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IMPACT OF OIL FIELD EXPLOITATION ON ECO-ENVIRONMENT OF THE DAQING LAKES

YU Shao-peng[1,2], LU Jin-fu[3], SUN Guang-you[1]

(1. Northeast Institute of Geography and Agricultural Ecology, Chinese Academy of Sciences, Changchun 130012, P. R. China; 2. Department of Geography, Harbin University, Harbin 150086, P. R. China; 3. Department of Environment Sciences, Northeast Normal University, Changchun 130024, P. R. China)

ABSTRACT: The Daqing lakes are located in the region with sub-humid continental monsoon climate. Through historical comparison of the environment before and after oil field exploitation in the area, the paper analyses the impact of oil field exploitation on the eco-environment of the lakes, including the impact of diversion works, drainage works, exploitation and utilization of groundwater, dropped crude oil and petrochemical wastewater on the lakes water body. The analysis shows that oil field exploitation caused serious pollution to soil in the lakes area and deterioration of the eco-environment. The impact became more evident with passage of time, and the intensity varied with areas, getting more serious from west to east, which meant that the eastern part of the lakes were influenced much more seriously by the human activities. To improve the eco-environment of the Daqing lakes and make them sustainable utilization, the effective protection measures should be taken.

KEY WORDS: oil field exploitation; lakes eco-environment; Daqing Oil Field; environmental pollution

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The Daqing lakes are located in the north of the Songnen Plain, the left bank of the Nenjiang River, extending to Anda in the east, the Songhua River in the south, the Nenjiang River in the west, Qiqihar and Mingshui in the north. The area of the lakes is 1196.34km^2, occupying 6.43% of the total land area. It is the biggest one of the lakes in the Songnen Plain(LU *et al.*,1998), which can be divided into floodplain lakes, ancient river-way depression lakes and terrace plain lakes from west to east. Taking physical geography map as an entry point, the author once analyzed the features and categories of the Daqing lakes(YU, 2001). In this paper the authors researched into the impact of oil field exploitation on the eco-environment of the lakes.

The area of the Daqing lakes was a desolate zone before the Qing Dynasty, with more brushwood, some foxes and rabbits, few of traces of human presence. It used to be a hunting terra at the beginning of the Qing Dynasty. The Bin – Zhou(Harbin – Manzhouli) railway and Sartu Station were begun to build here in 1897, and the railway was opened in 1903. The population was only about 1000 in 1945. About ten pastures were built in 1947, and an agricultural and pastoral area began to take shape in the area in 1958. Oil field exploitation began in 1959, and 70 000 workers and retired soldiers came here to exploit petroleum in 1960. Petrochemical industry started in 1970, and Daqing City came into existence on April 25, 1980. The population and industrial output value both increased quickly. At the end of 1995, industrial output value was 27×10^9yuan(RMB), accounting for 91% of the total output value. In 2000 Daqing City had a population of 2.506×10^6. With the quick increase of oil wells, pipelines, roads and population, the eco-environment of the Daqing lakes has been influenced greatly.

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Biography: YU Shao-peng (1972 –), male, a native of Xiuyan County, Liaoning Province, Ph. D. candidate, lecturer, specialized in environmental geography and wetland. E-mail: ysp1234@sohu.com

1 IMPACT OF OIL FIELD EXPLOITATION ON LAKES WATER BODY

1.1 Impact of Three Diversion Works on Lakes Water Body

1.1.1 Increase of lakes water amount

To meet the needs of water for petroleum exploitation, petrochemical industry, residents, livestock, agriculture, fishery and planting reed in the vast plain, and to improve the eco-environment of the west of the Songnen Plain, the Government built north, middle and south diversion canals which take the Nenjiang River as water source. We call them three diversion works.

North Diversion Canal was built in 1976, 115km long, from Taha in Fuyu County, through the Wuyur River, to Daqing and Hongqi reservoirs and Beiershili Lake. It can offer $464 \times 10^6 m^3$ of water per year. Middle Diversion Canal was completed in 1970, from Dadengke in Fuyu County, through Dongsheng Reservoir, Jiudaogouzi wetland to Lianhuan Lake and Dalonghu Lake. It provides $452 \times 10^6 m^3$ of water annually. South Diversion Canal was built in 1980, from Talin Hiag in Mongolian Autonomous County of Dorbod, through Wuerta Lake, Nanyin Reservoir, Niumaogou Reservoir to the Nenjiang River. Historical data indicated that most lakes in this area dried up in drought years. Through three diversion canals, some lakes have gained water supply and their water level has risen. The lakes were full of water after they had obtained totally about $5.44 \times 10^9 m^3$ of water by 1985. For example, in Lianhuan Lake, the average water level ascended from 137.48m to 139.00m when it obtained water since 1970.

