Pang Lei

Sludge Treatment and Disposal

Thesis

CENTRAL OSTROBOTHNIA UNIVERSITY OF APPLIED SCIENCES

Degree Programme in Chemistry and Technology

February 2010

TABLE OF CONTENTS

ABSTRACT

Thesis Abstract

Thesis Abstract Department Central Ostrobothnia University of Applied Sciences, Kokkola	**Date** 21 December 2009	**Author(s)** Pang Lei
Degree programme Degree Programme in Chemistry and Technology		
Name of thesis Sludge treatment and disposal		
Instructor Esko Johnon		**Pages** 47
Supervisor Kaj Jansson		

With the development of industrial economy and urbanization, the production of urban wastewater is growing. Sludge is a product generated from sewage treatment, so the amount of sludge produced is also increasing. It is easily led to secondary pollution by improper disposal. Sludge treatment and its disposal are important parts of wastewater treatment. The thesis deals with the problems of sludge secondary pollution. The environmental impact of sludge was summarized and methods of sludge treatment and disposal and the comprehensive utilization at home and abroad in recent years was introduced. The trend of sludge treatment and disposal for the future development was also observed respectively from four areas: the stabilization, reduction, harmlessness, and resource utilization of sludge. The way to dispose sludge for Tianjin Xian Yan Road sewage treatment plant was designed, combining with the current situation and existing problems as well as factors of constraints development in Tianjin, China.

Keywords

Sludge treatment and disposal, final disposal, resources utilization, incineration.

FORWORD

This is a project on sludge treatment and disposal. Also it is submitted as a bachelor's thesis for Central Ostrobothnia University of Applied Science. This thesis aims on preventing secondary pollution and researching how to effectively treat and dispose the sludge and its resource utilization.

The current situation proves the use of sludge treatment technology is not advanced in China. Sludge treatment rate is still relatively low, and people have not enough recognition of the needs for sludge treatment and disposal, and there is a serious shortage as many problems are still to be resolved. Therefore, my hometown Tianjin is set as an example, through analyzing the current situation and existing problems as well as factors constraining development in Tianjin, China. The first sewage treatment plant was built since 80 years in Tianjin. The rapid economic development in my city and the municipal government takes more attention to urban environmental construction and protection. Not only technology but also water treatment rate has been ranked first in China. In the last part of this thesis, I designed the way how to dispose sludge in the Tianjin Xian Yang Road sewage treatment plant from land use, landfill and incineration of three aspects.

Sludge contains not only large amounts of toxic and hazardous ingredients, but also contains lots of organic material. So methods to rationally use, turn waste into treasure, and enhance economic efficiency have important practical significance.

I wish to thank my supervisor Kaj Jansson, and give special thanks to my instructor Esko Johnson for advice and the great help while I was doing my graduation work.

Kokkola 21 December, 2009

Pang Lei

1 INTRODUCTION

With the discharging of wastewater of community and the increasing requirements of resource protection, new sewage treatment plants have been established. Sludge is solid waste which is generated from the process of wastewater treatment.

Due to the increasing rate of sewage treatment and the treatment level, sludge production will inevitably grow, which results in the problem in sludge disposal getting worse. In addition to a lot of organic matter, rich in nitrogen, phosphorus and other nutrients in urban sewage treatment process, sludge also contains heavy metals, pathogen, parasites and other toxic and harmful ingredients.

In order to prevent secondary pollution and to ensure normal operation and treatment of sewage treatment plants, the situation that sludge treatment and disposal issues occupy cannot be ignored in urban sewage treatment. Daily sludge production of sewage treatment plant must be disposed in time. Sludge would be in the anaerobic state and send out foul-smelling if stored over a certain time. It is the biggest problem for wastewater treatment plants.

The common feature of sludge is the high moisture which is generally up to 25-98%. Sludge is bulky and difficult to handle. The harmlessness of sludge pollution is more and more obvious as people's living standard is improving with the expansion of production scale.

The aims of sludge treatment are reduction, stabilization, absence of risks and resource utilization. To achieve the aims, it is a must to constitute sludge treatment and disposal systems through the combination of mechanical and processing facilities.

It is already an indisputable fact that improper handling of sludge causes secondary pollution. So the method to landfill is proposed, but it occupies a large space. What is more frightening,

the pollution of groundwater and heavy metal poisoning are infinite problems. Someone is proposed the principle of composting which is really turning waste into valuable material. However, cost-effective organic fertilizer not only promotes the plant's growth, but also promotes the plant variation.

