrology and water resources research [12]. In this paper, the one dimensional continuous wavelet analysis was used to reveal the cyclical characteristics and time variation of water quality parameters such as permanganate index (CODMn) and NH_3-N concentration at the upper Yangtze River. The investigations show its importance for further analysis of potential processes which impact water quality evolution, the control of water pollution, the safety of water quality of Yangtze River Basin.

II. Study area and data

A. Study area

The upper Yangtze River locates in west of inland core area of China, and the length is 4511 kilometers with basin area of 100.54 km^2 from Geladandong Snow Mountain of Tanggula mountain ranges to Yichang city of Yangtze River main stream. It locates in the transition zone of upper step of middle step of Chinese topography, formed by Qinghai-Tibet Plateau, Hengduan Mountain, Yunnan-Guizhou Plateau, Qinlin-Daba Mountain and Sichuan Basin. It spans three climatic zone of plateau, north Asia subtropical and central Asian subtropical zones, among which subtropical zones occupy the widest area. There are also south subtropical, warm temperatures, temperature; cold temperature zones [3]. Summer begins at the end of May lasting for 4~5 months. The hottest temperature is as high as 26~29, while the coldest one as low as 5~8. The extreme-cold temperature is between -6 and -2, with rare frost and snow. Frost-free period in one year lasts for 280~350 days, with annual precipitation of 1000～1300mm. Although rainfall is abundant in mountainous area at edge of basin, while uneven distributes in one year with a fact of that most rainfall (70~75%) takes place between June and October. In short, the prominent characteristics are a drought spring following by dry winter, an autumn of continuous rain behind summer water logging.

Panzhihua Longdong water quality automatic monitoring station was built in March of 2001, with the latitude and longitude coordinate of 101°30.39′ and 26°35.84′respectively. It belongs to main branches of Yangtze River watershed, and it is involved in state controlled water monitoring section locating in border of difference provinces. The management department of Longdong monitoring station is Panzhihua environment protection and monitor station.

B. Data source and preprocessing

The Network Data Center of China's Ministry of Environmental Protection (http:// www.zhb.gov.cn) provided water quality monitoring data of Longdong monitoring station weekly. The data source includes many type monitoring parameters, such as PH, CODMn and NH_3-N concentration. The temporal data series starts on December 29, 2003, and ends on December 26, 2010. Because of some monitoring data missed, an average value was calculated to fill the missing data according to the before-after context. The whole data series starts at the first week of 2004 with an arranged serial number of 1, and the last week of 2010 with the serial number of 364. In the analysis processes the first step is a correlation analysis in Excel to screen out two smaller correlated data series, and the selected ones being CODMn, NH_3-N concentration. The data processing and wavelet analysis are performed in the platform of Matlab 7.1[11]. When referred other related regions of upper Yangtze River, the average annual flow was divided into three periods. Reference to the criteria for the classification of the average annual flow of the other regions of the upper reaches of the Yangtze River, the region seasons were divided into: the abundant water period (July-October), the average water period (March to June), the dry period (November to February)[13].

III. METHODS

Wavelet Transform is a local transformation in time-frequency domain to extract information from signal efficiently, which is based on scale and translation invariant for multi scale detailed analysis of the function or signal. Different from the Fourier transformation, wavelet-analysis applies to the unsteady signal processing, which actually caters to the most of cases. Wavelet analysis of time-frequency analysis has the advantage over traditional at any time-frequency signal decomposition on the resolution, and take a good time-frequency resolution function and adaptive characteristics. Since it can gather signals in any detail, so then changes in different time scales can be observed [14]

When the $\Psi(t) \in L^2(R)$ meet the permit conditions of formula (1), $\Psi(t)$ is called as allowed wavelet or wavelet base.

$$C_\psi = \int_R \frac{|\Psi(\omega)|^2}{|\omega|} d\omega < \infty . \quad (1)$$

In formula 1, $L^2(R)$ is the square integral real space which defined on the set of real numbers, and t is a variable in time domain while ω is a variable in frequency domain. $\Psi(\omega)$ is the Fourier transformation of $\Psi(t)$ while C_ψ is an integral function of $\Psi(t)$, and is a part of the permission conditions as formula 1 depicted. The continuous wavelet can be achieved through dilation and translation by base wavelet function.