1.1.2 Improvement of lakes water quality to a certain extent

Taking Daqing and Hongqi reservoirs as examples, the indexes of pH value, COD_{Mn}, BOD_5, total hardness, total phosphorus, non-ionic ammonia and suspended substance were selected to analyze the impact of the diversion works on lakes water quality. According to investigation, the water quality of Daqing and Hongqi reservoirs was poor before they received the Nenjiang River water: salinity, total hardness and COD_{Mn} were high, pH value was in 8.6 – 9.0. When the two reservoirs received the Nenjiang River water, the water quality was improved to a certain extent.

On the one hand, having received a lot of relatively desalinated water from the Nenjiang River, the water in Daqing and Hongqi reservoirs was desalted gradually. Mineralization degree and sainity descended gradually, pH value also decreased and was in a stable state. The pH value of Daqing Reservoir ranged between 8.1 – 8.29 from 1985 to 1998, that of Hongqi Reservoir was 7.89 – 8.40. Total hardness also got lower, it reduced from 6.54 to 5.02 Germany Degree in Daqing Reservoir, and from 8.46 to 4.83 Germany Degree in Hongqi Reservoir.

On the other hand, the two reservoirs got organic matter pollution from the Nenjiang River water to a certain extent. According to the III Grade Standard of National Surface Water (reservoir) and the Grade Standard of Water Pollution Index, the water coming from the Nenjiang River had been polluted before it came to Daqing City, the indexes of COD_{Mn}, total phosphorus had gone beyond the standard. It can be seen from Fig. 1 that curves of aggregative pollution index (P) of Daqing and Hongqi reservoirs are closely correlated with the index curve of the Nenjiang River water, which indicates the water pollution of the two reservoirs came from the Nenjiang River (the peak values of P of the Nenjiang River and the two reservoirs were due to the influence of the extremely heavy flood in 1998). We can also conclude the variation trend of each pollution index of organic matter from monitored data in the past years. All COD_{Mn} values were higher than the standard from 1985 to 1994, and it showed a decreasing trend from 1985 to 1998 (Fig. 2). Total phosphorus values all exceeded the standard since 1985, but the variation was not obvious. Non-ionic ammonia and suspended substance exceeded the standard in one or two years in some sections. BOD_5 values accorded with the III Grade Standard of National Surface Water, but ascended along with passage of time.

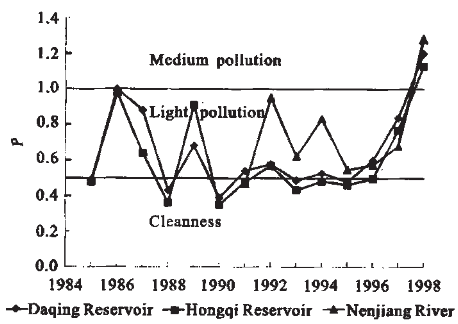

Fig. 1 Aggregative pollution index (P) curves of Daqing, Hongqi reservoirs and the Nenjiang River

Like North Diversion Canal, middle and south diversion canals increased lakes water amount, and improved the water quality to a certain extent.

