Journal of Environmental Sciences (China), Vol. 2, No. 2, pp 63–70, 1990 ISSN 1001-0742

Approaches to municipal wastewater irrigation and environmental protection

Gao Zhengmin[1]

Abstract—To reuse the water and nutrient resources from ecological point of view the goals, criteria and constraint conditions of the scientifically municipal wastewater irrigation are discussed as well as the practice in major municipal wastewater irrigation areas in China is introduced, of which particularly the effects of municipal water irrigation mixing with oil refinery wastewater on the agricultural ecosystem are studied and described. It has been revealed that benzo(a)pyrene in various parts of paddy crop is attributed to air pollution, water–soil pollution and biosynthesis of plant. Of exogenous contributions of benzo(a)pyrene in paddy shoot system under natural condition, the dominant factor is the air pollution, whereas the water–soil factor is considered to be secondary. Therefore, it is mostly urgent to control the air pollution source of benzo(a)pyrene, to which the edible parts of various green plants are exposed directly.

Keywords: municipal wastewater irrigation; land treatment system; benzo(a)pyrene pollution; ecological engineering.

INTRODUCTION

The agricultural ecosystem consists of green plants as "producers", insects as "consumers", soil microorganisms and soil animals as "decomposers" and various environmental factors. Man is not only the "super consumers", but also the labor creator and manipulator, standing in the center of agricultural systems.

Therefore, the effects of municipal wastewater irrigation on agricultural systems are complicated. They may be positive or negative, depending on wheather man is able to manipulate them or not. It would be better to make a concrete analysis based on the concrete conditions than to draw simple conclusions, which may be either absolutely affirmative or absolutely negative.

THE GOALS, CRITERIA AND CONSTRAINT CONDITIONS OF MUNICIPAL WASTEWATER IRRIGATION

So far as scientifically municipal wastewater irrigation is concerned, the following aims must be reached as possible (Ma Shijun, 1983; Gao Zhengmin, 1981; 1982; 1981):

[1]Institute of Applied Ecology, Academia Sinica, Shenyang, China

1. Utilizing water and fertilizer resources to increase agricultural production;
2. Saving the energy consumed;
3. Maintaining the biological quality of agricultural products;
4. Reducing the pollution load to the marine and fresh water ecosystems;
5. Preventing the secondary environment pollution, especially of long-term effects.

Municipal wastewater refers to the mixture of domestic and industrial wastewater. In no circumstances should any municipal wastewater untreated be used in irrigation.

Above all the municipal water is to be dealt with "in differentiation."

The constituents of municipal water, as a rule, is divided into four groups:

1. High toxic substances, including biological nondegradable (refractory) organic, heavy metals, carcinogenic and teratogenic agents, radioactive fission products, and infectants, viruses;
2. Dissolved inorganic substances, including N, P, K, Ca, Mg and other plant nutrients;
3. BOD, including organic wastes and common toxic organic substances.
4. Suspended solid.

As for the 1st group of particular pollutants we should apply quite modern, sophisticated and expensive techniques to pollution control, and a goal of "zero discharge" might be established and realized. And then these particular pollutants would be entirely eliminated, recovered or reused. They were absolutely prevented via translocation from entering the food chain of agricultural ecosystems. As a matter of fact in any treated municipal water effluent for the moment still remain such trace pollutants owing to the limitation of technical or economical conditions. So we must research thoroughly into the fate of these pollutants in agricultural ecosystem, especially in its food chains. Thus, we would be eventually able to manipulate the municipal water quality for irrigation in compliance with standards.

Now the secondary treatment of municipal water is popularized in the developed countries of the world. In China it is only in the developing stage.

In general the secondary treatment effluent still contains some SS, dissolved organic, inorganic salts, especially N, P, K, Ca, Mg nutrients, which are easy to cause eutrophication of the surface water. If one intends to improve the water quality, the tertiary treatment must be taken, while it is far from popularity.

May the scientifically municipal wastewater irrigation be substituted for tertiary treatment or partial secondary treatment, as an alternative soil-plant system treatment method, coupled with various lagoons and sedimentation ponds? The answer will be "yes", as long as the criteria and constraint conditions of the scientific municipal wastewater irrigation are more thoroughly researched. What we urgently need is a set of water quality standards for municipal wastewater irrigation, which have been developed and put in force in China (GB 5084-85, 1985).

The municipal wastewater irrigation fields will be urban-rural ecosystems, through which nutrients cycles and energy flows with high efficiency can be maintained.