$$\Psi_{a,b}(t) = |a|^{-1/2} \Psi\left(\frac{1-b}{a}\right) \quad (2)$$

Where $a, b \in R, a > 0$, for any function if it meet the condition of $f(t) \in L^2(R)$, then its allowed continuous wavelet transformation can be expressed by formula 3:

$$W_f(a,b) = \{f(t), \Psi_{a,b}(t)\} = |a|^{-1/2} \int_R f(t)\, \Psi\left(\frac{1-b}{a}\right) dt \quad (3)$$

In formula 3, a is the scale, and b is the translation, and that $W_f(a,b)$ is wavelet coefficients.

Application of Morlet wavelet in the study of time series is very extensive, for it can clear identify the random fluctuations and periodicity, its analytical form is:

$$\Psi(t) = Ce^{-t^2/2} cos(5t) \quad (4)$$

In formula 4, C is a constant. In order to determine the sequence of the primary cycle, the following wavelet variance test is performed:

$$W_p(a) = \int |W_f(a,b)|^2 db \quad (5)$$

Where $W_p(a)$ is the wavelet variance, reflecting the distribution of energy with the scale a, it can determine the relative intensity of various scale perturbation in a time series [15].

IV. RESULTS AND ANALYSIS

A. Time series analysis of water pollution index

The whole time lasted up to 25 weeks in which water pollution index reached IV or III level according to national standard in Longdong monitoring station of upper Yangtze River. Most case up to 80% with high water pollution index took place in late June to September, among which 22 weeks with a percent of 88% are mainly caused by COMMn increasing, and 3 weeks due to NH_3-N increasing. The whole time lasted up to 134 weeks in which water pollution index reached national standard of II, and 205 weeks of national standard I. In the relatively low water polluted period, it lasted for 155 weeks with low COMMn and NH_3-N, 79 weeks with high COMMn and low NH_3-N, 70 weeks with low COMMn and high NH_3-N. This indicated that in wet season water pollution is often more serious than dry and level season in Longdong monitoring station, the upper Yangtze River.

B. The wavelet multi-scale analysis of CODMn

Figure 1 showed a low-high-low repeated cyclical shock of COMMn in general in Longdong monitoring station, the upper Yangtze River of Panzhihua, although the shock amplitude was big while it trended to be weakened. The amplitude of wavelet coefficient reminded small from 1 to 145 week, and the biggest one happened from 180 to 210 week, while after 210 week amplitude became small and remained between -8 to 8. The main reason of this phenomenon is due to the uneven rainfall throughout one year, July to October for wet season, March to June for level season, November to February for dry season [13]. The maximum value of CODMn as high as 6 mg/L appeared in the 80th week or so, and it was on 10-16 of July, 2005, which was due to the plenty of rainfall bringing much more mud and sands mixed together than before, and the result is that the pollution of river was increased during the wet season. The minimum value is 0, appearing in the 124th week (14-20 of June, 2006) and 160th week (21-27 of January, 2007) or so. At that time it was in the level and dry season with much less pollution, and the water quality was good enough [16].

C. The wavelet multi-scale analysis of NH_3-N

Figure 3 indicated that NH_3-N concentration reduced gradually, and that amplitude of NH_3-N concentration always remained small at Longdong monitoring station, upper Yangtze River of Panzhihua. The maximum value of NH_3-N concentration took place at the 5th week (25-31 of January, 2004), and the secondary one at the 35th week (22-28 of August, 2004), at same time it got a bigger value at 70th week (1-7 of May, 2005) and 110th week (5-11 of February, 2006). Except that mentioned above NH_3-N concentration remained a relatively low situation, what's more there are six times NH_3-N concentration becoming zero. Since January of 2004, the rainfall in the upper Yangtze River has significantly decreased to an extent of much less than normal according to monitoring data, result in 47% reduction of the upstream water level compared to the same period in history. Precipitation reduction directly affected NH_3-N concentration in the water, so a result has being come with high NH_3-N concentration anomaly in the 5th week. Wavelet coefficient varied between -0.3 and 0.3 with a symmetry axis of 0, and the amplitude remained gently.