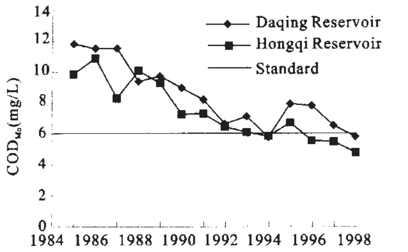

Fig. 2 The change of COD_{Mn} index of Daqing and Hongqi reservoirs

1. 2 Effect of Drainage Works on Lakes Water Body

1. 2. 1 Supplying water to receiving sewage lakes

Drainage works consist of two parts: one is discharging sewage pipeline, consisting of east and south stems; the other is receiving sewage lakes. The east stem mainly discharges the sewage from Daqing 300 000-t Ethylene Integrated Factory, by 28. 5-km pressure pipeline, the sewage flows into Qingken Lake, the Zhaolanxin River, and the Hulan River, at last into the Songhua River. The annual discharging sewage amount is $510 \times 10^6 m^3$. South main stem, taking the Anzhaoxin River as main stem, consists of east, middle, west and Xinglong embranchment lines. The annual discharge volume is $390 \times 10^6 m^3$. Furthermore, sewage can also enter closed lakes directly: the sewage of Heilongjiang Petrochemical Industry Plant is discharged into Tiebutie Lake, the sewage of Linyuan Oil Refinery into Duixi Lake, and the sewage of Chemical Addition Agent Factory and Methanol Factory into Damingshui Lake. In a word, these main discharge stems and more than twenty lakes, such as Zhongnei Lake, Kuli Lake, form a drainage system. Drainage works not only purify sewage naturally by these lakes, but also supply water to these lakes, thus effectively alleviating natural evaporation of lakes. So the lakes could not be dry all the year round, and the sewage can be purified in a long time.

1. 2. 2 Seriously polluting receiving sewage lakes

With the rapid development of oil extraction and petrochemical industry, and the increase of population in the lakes area, the wastewater coming from the drainage works increased quickly, and the sewage exceeded largely the standard. For example, among 85 discharge outlets of industrial wastewater and 77 domestic sewage discharge outlets monitored in 1998, 38 industrial wastewater outlets and 74 domestic sewage discharge outlets all went beyond the standard, the ratios of exceeding the standard were 44. 7% and 96. 1% respectively. Furthermore, the water coming from drainage pumping station also went beyond the standard. The substances that exceed the standard were mainly organic pollutants, which made receiving sewage lakes become an influx area, and also a region with serious organic pollution of water quality, thus speeding up lakes eutrophication.

According to the monitored result of water quality and the characteristic of each enterprise of drainage works, we took Zhongnei Lake as an example, and selected indexes of pH value, COD_{Mn}, BOD_5, non-ionic ammonia, volatile phenol, cyanide, petroleum and total arsenic to study the effect of drainage works on the pollution of lake water. Since the receiving sewage lakes just supply water for industrial use, we adopted the IV Grade Standard of National Surface Water. Monitored data indicate that the indexes of COD_{Mn} and BOD_5 exceeded the standard commonly from 1985 to 1998. The indexes of petroleum, non-ionic ammonia also exceeded the standard in some years. The indexes of COD were 62. 7mg/L in 1997 and 97. 9mg/L in 1998, much higher than the IV grade standard (20mg/L). As a whole, the pollution of Zhongnei Lake was generally medium or heavy except 1988. From Fig. 3 and Fig. 4, we concluded the variation trend of indexes. The indexes of COD_{Mn} were much higher than the IV grade standard(8mg/L) in all years, and presented oscillatory ascending trend from 1988. The indexes of BOD_5 were higher than the IV grade standard(6mg/L) and also presented oscillatory ascending trend. The indexes of petroleum fluctuated greatly and increased since 1994.

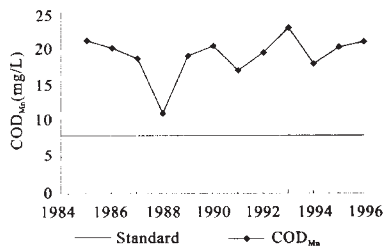

Fig. 3 The change of COD_{Mn} index of Zhongnei Lake

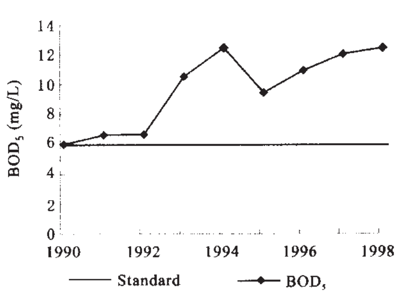

Fig. 4 The change of BOD_5 index of Zhongnei Lake

Like Zhongnei Lake, other receiving sewage lakes, such as Babaishang, Qingken and Kuli lakes also suffered from organic pollution to a different extent (Table 1). Moreover, statistical data in the past years indicate that the pollution was serious in low-water season, medium in mean water season and minor in high water season. The reason is that self-purification capacity of lakes water body was low, there was no enough rain water to dilute in low water season.