Research has shown that there is 2700-3300 kcal / ton of heat remaining after sludge is set. Research has shown someone even think that it can be not only used as fuel to generate electricity but also to make sintered brick. Someone found that sludge in the range of 200-800 ° C in the combustion process produces a large number of carcinogenic substances. How to deal with sludge becomes our puzzle.

To understand the general characteristics of sludge and to develop a proper way to handle sludge technology have become important concerns facing the current social development and political stability has caused wide attention by governments, social and production sectors in each country and begun to focus and research on an environmental hot-spot issue.

The research questions of the thesis are the following:

What is the environmental impact of sludge?
What are the technologies of sludge treatment and disposal?
What is trend of sludge treatment and disposal for the future development?
How to design the way to dispose sludge for Tianjin Xian Yang Road sewage treatment plant?

2 THE ENVIRONMENTAL IMPACT OF SLUDGE

2.1 Sludge organic nutrients and the effectiveness of land use

Sludge contains a large number of nitrogen, phosphorus, potassium, calcium and organic matter. Nitrogen and phosphorus are based on the principle of organic state while there are still many necessary trace elements of plant that can be released slowly and have long-lasting nature in sludge (Li 2002, 159-162).Therefore, sludge not only is a useful biological resource but also a very good soil conditioner and fertilizer.

TABLE 1. Nutrient composition results in sludge of 21 sewage treatment plant

Item	organic	TN	TP	TK
Average	37.18%	3.03%	1.52%	0.69%
Maximum	62.00%	7.03%	5.13%	1.78%
Minimum	9.2%	0.78%	0.13%	0.23%

Table 1 shows the average content of sludge organic is 37.18% in China. The average contents of total nitrogen, phosphorus, potassium contents are 3.03%, 1.52% and 0.69% respectively which exceeds the nutrient needs of the national composting standards. Thus sludge makes good organic manure. (Li 2002, 159-162.)

In addition, the statistical result also shows that sludge nutrient content is widely different in sewage treatment plants in different region. Organic content is relatively low in economically underdeveloped regions while sludge organic content is relatively high in sewage treatment plants in the economically developed areas. The nitrogen content of sludge does not have obvious regularity in cities. The potassium content of sludge is not

significantly changed in the same municipal area. (Qiao, Luo & Wu 2000, 1-6.)

Due to the impact on sludge's source and date of manufacture, sludge composition is quite different which involves living standards and habits in different regions in China. In the long run, nitrogen and phosphorus content in sludge will increase as the growing of dephosphorization and secondary sewage treatment process in wastewater treatment plant which will be conducive to sludge land-use and composting in China. (Li 2002, 159-162.)

Organic content is about 55-60% in China's urban sewage sludge while the European Union is between 70-80%. In general, the higher the organic matter content in fresh sludge, the higher digestion and decomposition. Sludge organic nutrients and trace elements can significantly change the physical and chemical properties of soil, which can increase the content of nitrogen, phosphorus, potassium, improve soil structure and promotes the formation of granular structure. Sludge organic nutrients and trace elements can adjust the exchange capacity of soil pH and cation and lower soil bulk density which increase soil porosity, permeability, field capacity and the ability to protect fertilizer. Sludge which is used as fertilizer can reduce the amount of fertilizers. Thus, costs of agriculture and environment pollution which is caused by fertilizers are reduced. (Li 2002, 159-162.)

2.2 Environmental pollution of sludge

Although sludge is rich in nutrients, it still contains a large number of pathogens, parasites, copper, zinc, chromium, mercury and other heavy metals, salts, as well as dioxins, radionuclides and other toxic refractory pests. These substances may cause greater harm to the environment as well as human and animal health. (Qiao, Luo & Wu 2000, 1-6.)

The high salinity in sludge can significantly improve the electrical conductivity of soil, destroy plant nutrient balance and restrain the absorption of nutrients in plants which even cause direct harm to plant roots. Also the antagonism between ions can effectively accelerate

nutrient leaching. (Li et al. 2003, 246-247.)

2.2.1 Pathogens

Pathogens in sewage (pathogenic micro-organisms and parasites) can be put into the sludge after processed. Over 1000 kinds of pathogens have been detected from fresh sludge in which parasites are the most harmful. There are four basic ways of polluting human or animals by pathogens in sludge.