Figure 4 reflects there was a fluctuation of amplitude on the NH_3-N variance value curve in 1th -15th weeks, a larger one in 15th -50th weeks, while a rising trend appeared after 50 weeks. The time cycle was about 50 weeks of 350 days, which indicated that there was a correlation with local cropping system. Each year before March it was the slack season of peasants with less fertilization and pesticide used, which may lead to the low NH_3-N concentration. After March, the spring ploughing started with more fertilization and pesticide used, maybe that was the main reason of NH_3-N concentration increasing [17].

V. Discussion

CODMn vibrated between -8 and 8 with the symmetry axis of 0 and rough cycle of 50 weeks in Longdong monitoring station, upper Yangtze River of Panzhihua City. The rate of change was very big showing a sharp falling flowed by a sharp rising in each cycle, and the maximum value appeared the 80th week. According to wavelet coefficient variance analysis the first cycle of CODMn was 42 weeks, and the secondary one of 10 weeks and 21 weeks. NH_3-N concentration vibrated between -8 and 8 with the symmetry axis of 0 and rough cycle of 52 weeks. The biggest change of variance curve appeared in 5th week of 2004, a bigger change in 35th, 70th and 110th week, except that mentioned above the curve showed a relatively gentle trend. The first small fluctuation of variance curve appeared in 1th-15thweeks, and a relatively big one in 15th-50th weeks. After the 50th week the variance curve showed a rising trend instead.

A. Influence of precipitation, sediment concentration on the water quality

The CODMn maximum value appeared in the wet period in Longdong monitoring station, upper Yangtze River of Panzhihua, was mainly due to the strengthening sediment erosion by abundant rainfall, with a result of sediment concentration increasing and water pollution accentuated. The CODMn minimum value appeared in dry and normal period due to much less sediment concentration and water pollution, so the water quality was good[15]. Faced with this situation, some work should be done including strengthening remolding of slope farmland, building forest of soil and water conservation, readjusting agriculture structure and fixing farmland. The region with a slope more than 25° should be return to forests or grassland. With the aim of development of regional economy and enrichment of farmers, the area of should be enlarged where commercial crops, forests and fruits growing.

B. Influence of agricultural production on the water quality

The cycle of NH_3-N concentration was about 50 weeks in Longdong monitoring station, upper Yangtze River of Panzhihua, mainly due to the local farming system. In order to reduce the effects of agricultural production activities on the water quality, what we should do including the following measurements, strengthening agricultural structure adjustment, developing ecological agriculture, promoting pollution-free agricultural production technology vigorously, reducing hazards of pests and diseases, decreasing pesticide used, implementing scientific application of fertilizer, increasing organic fertilizer while decreasing chemical fertilizer. At the same time, the efficiency of fertilizer should be improved; and the loss of nitrogen and phosphorus should be reduced to control the agricultural non-point source pollution effectively.

VI. Conclusion

The periodic characteristics and time variation rules of CODMn and NH_3-N concentration was investigated in Longdong monitoring station, the upper Yangtze River of Panzhihua based on 1-D continuous wavelet analysis. The result showed that water quality was affected by precipitation, sediment concentration, agricultural production activities in the very great degree, and the overall water quality pollution was reduced and has showed a gradual turn positive trend.

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REFERENCES

[1] Pu S C and Feng Q M, "Water pollution situation and counter measures in China," China Resources Comprehensive Utilization, vol. 26, no. 5, pp. 31-34 2008. (in Chinese)

[2] Chen J S and Xia X H, "Progress in research on river hydro-chemistry in China," Scientia geographica sinica, vol. 19, no. 4, pp. 290-294, 1999. (in Chinese)

[3] Chen Z J, "The strategic position and the ecological and environmental function of the upper reaches of the Yangtze River," Journal of Mountain Science, vol. 18, no. 3, pp. 258-262, 2000. (in Chinese)

[4] Jiang J, Zhuo H H, Fan W Z, et al. "Thinking on quality management system for water quality monitoring of Yangtze River," Yangtze River, vol. 43, no.12, pp. 86-88, 2012. (in Chinese)

