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ENVIRONMENTAL FEATURES AND WATER ENVIRONMENTAL PROBLEMS IN THE CONTIGUOUS REGION OF JIANGSU, SHANGDONG, HENAN AND ANHUI PROVINCES①

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ABSTRACT: Owing to intensive human activities and the floods of the Huaihe River in historic peiod, the contiguous region of Jiangsu, Shandong, Henan and Anhui provinces is suffering from a variety of environmental problems and natural disasters, of which water pollution and drought-flood disasters are most observable. Considering the special location and environmental status of the contiguous region, advices are proposed in the paper: perfecting trans-regional managements system of water environment incorporating basin management agencies in local government activities; strengthening cooperation of two agencies: water conservancy agency and environment protection agency; enhancing integrated control of water pollution and flood-drought disasters; taking the interests of the whole river into acount and paying attention to both storage and drainage; broadening sources of water supply and increasing water delivery; controlling pollutant discharge, developing water saving production system.

KEY WORDS: environmental problems, drought and flood disasters, water pollution, contiguous region of Jiangsu, Shandong, Henan and Anhui provinces

The contiguous region of Jiangsu, Shandong, Henan and Anhui provinces, with a population of 4660×10^4 in 1990, stretching along the China's eastern section of economic belt of new Eurasia Land Bridge, is situated in the northeastern part of the Huaihe River Basin, covering 7.73×10^4 km^2 of nine prefectures or municipalities, i. e., Xuzhou and Lianyungang of Jiangsu Province, Rizhao, Linyi, Zaozhuang and Jining of Shandong Province, Shangqiu of Henan Province, Huaibei and Suxian of Anhui Province. The region is a traditional agriculture area and an important energy base of China. Increasing environment problems, originated from natural evolution and unwise human activities, are threatening its sustainable development considerably.

1 ENVIRONMENTAL FEATURES

1.1 Severe Disturbance of Natural Environment Caused by Human Activities

The contiguous region is one of the birthplaces of China's ancient civilization. Deforestation, soil erosion and land degradation occurred with long - term and extensive reclamation and a successive wars. In particular, the Huanghe (Yellow) River flowed into the sea through the Huaihe River from 1194 to 1855 A. D., which deteriorated agricultural condition and eco-system by frequent flood and drought disasters. Since the 1950s investment to water conservancy project and infrastructure as well as reform of the eco-

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nomic system has improved regional economy greatly. However industrial development, particularly in coal mining, electric power, building materials and coking chemicals, produced heavy environmental pollution to the region. The population density of the contiguous region approached to 602 persons/km^2 in 1990. The rapid growth of population added much more pressure on land, water and other resources, also on environmental loading. The carrying capacity of land has reached to its limitation.

1.2 Great Effect of the Huanghe River's Floods on Relief and River System

The contiguous region can be divided into three landform districts, i.e., Luzhongnan (the center and south of the Shangdong Province) low mountains-hills district, Huaihai hill-plain district and Huang-Huai Plain district. The low mountains and hills in the north and east of the contiguous region decline gradually from north to south. Controlled by X-shaped fault, the major part of low mountains-hills region, the Yimeng Mountains, are jagged with hills and valleys. Soil erosion is remarkable there. The extensive Huang-Huai Plain, laying in the south and west of the contiguous region, declines, with an average gradient of about 0.15‰, from west to east with an elevation of 70 m at Minquan County, 40 m at Dangshan County, 20 m around Luma Lake and 2 – 3 m along the coast of Guanyun County (Ren *et al.*, 1992). The Huang-Huai Plain is composed mainly of the flood plain of the Huanghe River. The Huanghe River once took over the Huaihe River and its tributaries silting them up with large amount of sediments in the historic period. The Huaihe River Estuary was since shifted 80 km eastwards. Bank burst and frequent flood in the Huaihe River also remodeled the terrain and river system in its lower reaches. The original tributaries of the Huaihe River, such as the Yihe River and the Shuhe River, turned into independent rivers flowing into the sea. Nansihu Lakes (Weishan, Lake, Zhaoyang lake, Dushan lake, Nanyanglake) were formed and the Hongze Lake was expanded. The broad sand plain formed by the flood of the Huanghe River often suffers from the damage of sand driving wind. In Shangqiu City a vast strip of salinized land lies in the depression to the south of abandoned Huanghe River. During the rainy season flood and water-logging disasters frequently occur in the flat and low-lying area of the lower reaches of three rivers, the Huihe River, Tuohe River and Suihe River, around the Nansihu Lakes and along the New Yihe River.