1.3 Influence of Exploitation and Utilization of Groundwater on Lakes Water Body

Groundwater of Daqing City is the main source of industrial and domestic water. It can be divided into subsurface water and confined groundwater. The quality of subsurface water is not so good due to the influence of primary environment and human activities. On the contrary, except pH value, Fe, Mn and fluoride, which go beyond the standard in one or two sections, the water quality of confined ground water is comparatively good, better than that of the lakes. The groundwater exploited in Daqing City is mainly confined groundwater. Now, Daqing City has 46 groundwater sources, supplying 940 000t of water per day. To ensure high yield of oil, groundwater, oily water and disposed lakes water were poured into oil extraction floor since the 1970s. The annual recycle amount of groundwater increased quickly from $140 \times 10^6 m^3/a$ in the 1970s to $130 \times 10^6 m^3/a$ at present, which reduced the need of lakes water and held lakes water volume. But it is not a scientific method to exploit groundwater in large amount to meet surface water demand. As a result, the negative effect enlarged gradually, such as land subsidence and the appearance of doline.

Table 1 Pollution indexes of water body of three lakes in 1998 (mg/L)

Monitored section	COD_{Mn}	BOD_5	COD	Non-ionic ammonia	Petroleum	*P*
Babaishang Lake outlet	8.77	10.11	97.90	0.325	0.39	1.40(medium pollution)
Kuli Lake outlet	8.10	4.40	12.51	0.368	0.50	0.89(light pollution)
Qingken Lake outlet	8.40	9.35	64.70	0.238	0.53	1.17(medium pollution)

Some lakes have received the industrial and domestic groundwater with comparatively good quality, which had a positive effect on lakes water environment. For example, Xinhua Power Plant uses 80 000t of water per day. At the initial stage water of Xinhua Lake was used to cool generator, now groundwater has replaced the lake water, after cooling generator, poured into Xinhua Lake by opening water circulation. Supplying water amount that groundwater gave Xinhua Lake is $8.7 \times 10^6 t$ per year, which stabilized water volume of Xinhua Lake, and desalted water quality gradually. At the same time, Mineralization degree fell gradually, water temperature rose to a certain extent(but it did not come to thermal pollution of water body), and vegetation of lakeshores grew luxuriantly, fish also increased in the lake.

1.4 Impact of Dropped Crude Oil and Petrochemical Wastewater on Lakes Bottom Substances

According to investigation, Daqing Oil Field produces 74 500t of dropped crude oil per year in the course of oil extraction. About 30% of dropped crude oil flow into lakes nearby, a great deal of oily sewage come into lakes at the same time, besides, petrochemical wastewater enter lakes too, which certainly cause petroleum pollution of lakes bottom substances.

From Table 2, we can see that total hydrocarbon content of petroleum in bottom substances of Dongfeng and Zhouxia lakes polluted by oil extraction went beyond the standard 204.3 – 767.0 times and 16.3 – 33.9 times respectively, it went beyond standard 17.0 – 35.8, 6.5 – 8.5 times respectively in Daming and Duixi lakes which were polluted by petrochemical. These data testified effectively that the serious petroleum pollution of lakes bottom substances resulted from entering of dropped crude oil and petrochemical wastewater.

Table 2 Measured results of petroleum pollutants in lakes bottom substances (mg/kg)

Water quality	Name of water body	Petroleum total hydrocarbon	Aromatic hydrocarbon
Polluted water body	Dongfeng Lake(oil extraction)	1026.67 – 3840.00	228.14 – 853.33
	Zhouxia Lake(oil extraction)	86.67 – 174.50	19.26 – 38.48
	Daming Lake(petrochemical industry)	90.00 – 184.17	20.00 – 40.65
	Duixi Lake(petrochemical industry)	37.26 – 45.10	8.88 – 11.15
Control water body	Daqing Reservoir	3.42 – 5.00	0.67 – 0.91
	Ranghulu Lake	3.30 – 4.00	0.73 – 0.91

2 DETERIORATION OF ECO-ENVIRONMENT OF LAKES CAUSED BY OIL FIELD EXPLOITATION

The area of Daqing Oil Field used to be a boundless stretch of grassland, with little people before exploitation. It was famous for forage grass with high quality— *Aneurolepidium chinense*. With the intensified human activities in the course of oil field exploitation, the eco-environment of lakes was deteriorated as a whole, though some lakes in west and middle parts obtained the positive effect of water amount augment and relative improvement of water quality.