THE ECOLOGICAL AND ECONOMIC BENEFITS OF MUNICIPAL WASTEWATER IRRIGATION

The major municipal wastewater irrigation areas in China are the following: Beijing's Western Suburb, Shenfu, Shijiazhuang, Xi'an, Shanghai's Chuansha, Chengdu, Maoming, Zhengzhou, Baoding, Luoyang and Haerbin. Total irrigated area is around 200000 ha. These municipal irrigated areas are located in different climate–soil zones. In terms of types of cultivated plants and hydrological conditions they consist of two categories, i.e., paddy field (rice) and upland field (dry farming).

In the Southern China municipal water is mainly used as fertilizer resource, while in the Northern China it is used as both fertilizer and water resource.

The municipal water is rich in nutrients of N, P, K as a common character (Table 1).

Table 1 The contents of N, P, K in different irrigation areas

Irrigation areas	Effluents,	NH_4–N,		P_2O_5,	K_2O,
	ML/day	ppm	t/a	ppm	ppm
Shijiazhuang	530	20 (total N)	3900	6	
Baoding	160	57.8 (total N)	3400		
Xi'an	460	72	12000	8	24
Zhengzhou	234	15–40	1300–3000	5–23	5–10
Beijing's W Suburb		0.9–17		3–5	
Shenfu	260	30–50	2800–4700		
Shanghai's Chuansha	300	21.2	2300	10.7	
Total	1944		26000–30000		

The production of cereals has increased in a large scale due to the application of municipal water irrigation and serious field management, including N control to prevent unexpected overgrowth and unbalanced nutrition of the crops. For example, in Chengdu area the harvest of rice increased from 1.5–2 to 5–6 t/ha; in Shenfu area, from 2 to 6–6.75 t/ha; and in Shijiazhuang area, for wheat/rice double cropping, 12 t/ha, having about 70t/a. of chemical fertilizer saving in a production unit of the local community.

Meanwhile as a result of the purification function, municipal water irrigation has enabled the field runoff receiving water body to reduce pollution loading. For example, the pollution load of Wei River has been reduced since the Xi'an municipal water irrigation area was founded. Shenfu irrigation area has enabled the water quality of Hunhe River to be improved and the pollution of water source of Shenyang (South Tower) to be attenuated. The water quality of Baiyangdian Lake also has been improved by having the Baoding irrigation area.

ASSESSMENT OF POLLUTION IMPACTS ON ENVIRONMENT

Every thing in the world is divided into two. In the course of development for municipal irrigation area there were not always positive and expectable.

As a rule agricultural ecosystem can have a tolerance to environmental pollution loading within its own "elastic limitation", and the function of ecosystem can be recovered spontaneously after some shocking pollution loads at times. Once the shocking pollution loading is beyond its "elastic limitation", the structure and function of the agricultural systems will be broken down, and there will be no harvest at all.

The situation of Shenfu irrigation area would be taken as an example.

Shenfu municipal water irrigation area is located between Shenyang and Fushun cities in Liaoning province, with a total area 13000 ha. The 90% of the effluent is "trade" wastewater (64% oil refinery) and the rest is domestic sewage, with an average daily flow of 260 ML. The cereal crop grown on the area is rice.

In the growing seasons (April–September) the water is pumped from Hunhe River into the channel (5:1 or 5:3).

The oil refinery plants have applied the following wastewater treatment methods, since they were established.

1. Mechanical separation oil (merely) before 1975.
2. Flotation by pressure since 1975.
3. Speeded surface aeration since 1975.

It was expected that the following criteria for some major pollutants in the effluent would be reached after 1980:

oil	< 10 mg/L
sulfur	< 1 mg/L
phenol(volatile)	< 1 mg/L

It happened in the winter of 1965 when the surface of fields in the area was flooded in a deep municipal water layer of about 100cm, i.e. so-called "plain reservoir".

After that the soil of the area covering about 350ha suddenly became poisonous and the related cultivated rice appeared a serious symptom of phytotoxicity. Subsequently, it had not any harvest in that year.

In 1969 a field investigation and chemical analysis were conducted. It was reported that the essential factors for the rice phytotoxicity seemed to be oil and phenol in the polluted soil with the multiple and interactive environmental effects (Table 2).

Table 2 Degree of phytotoxicity of oil and phenol in the polluted soil

Degree of phytotoxicity	Indicators, ppm	
	oil	Phenol
Light (normal)	< 600	< 1
Medium	600–1000	1–2
Heavy	> 1000	> 2

It must be pointed out that once the agricultural ecosystem was polluted beyond its tolerance to pollution, it will have to take much time (several years), financial resource and labor force to abate the environmental impacts and recover its structure and function, applying different operations such as transport of polluted soil, deep tilth, washing and drainage, substituting new variety of rice and so on. One of our research projects focused upon the major organic pollutant residues of oil in the food chain. Results are as follows:

Oil

There is no statistically significant difference between oil contents of treated rice grains from municipal water irrigation area and ordinary water irrigation area.