1.3 Landscape of Sub-humid Warm-temperate Zone

The contiguous region is situated in the sub-humid warm-temperate zone. It is hot and rainy in summer, covered by tropical air mass, cold and dry in winter, overwhelmed by polar air mass. The mean annual temperature is 13 – 15℃, increases from north to south, and from coastal area to inland. Temperature in January is below 0℃, while in July ranges between 25℃ and 27℃. The annual accumulated temperature above 0℃ totals to 4000 – 5000℃ and frostless season lasts 200 – 220 days. The thermal condition is fit for double cropping one year. The mean annual precipitation, 605 – 929 mm, descents from east to west, with the maximum in Ganyu County and the minimum in Liangshan County. Rainfall is the highest in July and the lowest in January. Annual precipitation in rainy year can be three or four times as high as that in drought year. The mean annual dry index, about 1.1 – 1.9, increase from east to west. It is apparent that this region is characterized by sub-humid climate(Ren *et al.*, 1992). Broadleaf deciduous forests are typical zonal vegetation in the region. The current vegetation are second forest, without any traces of original forest. Forest coverage is pretty low, 12% in Yimeng Mountains, 14% in Huaibei City and 5.5% in Shangqiu City. Zonal soil in the region includes brown earth and drab soil. There are much regosolic drab soil and brown earth, with some gravels and low capacity of storing water and maintaining fertility in the Yimeng Mountains. Yellow fluvio - aquatic soil, widely distributed in the