2. 1 Seriously Pollution of Soil Conditions in the Lakes Area

The soil of lakes area fell under pollution to a certain extent in the process of oil field exploitation. Contrasting with soil background value of Daqing City, we found that in the lakes area the pollution of soil conditions in both oil field exploitation region and petrochemical industry region was more serious than that in pasture and agriculture regions (Table 3).

The monitored results from 30 soil samples in the lakes area of both oil field exploitation and petrochemical industry regions indicate that the main pollutants were petroleum hydrocarbon, hydroxybenzene, sulfide and metal lead. Hydroxybenzene pollution ranked the first in the list of light pollution, and petroleum hydrocarbon the first in the list of medium pollution (Table 4). The hydrocarbon, hydroxybenzene and sulfide pollution came from dropped oil, artesian well mud, rock detritus and oily sewage produced by oil field exploitation and petrochemical industry. Though recovery rate was 60% of dropped oil, 80% of mud, and treatment rate was almost 100% of oily sewage, there was still about 10% of oily substance penetrating into the soil. Since the degradation speed is slow and annual input of pollutants are more than that decomposed, these substances enriched gradually to pollute soil. Lead pollution was fairly serious and common in heavy metal pollution, which was caused by discharged tail gas of trucks carrying oil.

Table 3 Comparison of average value of soil conditions with background value (mg/kg)

Element	Background value*	Oil field exploitation region	Petrochemical industry region	Pasture region	Agriculture region
Hydroxybenzene	0. 032	0. 048	0. 040	0. 031	0. 031
S	0. 070	0. 130	0. 120	0. 090	0. 080
Petroleum hydrocarbon	48. 360	78. 010	72. 800	38. 440	50. 640
Pb	15. 422	24. 338	19. 105	16. 473	17. 534
Cu	12. 489	20. 146	15. 011	12. 900	13. 277
Cr	32. 534	46. 133	35. 562	33. 123	34. 552
Ni	16. 571	20. 013	18. 945	17. 505	17. 460
Hg	0. 0125	0. 0159	0. 0175	0. 0151	0. 0155

* Source: The reports of Daqing Environmental Quality, 1996

Table 4 Pollution of 30 soil samples from oil field exploitation and petrochemical industry regions

Evaluation factors	No pollution		Light pollution		Medium pollution	
	Sample number	%	Sample number	%	Sample number	%
Hydroxybenzene	5	17	22	73	3	10
S	15	50	10	33	5	17
Petroleum hydrocarbon	8	27	10	33	12	40
Pb	4	14	16	53	10	33

2. 2 Rapid Grassland Degradation and Serious Desertification

With oil field exploitation, land occupation of oil field has increased yearly. By the end of 1995, 296km^2 of land around Daqing City had been occupied by oil field, consequently 46. 8km^2 of land was used for reclamation, 67. 9km^2 for virescence, and 155km^2 for residential area and urbanization. Land exploitation listed above and grassland over-herding were the direct reasons for grassland loss around Daqing lakes, which resulted in rapid degradation of grassland. Statistical data show that grassland coverage decreased quickly from 85% before oil field exploitation in the late 1950s to 25% up now; degraded grassland made up nearly 80% of total grassland, the rate of grassland degradation for most grassland was 1.5%, and even reached 2% in parts of the region. Types and area of grassland with high quality grass decreased gradually, for grass became sparse and short, grass quality degraded, grass yield reduced quickly from 2625kg/ha in the 1950s to 1200kg/ha at present (ZHENG and LI, 1999). *Aneurolepidium chinense* community and *Aneurolepidium chinense-Stipa baicalensis* community were originally dominant in the most of the region, and now have lost their predominance. Now only sparse *Aneurolepidium chinense* community that degraded seriously can be seen in a few parts of the region, in most parts of the region, it has been took over by transitional community—Herbosa community, in which the main grass species were *Artemisia*, such as *Artemisia mongolica*, *A. annua*, *A. sievesiana* and *A. japonica* etc. Poisonous and harmful species of grass not suitable for livestock increased, in the meanwhile halophyte such as *Suaeda* spread quickly. Something worth mentioning is that some hydrophytes grew luxuriantly on lakeshore of some lakes that have received adequate water from the Nenjiang River.