Pathogens contact with the sludge directly being infected through direct contact with the food chain and sludge. Water bodies are contaminated by pathogens. Pathogens contaminate all soil firstly, and then they pollute water bodies. Sludge used for agricultural causes underlying epidemics which is primarily considered to be related to salmonella and eggs of the tapeworm. (Li et al. 2003, 246-247.)

2.2.2 Nutrient pollution

When using a large number of sludge which is rich in nitrogen and phosphorus in loose soil of the higher rainfall areas, and when decomposition velocity is higher than the rate of plants absorb nitrogen and phosphorus. The water contains nitrogen, phosphorus and some nutrients may flows into ground surface water body which causes eutrophication and into the ground which pollute underground water with the loss of water. Therefore, the migration of nitrogen, phosphorus and other nutrients to environmental impact is a long-term monitoring and research work. (Qiao et al. 2000, 1-6.)

2.2.3 Organic polymer pollution

Municipal sludge mainly contains benzene and chlorophenol. Despite the current worldwide research on organic pollutants in municipal sludge, research indicates the characteristics of organic pollutants in sludge and its behavior, ecological effects and control measures in the agriculture environment of an agricultural city. (Li et al. 2003, 246-247.)

2.2.4 Heavy metal pollution

There are 70-90% of heavy metals transferred into the sludge by adsorption or precipitation in the sewage treatment process. Some heavy metals such as cadmium and chromium mainly are derived from emissions of wastewater from industries. Heavy metals such as copper and zinc are derived from pipes system of family life. Heavy metal is an important factor to limit large-scale land use, because the heavy metals accumulate on the ground surface after sludge is applied to the soil. In addition, for heavy metals, solubility is generally very small, the property of heavy metal is relatively stable and it is difficult to remove. Thus the potential toxicity easily accumulates in animals and humans. (Zhang, Lin & Jin 1996, 296-299.)

TABLE 2. Comprehensive 44 urban sewage treatment plant sludge heavy metals results in china. Unit: (mg/kg)

	Cd	Cu	Pb	Zn	Cr	Ni	Hg	As
Average	3.03	338.98	164.09	789.82	261.15	87.80	5.11	44.52
Maximum	24.10	3068.40	2400.00	4205.00	1411.80	467.60	46.00	560.00
Minimum	0.10	0.20	4.13	0.95	3.70	1.10	0.12	0.19

Statistical results indicate that in China’s urban cities, heavy metal pollution is mainly Zn and other heavy metals at low levels. Extensive use of galvanized pipes in domestic sewage

sludge in China causes one of the reasons why Zn is in higher levels. In some cities, domestic sewage and industrial sewage are treated together which results in Cr (in the case of leather industry wastewater), Cd (in the case of electroplating wastewater), Pb (in the case of smelting waste water) and Hg (in the case of plastics industry wastewater) in higher levels. (Chen et al. 2003, 561-569.)

3 SLUDGE TREATMENT TECHNOLOGIES

Generally, sludge treatment can be divided into two stages: The first stage is to make the original sludge which contains higher water ratio to reach the reduction by ways of concentrating or dehydrating. The second stage is to decrease the contents of organic matter in the sludge to reach further stabilization by the main way of digestion. (Zhao et al. 2001, 23-25.) The sludge disposal is after sludge treatment to achieve harmlessness and resource utilization ultimately.

The traditional process of sludge treatment is handled firstly, and then its disposal. That is, concentration → digestion →conditioning → dehydration → final disposal. (Dang 2007, 1-6.)

The remarkable characteristic of sludge is that it contains a large amount of water. Thus the most important action is to remove the moisture content and the next important is to decompose the organic matter during the process of minimizing and stabilize sludge. (Li 2002, 159-162.)

The general waste is made up of moisture content, a combustible component and an incombustibility component, which are generally called the three contents. The combustible component can be called organic matter, and incombustibility component can be called inorganic matter. Therefore, the major process of organic sludge treatment system is concentration → dehydration → drying → incineration → final disposal, but the major process of inorganic sludge treatment system is concentration → dehydration → drying → final disposal. (Zhao et al. 2001, 23-25.)

The main purpose for sludge treatment is:

- To decrease the moisture content and to lower the volume for easiness of follow-up process, utilization and transportation.