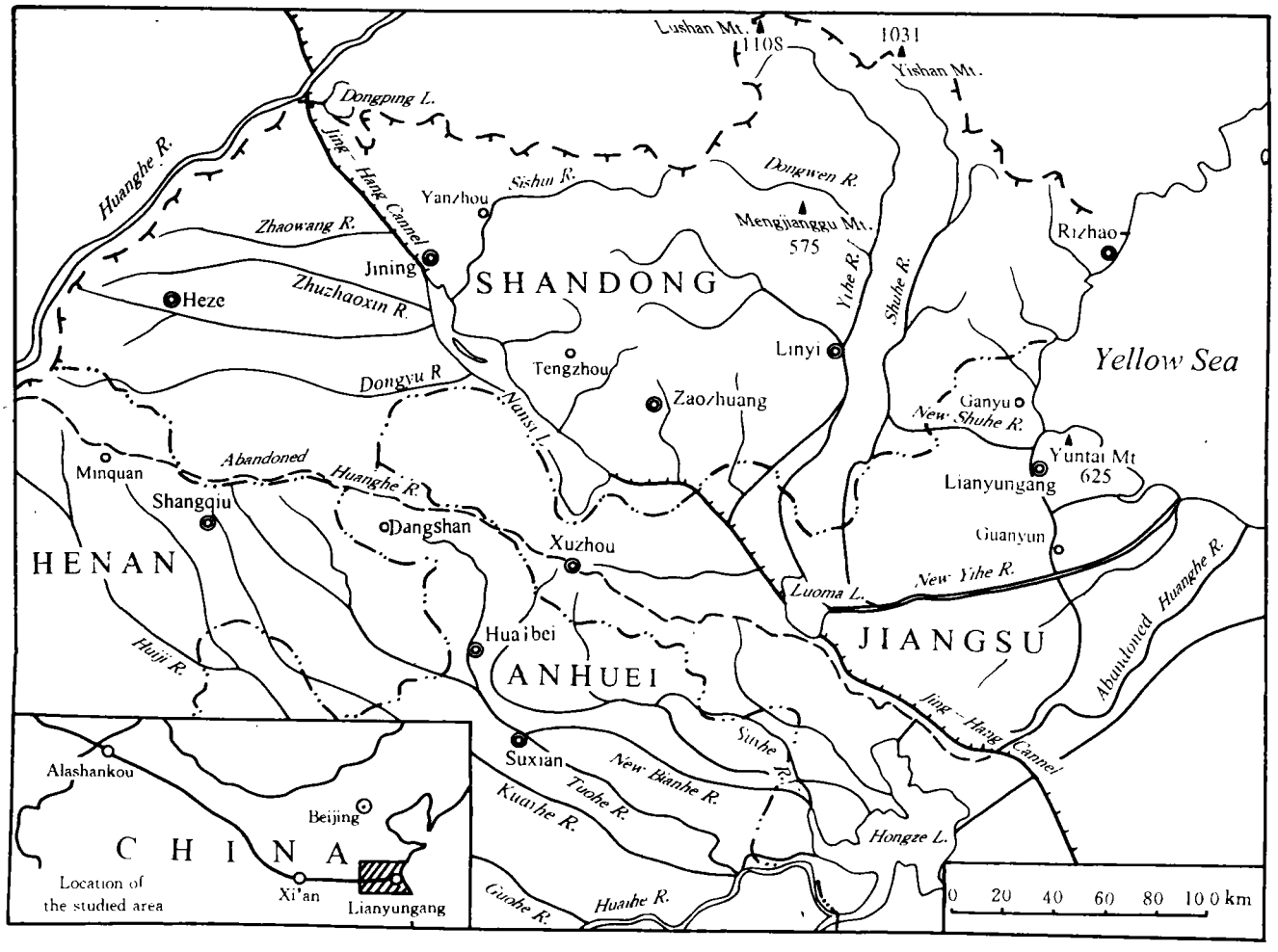

Fig. 1 The sketch map of studied area

flood plain of the Huanghe River, is poor in fertility and sandy in texture except for clay and loam. Besides these soils, saline fluvio-aquatic soil and saline-alkali soil are scattered in this region.

1.4 A Great Variety of Environmental Problems and Disasters

Environmental problems and disasters in the contiguous region are mainly flood and drought disaster, soil erosion, river and lake siltation, damage from wind-drift sand, soil salinization, air pollution, water pollution, land subsidence from coal mining and land occupied by gangue. Those that are relevant to water environment are flood and drought disaster and water pollution etc. Unpleasant natural condition has made the ecosystem in this region fragile. Dry climate, great yearly and seasonal variation of precipitation , remodeled river system by floods of the Huanghe River are major inducements to flood-drought hazards.

Unwise human activities upgraded environment disruption. Rapid development of industry and the establishment of energy base has led to water pollution by ascent pollutant discharge and land subsidence by coal mining. Poor coordination between the upper reaches and lower reaches for water resource distribution and sewage discharge made it even more difficult both to reduce drought and flood disasters and to control environmental pollution.

Table 1 Main environmental problems

District	Mainly by natural process	Mainly by man-made process
Luzhongnan low mountains-hills	1. Drought disaster, flood disaster in piedmont plain 2. Soil erosion in low mountains and hills 3. Reservoir siltation	1. River pollution 2. Land subsidence and land occupation in coal mining area of Yanzhou and Tengxian Counties
Huai-Hai hills-plains	1. Drought disaster, flood and water-logging in the lower reaches of rivers 2. Soil erosion in hill areas 3. Siltation in rivers, lakes and reservoirs	1. Air pollution in cities and industrial area 2. Water pollution in Kuihe River and Zhangtong River 3. Land subsidence and land occupation in coal mining area of Xuzhou and Huaibei
Huang-Huai plain	1. Drought in the northern part, drought and flood in the southern part 2. Damage of wind-drift sand in dike breaching fan-shaped plain and beach of abandoned Huanghe River 3. Soil salinization and alkalization	1. Air pollution in urban, industrial and mining areas 2. Water pollution in Guohe River, Huihe River, Suihe River and Nansihu lakes

2 WATER ENVIRONMENTAL PROBLEMS

A clean water environment is a key condition to sustain eco-system and economic development. The noteworthy problems in water environment in this region are flood, drought and water pollution.

