Non-point pollution from China’s rural areas and its countermeasures

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Abstract Most lakes in the eastern part of China are eutrophic and non-point pollution accounts for more than half of the nutrient load to the lakes and reservoirs. Some efforts have been made to reduce the non-point source pollution in the catchments of sensitive water bodies. Technologies for the control of non-point pollution in Chinese rural areas are multipond systems, biogas fermentation, hilly area ecological agriculture, constructed wetlands, ecotone engineering and others. They are effective in the removal of nutrients from the runoff water or reduction of waste, and they are used with multi-purposes. To control non-point pollution, the cooperation with farmers and other residents in the countryside is the key to success, and the program has to consider their benefits. There are still many difficulties with its control, and more efforts are needed to develop suitable technologies and environmental education.

Keywords China; control technology; non-point pollution; rural area

The general situation of non-point pollution in China

The non-point pollution from rural areas accounts for more than half of the phosphorus and nitrogen load to most lakes and reservoirs in the eastern part of China. Although urbanization is developing rapidly, 71% of the population still live in rural areas without sewer networks and sewage treatment. In the past 20 years, waste recycling in the land was decreased greatly with labor costs increasing and more chemical fertilizers being used. In 1996, the chemical fertilizer application in China was 35.9 million tons, with a 10 million ton increase on the figures for 1990. The application rate per unit area was 2.6 times more than that of the world average. Large-scale animal breeding by farmer families has become a new pollution source. Presently, the pig population has reached 400 million and the population of large animals, such as horses and cows, is more than 100 million. In 1995, the manure produced by breeding animals was 2.49 billion tons in the whole country, 32% more than in 1988 (CYA Editorial Committee, 1990–1996). The wastewater discharged from the breeding farms usually contains higher contents of nutrients and organic pollutants than sewage.

In China, the areas of rapid development are facing more serious non-point pollution problems. The people in the countryside produce much more solid waste, which is not treated. Many township factories have been constructed and they have become new pollution sources. The energy structure in the countryside is changing rapidly. Instead of being burned as fuel, much of the agricultural waste is accumulated in the villages and by the riversides. The runoff can wash them into the water after rains. The other causes for accelerating non-point source pollution are deforesting activities, degradation of wetlands, bad sanitation, improper tillage and wastewater irrigation.

The serious non-point pollution causes great degradation of water quality in most lakes and reservoirs in China. The majority of lakes in the eastern part of China are eutrophic and that causes many environmental problems. The worst cases are in Taihu Lake in Jiangsu Province, Dianchi Lake in Yunnan Province and Chaohu Lake in Anhui Province. The
environmental and water resource administrations selected the Pollution control in three lakes as the national environmental project. People are beginning to realize that controlling the non-point source pollution is an important part in the overall environmental improvement program.

In China, as in other developing countries, the basic need is to feed the people by enough grain production in order to support the large increasing population. The key to success in reducing non-point source pollution is a program that also benefits the local farmers, so that they are willing to cooperate. The maintenance costs of non-point pollution control cannot be always paid by the government and it is the farmers who should do it for their own benefit. This is a great challenge for the scientists in this field. With many efforts, several ecological technologies have been successfully developed on the principles of material cycling and minimization of wastes with product chains.

Control technologies and management used in China
The following are some countermeasures suitable for different conditions and they are quite successful in the control of non-point pollution.

The multipond system
This is a typical Chinese system and the main purpose of this system is to recycle water in agricultural lands. The system is composed of many tiny ponds scattered in crop fields. The area of each pond varies from 0.05 to 1 hectare. People describe them as 'thousands of ponds scattered in thousands of hectares of rice fields'. Each pond has a small catchment of 0.5 to 10 hectares and the pond provides the surrounding agriculture land with irrigation water. Multipond systems have a history of more than 1000 years and their original purpose was for irrigation.

These ponds are connected with small ditches and functioned as recycling centers, close to the non-point sources such as villages, dry cropland, rice fields and hilly lands. Long-term measurements in the Liuchahe subcatchment of Chaohu Lake, at the river mouth and samples of the individual land plots, were carried out to analyze the flow water, sediments and nutrients. We found that in the five recorded years, the retention of non-point source nutrient load in the runoff by multipond system was as follows: 97% in 1997, 98% in 1988, 99% in 1994, 97% in 1995, and 94% in 1998 (Yin et al., 1993; Yan et al., 1998; Yin et al., in press). The slightly lower retention in 1998 was because of the higher precipitation depth in that year.