- To achieve sludge hygienization and stabilization.
- To optimize the ease of utilization of sludge resources through the improvement of the component and some nature of sludge after processing. (Wang 2006, 1-6.)

3.1 Existence form of sludge moisture content and its drying feasibility

There is a large difference between the drying characteristics of sludge and crystalline substance. There are four existence forms of the moisture content exist in sludge: interstitial water, capillary with water, surface adsorption of water as well as the combination (internal) of water reflecting the combinative situation of water and sludge solid grain respectively. (Xue 2002, 41-46.)

The interstitial water is surrounded by the lump with size of the sludge block, and it cannot be combined with solid directly. In addition, its acting force is weak. Therefore it can be easily separated. The interstitial water occupies 70% of total sludge. This part of water is the main object for concentrating sludge. (Yang & Liu 1999, 1-6.)

All kinds of capillary bound moisture in sludge occupy a small moisture content in sludge and it needs the upper mechanical action and energy to separate capillary bound moisture, which can remove this part of water by the opposite action force of surface tension of capillary water. (Wang 2006, 1-6.)

Sludge is often in the colloidal state. The colloidal particle is vey small but larger than the surface area. More water is absorbed by surface tensions, and adsorbed water on the surface is more difficult to remove, so the ordinary concentration or dehydration methods cannot be applied to remove this water. Coagulant should be added generally so as to reach desublimation which can separate the solid sludge and moisture content easily. (Yang & Liu 1999, 1-6.)

A part of sludge water is surrounded by the cell membranes of micro-organisms to form internal bound water. The internal water and solid combine tightly which must be destroyed to remove the cell membrane. Available biological action (for example, aerobic composting and anaerobic composting) causes cells to process biochemical decomposition or to destroy cell membrane by other methods, so that the internal water becomes the external fluid to be removed. (Wang 2006, 1-6.)

3.2 Concentration

The purpose of concentration is to obtain clear separated water, to obtain high concentration of concentrated sludge. The key point that increases the concentration of concentrated sludge is to reduce the amount of concentrated sludge and increase the sludge concentration time. But reducing the concentrated sludge too much or increasing the load will result in quality deteriorating of separation water, and in reducing the recycle rate of sludge (Xue 2002, 41-46.). The concentrated sludge is mainly to remove interstitial water. The concentration can be divided by three categories: gravity, flotation and centrifugal concentration. The more commonly used category is gravity concentration. The following points out the concentration ways separately.

3.2.1 Gravity thickening

Gravity thickening is an old method to make sludge separated to achieve obtain static subsidence. The early period of subsidence is isotropic sedimentation field with the linear settlement orientation. But after the migrating domain, sludge compresses the lower slurry which causes transition to compaction settlement domain whose subsidence velocity becomes slow due to interface settlement and slurry compaction. (Wang 2006, 1-6.)

3.2.2 Flotation concentrate

A concentration method which absorbs bubbles floating to deal with difficult settlement of sludge particles can be used. Micro-bubble is a condition for high-efficiency operation. According to the different method of generating bubble, the method can be divided into pressurized flotation and the pressure flotation. (Dang 2007, 1-6.)

Pressurized flotation mixes the air into the pressurized water or the original sludge in the pressurized conditions. The mixture releases tiny air bubbles under atmospheric pressure in the floatation tank. The process of adsorption of floating sludge particles is to achieve the enrichment in sludge. (Xue 2002, 41-46.)

Pressure flotation is a kind of method where micro-bubble is precipitated by the air which is dissolved in high pressure at atmospheric pressure. This method is used for sludge adsorption. (Dang 2007, 1-6.)

3.2.3 Concentration by centrifuging

Concentration by centrifuging is the sludge difficult to concentrate is forcibly concentrated in centrifugal force field. Concentration by centrifuging can be divided into vertical and horizontal centrifugal thickener according to the different directions of rotation axis. (Xue 2002, 41-46.)

3.3 Sludge digestion process

3.3.1 Digestion process

The sludge contains a lot of harmful ingredients after volume is reduced. Prior to disposal,

sludge needs to be converted into inert ingredients. The most commonly used method is to stabilize biodegradation. Because the intention of this process is making materials the final sterile product, digestion method should be often applied. Sludge digestion can reduce the further sludge volume and make solids inert materials without germs generally. (Wang, Cui & Wang 2000, 25-28.). Through anaerobic digestion or aerobic digestion, the purpose of sludge digestion can be achieved.