[5] Zhang Y P, Zhou A G, Liu C F, et al. "Phthalic acid esters in Wuhan section of Yangtze River," Environmental Science and Technology, vol. 34, no. 11, pp. 130-134, 2011. (in Chinese)

[6] Chen R Y, Tu A G, "Assessment and prediction of water quality in the Yangtze River Basin," Environmental Science and Technology, vol. 31, no. 12, pp. 169-173+178, 2008. (in Chinese)

[7] Chang F X, Zhang Z Y, Chen J, "Study on optimal model of water resources rational allocation in Yangtze River Basin," Yangtze River, vol. 41, no. 7, pp. 5-9, 2010. (in Chinese)

[8] Li M S, Zhang J H, Liang N, et al. "Comparisons of some common methods for water environmental quality assessment," Progress In Geography, vol. 31, no. 5, pp. 617-624, 2012. (in Chinese)

[9] Liu X H, Hu A Y, "Research on water quality change of Danjiangkou Reservoir on the Hanjiang River," Yangtze River, vol. 39, no. 15, pp. 36-38, 2008. (in Chinese)

[10] Shi K, Zhang B, Ai N S, et al. "Detrended fluctuation analysis of precipitation time series in Yuanmou dry-hot basin over the last 50 years," Journal of Mountain Science, vol. 26, no. 5, pp. 553-559, 2008. (in Chinese)

[11] Wang H P, Zhang B, Liu Z H, et al. "Wavelet analysis of air pollution index changes in Lanzhou during the last decade," Acta Scientiae Circumstantiae, vol. 31, no. 5, pp. 1070-1076, 2011. (in Chinese)

[12] Wang W S, Ding J, Xiang H L. "Application and prospect of wavelet analysis in hydrology," Advance In Water Science, vol. 13, no. 4, pp. 515-520, 2002. (in Chinese)

[13] Fu J X, Zhang X B, Yan D C. "Seasonal variations in TP, BOD5 and CODMn of the Jinshajiang River, Minjiang River and Changjiang River nearby Yibin City," Earth and Environment, vol. 36, no. 4, pp. 336-341, 2008. (in Chinese)

[14] Zhang B, Lei J R, Liu G C, et al. "Multiple scales variations of precipitation in Yuanmou Dry-hot Valley in the past 50 years," Journal of Mountain Science, vol. 28, no. 6, pp. 680-686, 2010. (in Chinese)

[15] Lee D T, Yamamoto A. "Wavelet analysis: Theory and applications," Hewlett Packard journal, no.45, pp. 44-52, 1994.

[16] Liu T T, Zhang S, Wang D Y, et al. "Seasonal variation and output of CODMn and BOD5 in the Jialing River," Journal of Southwest University (Natural Science Edition), vol. 31, no. 1, pp. 168-172, 2009. (in Chinese)

[17] Zhu Z J. "The principal patterns of multiple cropping system with striped land in Sichuan Basin," Herald of Agricultural Sciences, vol. 1, no. 4, pp. 30-34, 1986. (in Chinese)

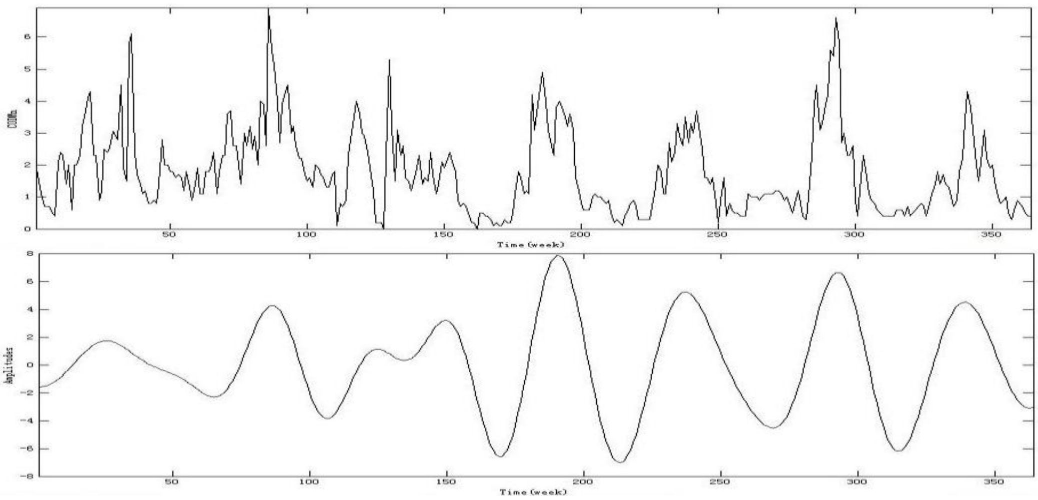

Fig. 1. Weekly changes and wavelet coefficient of CODMn.