The main functions of the multipond systems are the recycling of water and nutrients among the ponds and fields. The results of our research shows that the multipond system benefits the non-point pollution control as well as the agriculture in local areas. The multipond systems have a main function of storm water storage. Thus, they can prevent or reduce the harm of flood and drought. The ponds act as nutrient recycling centers (Korn, 1996). The small ditches with dense vegetation have a good filtration effect. This function is similar to the small headwater streams described by Peterson et al. (2001). The farmers like the ponds because they can use the water for irrigation, clothes washing and animal drinking. Because the ponds are small, it is easy for the farmers to take the mud out. Their construction is cheap, in terms of manpower and materials of clay and stone. To store and use the water requires no or little energy. Because of these reasons, to use multipond systems for nonpoint pollution is sustainable. At present, the restoration actions are conducted on a large scale in Anhui Province, in order to control the eutrophication of Chaohu Lake. The government encourages the farmers to restore the ponds by contributing 5% of the cost of large pond construction and making a policy of constructor usership of the pond for 50 years. Because the farmers cooperate well, these efforts are beginning to show effectiveness.
Bio-gas fermentation and bio-fertilizer production to reduce agricultural wastes

Improvements in the living standard of the farmers causes a large increase of solid wastes and a worsening situation of non-point pollution in the countryside. Originally farmers used crop stalks as fuel and made animal manure organic fertilizer. Because the energy consumption structure has been changed in many villages, large amounts of crop stalks are left around their houses and in the fields. Sometimes these wastes are thrown into the rivers or washed into the river after heavy rains to cause non-point pollution.

Bio-gas fermentation takes the organic waste as its raw material and produces bio-gas as an energy source. The fermentation tanks are designed in small sizes for the families or in large sizes for the communities. Many provincial administrations do training for the farmers in bio-gas tank construction and it is most successful in Sichuan and Guangxi Provinces. There are many advantages. First, it improves sanitation in the countryside and it reduces farmers' activities of cutting trees in the mountain so that the vegetation can be restored and erosion reduced. According to 1995 statistics, there are 5.7 million family bio-gas tanks nationally and 25 million people can use bio-gas as their daily fuel. These bio-gas tanks treat 29 million tons of manure and 120 million tons of sewage per year (Hong, 1996). Although it is still a small portion of the countryside of China, that is a good trend for future developments in reducing the non-point source pollution. Bio-fertilizer production has become a new industry in the countryside. It is based on modern technology with good design and, in an effort to reduce costs, new fermentation micro-organisms are employed. Some products combine the organic material with inorganic synthesized fertilizer in different compositions for different purposes.

Hilly area ecological agriculture patterns

The main scope of hilly area ecological agriculture patterns is to reduce soil erosion and to increase the farmers' income. In the planning of hilly areas, it is designed that the forests should be planted at the hilltop, tea and fruit gardens planted on the hillside, crops should be planted in the valley terrace and the fish ponds constructed in the low land of the valley (Wang and Yin, 1998). With a combination of crop planting and husbandry feeding, the material and energy is recycled while the wastes are greatly reduced (Figure 1). This system, with a slightly different structure, is suitable in both the south and north regions of China. The forests, tea trees and fruit trees can greatly reduce soil erosion. Meanwhile, the soil, nutrients and organic material washed downwards to the waters can be intercepted and reused several times by the farmlands and fish ponds in the lower part of the valley. With quantitative management of material cycling, the productivity is increased systematically and waste washout by runoff is

Figure 1 The material recycling chain with a combination of planting and feeding, an example of the concept of ecological agriculture (figure from Wang and Yin, 1998). There are products and yields for the farmers from most of the compartments.
minimized. The farmers can increase their income from the sale of tea, fruit and fish and meanwhile their basic needs for the grain is guaranteed. There are good demonstration examples at Three Gorges Reservoir regions, hilly areas in Jiangxi Province and Taihang Mountain areas in Hebei Province (Huang et al., 2000, Xu et al., 2000). The concept of ecological agriculture was first developed by Professor Shijun Ma in China and different patterns can be applied for different purposes (Ma and Li, 1987; Wu, 1989). Based on these principles, many ecological counties are being constructed in many provinces.