The data will be divided into two categories for micro-organisms in anaerobic digestion: acid-producing bacteria and methane bacteria. Therefore, we are also able to divide anaerobic digestion into two steps. (Dang 2007, 1-6.)

Anaerobic digestion is a kind of digestion that uses a variety of anaerobic bacteria to periodically break organic matter in the sludge down and eventually produce CH_4, CO_2, H_2S and NH_3. (Zhang & Hua 2004, 13-15.)

The first phase is to lower molecular and liquefaction technology to produce low-level fatty acids, and alcohol when the carbohydrate, protein, fat, bacteria and other organisms of sludge are in the hydrolysis acidification. Acid is generated under the action of anaerobic bacteria of similar weight and then enter acidic fermentation phase. The second phase is often referred to methane fermentation. PH should be reduced to 5-6 in the early stages of acidic fermentation and acetic acid, propionic acid and other organic acids will be generated and CO_2 gas will be produced as main gas. Parts of the organic acids are broken down into CO_2 and CH_4 and amino acids are broken down into NH_3 which the result PH is raised in the decreasing period of acidic. In the next period of methane fermentation, pH goes up to 7.0 -7.4 resulting in a large number of methane-based gases (Dang 2007, 1-6; Zhang & Hua 2004, 13-15.). Because the two kinds of bacteria can only survive in an oxygen-free environment, the anaerobic digestion reactor must be closed.

Sludge can also be stabilized by aerobic digestion. The working principle is that microbial organisms in the sludge processes in endogenous metabolic. Activated sludge

micro-organisms can be oxidized by itself and decomposed into carbon dioxide, water and ammonia, so that sludge will be stabilized. Furthermore, aerobic digestion is not sensitive to environmental conditions or limitations of epidemic change (Shen 2004, 55-64.).

Aerobic digestion as a conventional technology of sludge stability is less used in China, due to the need for oxygen, slightly high cost in operating and incapability of producing methane gas and other useful by products. (Zhang & Hua 2004, 13-15) However, aerobic digestion has convenient operation and management. Its operation is flexible, its investment is low and treatment is not failure easily. The organic matter in sludge can be removed and the sludge volume can be further reduced after the sludge digestion.

3.3.2 Factors affecting digestion

Anaerobic digestion is a biological reaction so it is affected by reaction temperature. With the increasing temperature, the reaction rate is accelerated at a certain temperature range. The medium temperature around 20-30days is needed for digestion in the middle temperature domain which is usually 30-35 ° C, or the days of digestion is shortened to 10-15days in the high-temperature digestion in the 45-50 ° C. (Zhang & Hua 2004, 13-15)

Concentration of the used sludge is 2-3% for gravity concentration of sludge. Even if the concentration of digested sludge which is extracted is processed in solid-liquid separation in the secondary sedimentation tank, their concentrations do not have apparent differences. (Wang 2006, 1-6.)

The substances that affect the anaerobic digestion are Cr, Cu, Zn and other heavy metals, cyano, phenols, carbon tetrachloride and other organic compounds, NH_3, etc. (Dang 2007, 1-6)

3.4 Sludge conditioning treatment

At municipal wastewater treatment plants, the solids in sludge are mainly colloidal particles. The structure is complex and hydrophilicity is strong. Therefore, sludge is conditioned before sludge dewatering in order to change properties and components of physical and chemical of sludge particles surface, to destroy colloidal structure of sludge and to reduce the hydrophilicity with water so that the dewatering properties is improved. (Chen & Sun 2006, 1-6.)

Sludge conditioning of inorganic or organic which has charges will take chemical reaction in surface of colloidal particles and neutralize particles charges in sludge so that the water is separated from the sludge particles. Conditioning affects good and bad side related to conditioner type, dosage, and environmental factors (Chen & Sun 2006, 1-6.). Common conditioners can be divided into organic and inorganic conditioner. From the development of trend, the used organic conditioner is more often. Although heating conditioning and refrigeration conditioning has lots of advantages, but the using is less because of high investment and high energy consumption. (Dang 2007, 1-6)

3.4.1 Conditioning and dehydration

The process of treating sludge conditioning and dehydration is an important part of minimizing production and reducing volume which has purpose on landfill waste disposal and incineration during sludge disposal. The organic matter rate in sludge is usually as high as 70-85%. Concentration and dehydration are difficult to be achieved, so appropriate pre-treatment to improve the dewatering performance should be implemented when dealing with the sludge which is difficult to be disposed. (Yu, Tian & Wang 2005, 1-6). Representational methods of sludge conditioning are the following: washing method, drug addition method, heat treatment method and the freezing of dissolution method.