This area belongs to semi-humid and semi-dry continental climate, especially from spring to early summer, the climate is dry with little rain but strong wind at the same time, so it is easy to give birth to desertification. For the natural degradation process is slow, the extent of desertification in the area was light before Daqing Oil Field exploitation. After oil field exploitation, on the one hand, there have constructed dense oil wells and pipelines with passage of time, grassland was destroyed, salt congregated to the soil surface. As a result, the process of salinization and alkalization quickened, and extended alkali spots appeared (SUN *et al.*, 2001). For example, alkali spots around Zhongnei, Xidahai, Beiershili lakes began to expand. In some places, large area of wasteland began to appear. According to investigation, salinized field around Daqing now has reached 139 000ha, amounting to 28.3% of the total area. On the other hand, grassland environment disturbed by oil field exploitation accelerated the movement of the sandstorm (XIAO, 1995). The concrete example is that patches of shifting sand and active sand dunes have reached an area of 87 000ha, especially active sand dunes became more severe after the vegetation on the west side of these lakes was deteriorated badly. The area of desertification expanded quickly around Lianhuan and Dalonghu lakes in Taikang County: the borderline of desertification had moved about 9km from Taikang County into Daqing City before 1957, but it had extended to 21km in Daqing City in 1981. The moving speed was quite striking, 0.5km per year. The desertification phenomenon mentioned above around the Daqing lakes is the result of natural factors and human activities, but the process of natural factors is very slow. So the desertification phenomenon is mainly the result of all kinds of human activities, especially oil field exploitation.

3 STRATEGIES FOR PROTECTING THE ECO-ENVIRONMENT OF THE DAQING LAKES

The analyses mentioned above show that oil field exploitation plays an important role in the deterioration of eco-environment of the Daqing lakes. These effects deepen with passage of time, and the intensity varies in different areas. Lakes in the middle and west parts of the area were affected slightly by human activities, for middle and south diversion canals did help these lakes maintain their water quantity. So quality of water and eco-environment turns better. Lakes in the east part of the area were affected greatly by oil field exploitation. For example, oil wells stood up in great numbers, land use for residents expanded greatly, roads and pipelines densely covered, primary vegetation was damaged badly, desertification became more and more severe. Though North Diversion Canal improved water supply for living and industry greatly, dropped crude oil, domestic sewage and petrochemical wastewater coming from drainage works have a great impact on lakes nearby: the water quality of these lakes and soil conditions were contaminated seriously, eco-environment was damaged badly. To improve the eco-environment of the Daqing lakes and make them sustainable utilization, the following protection measures should be taken.

3.1 Controlling the Quality of Water Coming from the Nenjiang River and Preventing Polluted Water Entering Lakes

At the crossover point of the Wuyur River and the Shuangyang River, water coming from the Nenjiang River is polluted by wastewater discharged from factories along these rivers to a certain extent. The water polluted by organic pollutants is the main source of organic pollutants going beyond the standard in these receiving water lakes, such as Daqing Reservoir. In order to supply high quality water for people's living, and aquaculture and agriculture in Lianhuan Lake and other lakes, we should monitor the drainage basin of the Nenjiang River and control the quality of water coming from the Nenjiang River strictly.

3.2 Developing New Techniques, Controlling the Pollutants from Industrial and Domestic Wastewater

Though more than ten sewage treatment plants have been set up in Daqing City, their disposing capacity is still very limited. Besides adopting traditional sewage treatment plant, oxidation pond, and limiting the total discharging of pollutants, advanced techniques should be introduced. At the same time biologic techniques to dispose of polluted water in these receiving sewage lakes should be used extensively so that pollutants in these lakes can decrease to a acceptable amount, at last the lakes can self dispose of the received pollutants.

3.3 Intensifying the Recycle and Disposal of Dropped Crude Oil

The dropped crude oil and the water polluted by dropped crude oil are the origins of petroleum hydrocarbon pollution in bottom substances. It is an important task to control the amount of the dropped crude oil, to set up efficient organizations to recycle dropped oil and to improve the recycling rate greatly for dropped oil.

3.4 Reasonably Planning the Function Zones, Strengthening the Eco-environment Construction

The Daqing lakes can be divided into drinking water zone, aquiculture zone, industrial water zone, irrigation zone and tourist zone according to geographical location, characteristics of water quality and water usage situation of these lakes, corresponding protection measures should be taken according to the function of the lakes.

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