2.1 Frequent Flood Damage

Flood disasters were recorded frequently in this region. In the Yihe-Shuhe-Sibe River basin happened 56 floods 12th century ago, once every 20 years. Nine floods occurred in the 12th and the 13th centuries, once every 10 years. 45 floods in the 14th and 15th centuries, about once every five years, 202 floods between the 16th and the 19th centuries, about once every two years (Fig. 2). The construction of water conservancy projects since 1949 has mitigated flood disaster considerably. Flood disaster occurred in 1957, 1963, 1974 and 1993, about once every 10 years. Statistic data revealed that annual drowned area between 1949 and 1984 was 5.2×10^3 km^2 in the basin of the Yihe River, Shuhe River and Sihe River. The flood embraced 18.2×10^3 km^2 in 1957 and 19.9×10^3 km^2 in 1963. Annual death caused by flood was 66 persons between 1949 and 1991. Flood induced death tends to decrease yearly, while economic loss tends to increase sharply.

Storm water, slow outflow of lakes, damage in river dikes or reservoir dams often provoke flood hazard in this region. A heavy storm to upper-mid reaches of the Yihe River and the Shuhe River in August 1974, with a high daily rainfall up to 250 – 300 mm, produced a fast runoff of 1.06×10^4 m^3/s at Linyi Hydrological Station, which induced a flood hazard to the lower reaches of the rivers. Blocked by small outlet of Nansihu Lakes, overflow frequently torments the lake touching low-lying land. Low criteria in construction of river dikes and reservoir dams weakened their capacity against floods. Dikes of the Yihe River and the Shuhe River broke at 68 places along 50-km river course during high water period in 1974, which inevitably led to a hazard in the site. Banks broke along upper tributary of the Yihe River once drowned five coal mines, two golden mines and some barns.

Flood disaster can be also induced by unwise human activities. Soil erosion aggravated by deforestation minimized retention capacity of reservoirs by silting up them. Urbanization enlarges paved ground,

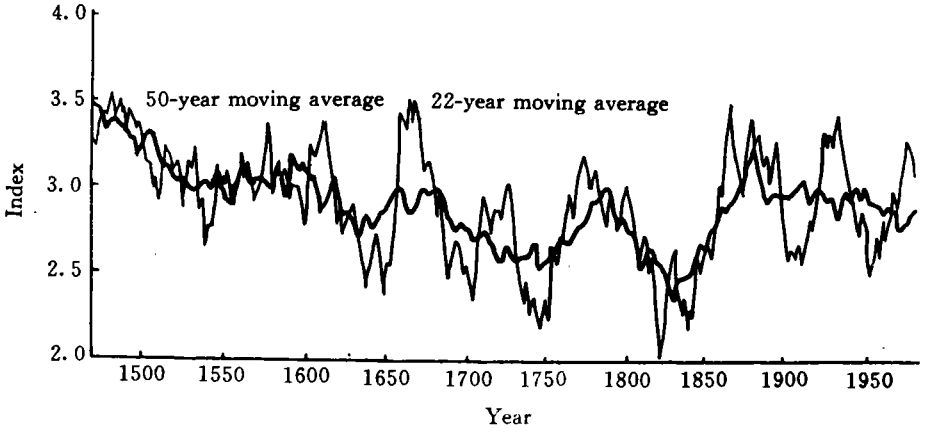

Fig. 2 Frequency of flood disaster in history in Yihe-Shuhe-Sihe river basin

cuts down infiltration amount, increases flood frequency and flood peaks, therefore upgrades flood disasters. Hazard loss also increases with urbanization for social valuables tend to concentrated in urban area.