First, to remove the gel substance which is impact solid-liquid separation and drugs should be added; second, the purpose of washing method is to save the amount of adding drugs. The drug addition method is a general pre-treatment method. The used drugs are industrial lime, ferric chloride, ferrous sulphate; sometimes dust and sawdust. (Yang & Liu 1999, 1-6.)

In order to improve sludge concentration and dehydration, conditioning of heat and pressure for sludge can be carried out so that hydrophilic organic colloid material are hydrolyzed, its grain structure is changed and part of the organic matter are allowed to decomposited. According to the different temperature can be divided into the high temperature pressurized conditioning (170-200 ° C) and low temperature pressurized conditioning (150 ° C below). (Yang & Liu 1999, 1-6; Dang 2007, 1-6.)

This method should be applied for dewatering treatment of radioactive sludge. It is commonly used in occasions with suitable climate and soil and cheap hot and cold source. This method is a specific and effective method for sludge treatment by using of vaporized heat. (Dang 2007, 1-6.)

3.4.2 Factors affecting the performance of dehydration

The main factors that affect the performance of sludge dewatering are sludge concentration, the rate of containing organic matter and the properties of sludge after conditioning with coagulant. Different methods for water treatment also impact sludge concentration. Sludge generated by water treatment facilities mainly consists of raw sludge generated by the initial settling tank and remaining sludge generated by final sedimentation tanks in activated sludge treatment. (Yu, Tian & Wang 2005, 1-6).

Whether the sludge mixed, and concentrate method has a great influence on the dewatering performance. Due to the occupancy rate of organic matter increasing in recent years

especially the weakness of concentration of the remaining sludge, mechanical concentration method and concentration by centrifuging and pressurized flotation are used more and more.

3.5 Sludge drying and incineration

Heat drying is to dry sludge by thermal energy. The sludge shows granular or powder after drying whose volume is only 1/5-1/4 original sludge. The sludge after drying compared to the wet sludge can significantly reduce the volume because microbial activity whose moisture content is less than 10% can be completely inhibited and avoided to become moldy smell. Thus the final product is odorless and pathogens-free which reduces the negative effects of the sludge and helps store and transport (Qiu & Wu 2007, 1-6.).

Sterilization with high temperature is very complete in the heat drying process whose products can fully achieve the health indicators and can improve the performance of sludge. The product can be used for alternative energy sources and for land use.

The method which sets incinerated as core is the most radical approach which can be divided into two categories: in first group, dehydrated sludge will be sent into incinerator and it will be burnt directly, and in the second group, dehydration of sludge is to be dried firstly and then incinerated. Sludge incineration requires sludge that has higher calorific value, so sludge is not sent into digesting process generally. (Wang 2006, 1-6; Zhang & Chen 2000, 58-61.) The currently used combustion equipment is the rotary incinerator, multi-stage incinerator and fluidized bed incinerator. (Dang 2007, 1-6)

4 THE TRADITIONAL WAY OF FINAL SLUDGE DISPOSAL

Sludge needs disposing after being treated by a variety of methods. Traditional sludge disposal techniques include sanitary landfill, incineration, agricultural use, composting and ocean dumping. But the traditional sanitary landfill, incineration and agricultural land use still dominate because these three technologies were first developed, the time be used is longest and the technologies are the most mature with its unique advantages.

A typical sludge treatment and disposal process:

Landfill: Concentration → Dehydration → drying → Landfill
Incineration: Concentration → Dehydration → drying → incinerate → Landfill
Composting: Concentration → Dehydration → composting

4.1 Sanitary landfill

Sludge sanitary landfill technology was put into practice in the 1960s. It is based on the environmental protection requirements and the improvements in the traditional landfill. Sludge can be landfilled alone or with other solid wastes (such as municipal solid waste). So far it is already a relatively mature technique in sludge disposal. (Pu & Wu 2006, 14-16.)