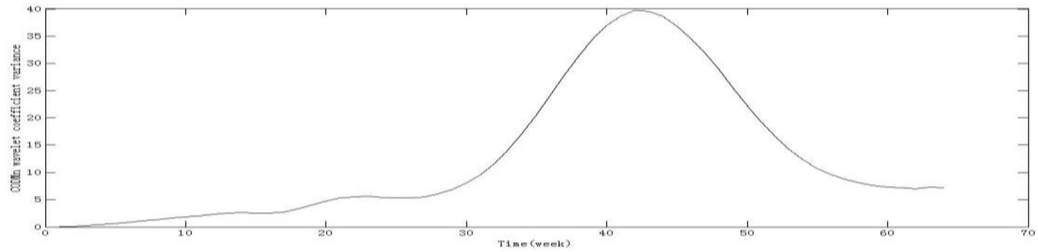

Fig. 2. Wavelet coefficient variance of CODMn.

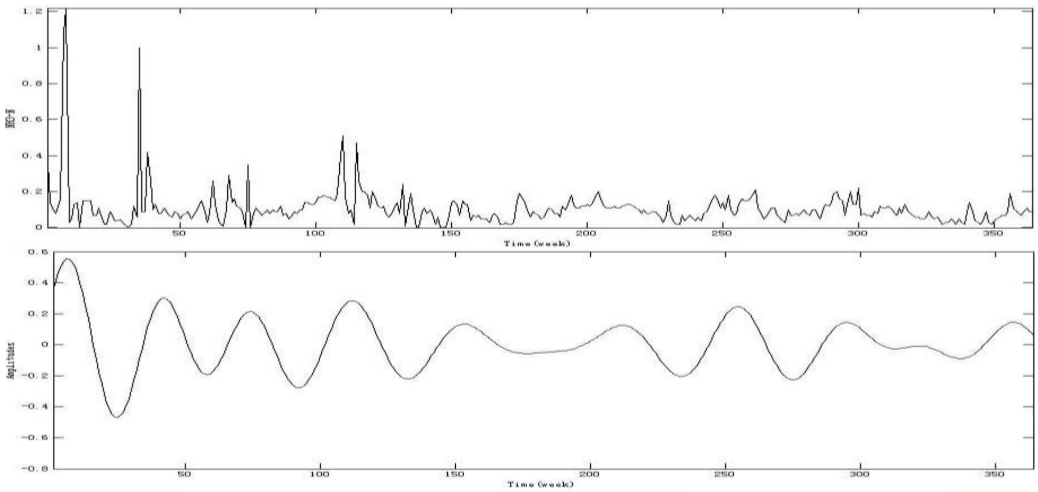

Fig. 3. Wavelet coefficient variance of NH_3-N.

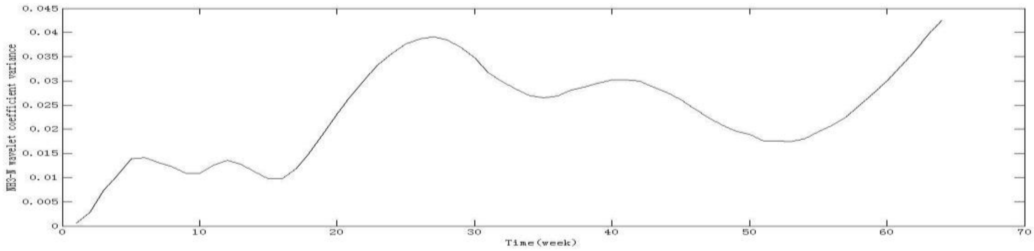

Fig. 4. Wavelet coefficient variance of NH_3-N.