**Constructed wetlands to remove non-point source nutrients**

Dianchi Lake in Yunnan Province receives extensive non-point source pollutants from the watershed. The scientists cooperated to extensively research how to reduce the non-point pollution (Jin et al., 1995). They constructed several wetlands and sedimentation beds as demonstration facilities in the lake tributaries for the removal of nutrients and suspended sediments. Such systems are composed of ditches, sedimentation dams, wetlands and ponds. The effects are very significant. As calculated in their technical report, total nitrogen (TN) removal was 22–77% and total phosphorus (TP) removal was 33–86%. The sediment removal was 52–96%. The constructed wetlands not only reduce the non-point source pollution, but also benefit agricultural production by enlarging the irrigation area and aquaculture production. However, the constructed wetlands and sedimentation beds need more maintenance funds because the government has to take the sediments out every two years. Wetland systems are constructed in many other regions to control non-point pollution.

**Filtration effects of healthy land or water ecotones**

When runoff passes through the healthy ecotone wetlands into a river or lake, the water can be filtered and nutrients are removed. We did experiments in the lakeside wetlands of Baiyangdian Lake and the results show that the wetland ditches and reed field soil retained a large portion of nutrients. The retention of total nitrogen (TN) and total phosphorus (TP) by surface flow through a 300 m ditch was found to be 42% and 65%, respectively. The retention of TN and TP by an 8 m stretch of reed community soil was 59% and 88% (Yin and Las, 1995). The retention by the reed community mainly happened at the root (rhizosphere) channels below the soil surface. The scientists from the Institute of Applied Ecology did similar research in the Liaohe River delta reed land to remove contaminants entering the Bohai Sea. The ecotone engineering stabilizes the river and lake shores and good vegetation enhances the sedimentation of nutrients. It is a good method to reduce non-point pollution.

Table 1 shows the characteristics of the above technologies used in China. Most of them do have other benefits for the local farmers. Besides engineering methods, there are ecological agricultural techniques, such as no tillage technology, grass planting and eco-fertilization, to reduce non-point pollution. Institutional reformation is also important. The actions include the protection of the farmer’s right of land use to reduce the soil erosion and training for correct fertilization and better sanitation.

In recent years, the central government has launched a national program to turn improper land use from agriculture to forest, grassland and wetland, in order to protect the environment. The central government provides financial support to aid the farmers in this program. Up to April 2001, the first stage, a total area of 80,000 hectares has been turned from agriculture to forest, grassland or wetland. This program is showing its positive effects on environmental restoration.

**Major difficulties in the control of non-point pollution in China**

Non-point source control is a heavy-duty task in China. Although we have made some progress, there are many difficulties to achieving this. According to the development
The economic growing stage of GNP per capita from US$1000 to US$3000 is a critical period for the non-point pollution increase. In this stage, the production and living standards of the people rise rapidly but government regulation and people's environmental consciousness lags behind. At present, GNP per capita in China is US$800 and it is just the beginning stage of the critical period. It is expected that non-point source pollution will be developing in China and we should be greatly concerned about it.

The major difficulties in controlling non-point pollution in China are the following:

¥ The control of most point source pollution has not been completed. The governments usually put their priority on controlling the point source pollution. Non-point pollution control efforts have not been made in most regions.

¥ The people in the countryside are at a less developed stage. They are poorer and less educated than those in the cities. People in the countryside are struggling to gain their basic needs for life at present. Their environmental consciousness is relatively low.

¥ In many areas, the agricultural network is greatly weakened. The agronomists and technicians cannot get enough support from the government in many of the counties. The farmers cannot obtain guidance in running environmentally friendly technologies. In many extreme cases, the dose is five or six times higher than the crop needs.

¥ There are not enough suitable techniques for the control of non-point source pollution as well as for the benefits of the local people.

¥ There is no legal system to control the non-point source pollution in China.

Much more effort is needed in the future, otherwise the pollution situation will reach a point at which the costs of the restoration are enormously high.

Conclusions

The non-point source pollution from rural areas is serious and it threatens water resource safety in China.

China is a developing country. The practical countermeasures to control non-point pollution at present are those which also favor the farmers in some respects. Good examples are multipond systems, bio-gas fermentation, bio-fertilizer production, constructed wetlands, ecotone engineering and hilly area ecological agriculture. Their key contents are material cycling and they are effective in nutrient load reduction.

Being at the critical period of rapid economic development and with non-point pollution increasing, China is facing many difficulties with pollution control. The government needs to put non-point pollution control into action and there is a need for extensive environmental education. More research should be done on technology development. It is most important to improve the management and development of a legal system for non-point pollution control.
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