2.2 Drought and Water Shortage

By historical records in this region there were 80 drought years and 106 slight drought years between 1470 and 1979. One dry season or year was frequently succeeded by another (Meteorology, 1981) (Fig. 3). Successive drought years from 1988 to 1990 dried up upper parts of Nansihu Lakes. Drought areas were estimated 3.5×10^3 km^2 average per year from 1949 to 1991. Drought area was reported to be 9.9×10^3 km^2 in 1966 and 10×10^3 km^2 in 1977. Paddy-field nowadays along Liang – Ji Canal and Nansihu Lakes is half by area of that in the 1970s, resulting from water source reduction. Drought took place once every 3 to 5 years in Shuxian County, and once every 2 to 3 years in Shangqiu County.

Insufficient local water resource, unstable passing runoff and rapid growth in water demand are major provocative factors to frequent drought in the region. Owing to high population density, runoff per capita in this region is 73% of that in the Huaihe River Basin, or 20% of national level, although its runoff module approximates to that of the Huaihe River

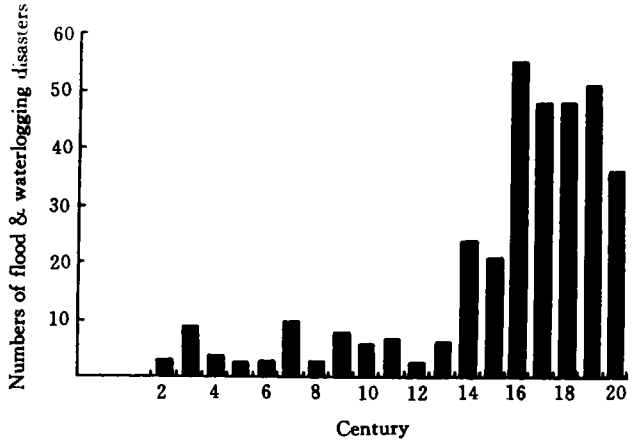

Fig. 3 Curves of drought and flood disasters in recent 500 years in Linyi

basin or national level (Table 2). The reduction of runoff in the Huanghe River and the Huaihe River in recent years as well as the degradation of water quality in the rivers made it impossible to transport water into the region. Most of passing water fluctuating at similar pace with local runoff, brings hardly additional water to the region. No more than 25% of passing water through Xuzhou, 75×10^8 m^3 by volume, three times higher than local runoff, is consumed in normal years in the region. From June to September 88.5% of passing water from the Yihe River and the Shuhe River rushes in the region, while only 11.5% of that flows into the region during other dry months (Office,

Table 2 Comparison of water resources in the area and the relevant area

Region	Runoff module (10^3 m^3/km^2)	Water resource in total (10^9 m^3)	Water resource per capita (m^3)
Bordering area of four provinces	305	23.564	495
Huaihe River basin	317	85.454	681
Whole country*	295	2 812.440	2 481

* Source: CISNR, 1990.

1990). Periodically drying-up in river courses made water resource unstable.

2.3 Increasing Water Pollution

Flourish of small enterprises in recent years, particularly small paper mills, tanneries, chemical fertilizer factories, discharged large amount of waste water into rivers and lakes to cause water bodies polluted seriously. In the Huaihe River basin, for instance, by 1994 there had appeared several thousand small paper mills. In a small town in Anhui Province there were 500 small tanneries, and 50 small paper mills at a township of occurred five noticeable pollution mishaps, which were caused by waster water from small paper mills in Xuzhou City in 1988 which resulted in direct economic loss of 500 000 yuan (RMB). Coal mining in Yanzhou, Tengxian, Xuzhou, Huaibei also polluted water sources nearby and underground water.

Among waste water received by main rivers, and lakes in the region industral waster water made up 85%. Waste water received by rivers and lakes in 1994 totalled 10×10^8 tons, containing 85.2×10^4 tons of harmful substances. The total waste water and total toxic materials received by the Yihe River were respectively 1.1×10^4 tons and 4.6×10^4 tons, the Shuhe River 0.8×10^8 tons and 6.5×10^4 tons, Nansihu Lakes 4.1×10^8 tons and 44.5×10^4 tons, Hongze lake 1.7×10^8 tons and 8.7×10^4 tons.