Phenol

The phenol content of treated rice grain from municipal water irrigation area is significantly higher than that from ordinary water irrigation area.

Fortunately the phenol contents of rice grain from municipal water irrigation area are within the acceptable range for cereal grain < 1 ppm.

Benzo(a)pyrene

Benzo(a)pyrene is the well known and ubiquitous carcinogen of hydrocarbons. This compound has a low solubility and occurs in municipal water(oil refinery wastewater), and is mostly absorbed on suspended particles up to 5000–7000 ppb.

Recent analyses have demonstrated that benzo(a)pyrene is widespread not only in the marine environment, but also in all the terrestrial ecosystems.

It was originally thought that this compound found in some vegetation was due to air or soil pollution, but it was later clear that higher plants can also manufacture it .

Since 70's the problem concerning carcinogenic benzo(a)pyrene (BaP) pollution in soil–plant system has appeared as one of the focuses in practice and environmental investigations (Gao Zhengmin, 1981).

A great number of soil samples from different sites of the whole range of Shenfu municipal irrigation area were collected to assess the benzo(a)pyrene. It has been revealed that benzo(a)pyrene content of soil ranged from 30 to 500 ppb. Meanwhile the benzo(a)pyrene in rural soil far from municipal water irrigation area is only < 10 ppb as background.

What is the difference between benzo(a)pyrene content in treated rice grain from the background area and from the different sites of municipal water irrigation area?

It is interesting that there is not statistically significant difference between them. The benzo(a)pyrene content of treated rice grain from all areas is < 1 ppb.

On the other hand, it was revealed that benzo(a)pyrene content of untreated rice grain, especially rice bran from municipal water irrigation area is about several times as high as that from ordinary water irrigation area.

The latest results of simulating experiments show that BaP contents in various parts of paddy plant are attributed to air pollution (Table 3), water–soil pollution and biosynthesis of plant respectively (Table 4). The order of BaP concentrations in paddy plant is as follows:

root $\gg$ stem+leaf > hull $\gg$ grain

BaP from biosynthesis of plant itself is defined as "background". Of exogenous contributions of BaP under natural conditions, the dominant factor is air pollution whereas the water–soil factor is considered to be secondary.

Table 3 Micro–aerosol material and fall–out dust containing BaP under different conditions

		Micro–aerosol material			Fallout dust,
Condition	Measured period	Number of determination	BaP, $\mu g/100m^2$	Weight of MAM*, $mg/100m^2$	$\mu g/m^2$ 60 days
Under control	7.11–9.24	8	ND	1.60	ND
Without control	7.11–9.24	8	0.91	43.88	110

MAM*: Micro–aerosol material ND: Not detected

Table 4 Distribution of BaP in various parts of paddy plant under controlled air pollution

Parts of plant	Grain		Hull		Stem		Root	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
Sand culture no BaP added	0.1	0.01	1.0	0.41	3.6	0.42	13.1	1.63
Soil culture +170 ppb BaP	0.1	0.04	1.9	0.23	4.1	0.28	50.4	1.48
Sand culture + 2×50 ppb BaP	0.3	0.01	2.6	0.07	4.8	0.80	1704	291
Sand culture + 2×100 ppb BaP	0.2	0.06	1.0	0.75	4.6	0	3679	110
Sand culture + 2×500 ppb BaP	0.1	0.04	2.8	0.62	6.9	0.34	12055	644

DISCUSSION AND CONCLUSION

1. The current standards for irrigation water quality is being implemented which mainly guides the application of wastewater for agriculture purpose. Nevertheless, the real picture of wastewater irrigation seems to be complicated.

2. Along with water pollution control, it is urgently to control the air pollution, to which the edible parts of various crops are directly exposed as well as water–soil pollution control.

3. As science and technology is advanced with time, wastewater irrigation areas are to be reformed and reconstructed according to the principles of ecological engineering land treatment systems (Gao Zhengmin, 1986; 1988) to meet the comprehensive requirements of environmental protection.

4. In any case we can not perfectly get benefits from wastewater irrigation practice unless we realized much better and bring its harmful side effects under control.

REFERENCES

Gao Zhengmin, Environmental Science of China, 1981, (6):7

Gao Zhengmin, Environmental Sciences of China, 1982, 11(5):76

Gao Zhengmin *et al.*, Acta Scientiae Circumstantiae, 1981, 1(1):12

GB 5084–85, Standards for Irrigation Water Quality, Adopted and Issued by EPA China, April 25, 1985

Gao Zhengmin, Studies on pollution ecology of soil–plant systems, Beijing: China Science and Technology Press, 1986

Gao Zhengmin, Urban Environment and Urban Ecology, 1988, 1(2):15

Ma Shijun, The Journal of Ecology, 1983, (4):20