Monitoring data showed that water quality went worse yearly in this region. Water quality worse than grade III was detected 37.7% of all tested river course in 1981, and 48.2% in 1986. River sections that water quality didn't accord with drinking, fishery and irrigation make up 38.7%, 28.8% and 1.0% of the total monitored river sections in 1981, and respectively 43.5%, 34.5%, 11.5% in 1986. Data in 1994 show that 50% of river sections in the Huaihe River basin has no used value. More than 160 pollution mishaps happened, which perplexed million people there for drinking water and hindered the industrial and agriculture production and people's life.

The surface water pollution of this region belongs to organic pollution, the main pollutants are permanganate, volatile phenol, dissolved oxygen, BOD_5, ammonia nitrogen, non-ion ammonia, etc.

Of 19 river sections monitored in 1994 and 1995, 15 river sections were polluted to Grade V during low water period from December to February. Some pollutant index of most rivers exceeded water quality standard of Grade Ⅲ tens of times. Pollutants were diluted by runoff during high water period of from June to August, which upgraded water quality of four river sections from Grade V to Grade Ⅲ, that of four river sections from Grade V to Grade IV.

Pollutants, mainly organic waste, made surface water in the region high in COD_{Mn}, volatile phenol, BOD_5, $NH_3^+ - N$, NH_4 and low in dissolved oxygen. Monitored data revealed that water in the Grand Canal near Xuzhou was worse than Grade V. Dissolved oxygen, COD_{Mn}, BOD_5 were 50% – 100% beyond standard of Grade III. Oil content was 14 times higher than standard of Grade III.

River pollution also mallet underground water quality decline. Total hardness of most wells were higher than drinking water standard. Mercury was detected from two-thirds of wells along the Kuihe River.

3 STRATEGIES FOR WATER ENVIRONMENT MANAGEMENT

3.1 Perfecting Trans-regional Management System of Water Environment

1) Incorporating basin management agencies in local government activities. In the border region, water environment management has been hampered by administrative problems relevant to bordering of four provinces. Therefore, it is important for more effective management of water environment to introducing a management model coordinating basin management agencies with local governments. Basin agencies should be responsible for distributing water resource, settling down dispute between upper and lower reaches in water pollution, handling of pollution events and controlling sewage discharge etc.. An individual local government is not able to deal with above mentioned problems but to manage specific issues such as control of pollutant, charge for waste discharge etc..

2) Strengthening cooperation of two agencies: water conservancy agency and environment protection agency. In 1983 Ministry of Water Conservancy and National Environment Protection Agency declared that dual leadership would be given to the water resource conservation. The cooperation of two agencies is helpful for protection of water resource and water environment.

3.2 Enhancing Integrated Control of Water Pollution and Flood-Drought Disasters

1)Taking the interests of the whole river into account and paying attention to both storage and drainage. The feasible methods are: (1) reducing pressure on flood disaster in the lower reaches and enlarging reservoir storage by raising the reservoir stage in the upper reaches of Yihe River, Shuhe River and Sihe River to utilize water more effectively; (2) mitigating soil erosion and reservoir siltation by afforestation; (3) enlarging flood outlets in Nansihu Lakes and Yihe River and Shuhe River by dredging water courses in the middle and lower reaches and digging a new channel leading the Yihe River flowing into the Shuhe River.

2) Opening new water sources and increasing water supply. Transferring water from the Changjiang (Yangtze) River into northern China seems helpful to increasing water resource in the border region. Ground water should be used for farmland irrigation in extremely water deficient plain.

3) Controlling pollutant discharge. Objective of water environmental protection is to control both concentration and total amount of sewage discharge by effective measures to reduce discharge amount of pollutants. According to the distribution of total emission control, all provinces, municipalities, counties, villages and enterprises should put the total discharge of pollutants under control within respective share in this region.

4) Developing water-saving production system. Firstly, the efficiency of agricultural water supply can be raised by popularizing water-saving irrigation techniques, such as sprinkler irrigation and pipeline irrigation. Secondly, intensive water-saving agriculture, using large plastic canopies and drought-enduring crops, should be applied. Thirdly, measures should be taken to improve repeated utilization of industrial water and to develop low water-consuming industry by reforming industrial structure. Fourthly, reuse of waste water should be adopted in the light of local conditions.

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