Sanitary landfill technology has an advantage of low investment, large capacity and yield faster results. But there are the following problems: Firstly, the sludge landfill has higher requirements in the soil mechanical properties of sludge. It needs large venues and a lot of transportation costs. Secondly, residual sludge generally still has about 75% moisture content after dewatering, so the sludge landfill site must be anti-infiltration treated, otherwise it will contaminate groundwater resources. Thirdly, sludge landfill increases the

difficulty in the work of landfill compaction machinery and increases the poor health conditions in landfill site. It also has tremendous impact on the surrounding environment. Lastly, various countries improve the requirement and management in selecting landfill site, techniques and standard of pollutant treatment from protecting land and environment point of view in recent years that is why results in the significantly increasing in sludge landfill costs. (Pu & Wu 2006, 14-16; Li & He 2005, 101-103.)

Sludge landfill technology did not ultimately prevent environmental pollution, but it only delayed the time of generating pollution. The sludge disposal problems are still not solved from the source and the fundamental which determines the sludge landfill technology is a clean, resource-based disposal technology that can be developed in the future. European countries generally agree that landfill is not a technology that meets the sustainable development of sludge treatment technology. (Pu & Wu 2006, 14-16.)

4.2 Incineration

Sludge incineration was put into practice in Michigan in 1934. Sludge incineration refers to the sludge after dehydration or drying that is sent into the burning furnace for heat treatment process with sludge own higher organic ingredients and a certain calorific value. (Yin & Tan 2005, 143-145.)

The advantage of incineration technology lays in the thoroughness to achieve the purpose on sterility and minimization of sludge with high speed and effectiveness. The reduction rates can reach 95%. The incineration makes organic matter CO_2, H_2O and N_2 gas and other substances, its products being sterile and odorless inorganic residues. Organic matter in sludge is completely within the oxidation. While the moisture content is zero, a storage device is not needed in bad weather conditions, and heavy metals are almost entirely trapped in the clinker except mercury. (Li & He 2005, 101-103.)

Incineration may be more cost-effective when resulting in higher transport costs caused by faraway the landfill or concentration of sludge disposal sites for the sewage treatment plant in large cities. Due to the process improvement in recent years, a pre-drying - fluidized bed incineration technology is used. Sludge can be burned directly without auxiliary fuel when the moisture content is above 38%. Part of inappropriate resource utilization in the sludge can be fully processed. (Li & He 2005, 101-103; Yang & Du 2002, 31-33.) Incineration technology has been widely applied especially in Singapore, Western Europe and Japan. (Xu, Sun & Ren 2007, 509.)

However, the disadvantage of incineration is that heavy metals in sludge pollutes the atmosphere again with the spread of smoke and dust. There is rich inorganic matter in burnt residue that likely results in soil contamination after landfill again and indirectly causes secondary pollution in water bodies, while incineration also wastes a lot of nutrients in the sludge. In addition, if investments in equipment, operation and maintenance are higher, the difficulty of promotion increases. Some major cities are building or have built a number of municipal solid waste incineration markets in China in the recent years.

4.3 Agricultural use

The advantage of agricultural sludge is that sludge is an effective biological resource. Sludge not only contains a lot of organic material but also has nitrogen, phosphorus, potassium and other nutrients for plant growth. Sludge can improve soil conditions for crop growth as a natural organic fertilizer which is used by land and farmland. Therefore, agricultural land use of sludge is a sludge treatment method which is positive, effective and safe. The rational use of sludge cannot only solve the problem of environmental pollution caused to the release, but also open up new organic manure for agriculture.

The method of agricultural use has more than 20 years history of China, and the agricultural use of sludge has received attention in foreign countries. In Europe, due to the

EU law, ocean dumping is prohibited since January 1st, 1999. Therefore increasing the proportion of sludge agricultural use became the best way for each country to solve the sludge disposal in short-term. (Werther & Ogada 1999, 55-116.)

At present, the rate of municipal sludge agricultural use is up to around 50% in the United Kingdom, France, Switzerland, Sweden and the Netherlands. The rate in Luxembourg is more than 80%. (Yin & Tan 2005, 143; Dai 2007, 57-59)

However, applying for this technology must be implemented by strict criteria, otherwise it will cause more serious environmental pollution, or even lead to disease of plants, animals and humans. This is because sludge contains a large number of pathogenic microorganisms and parasites, heavy metals and other toxic and harmful substances.

If sterilized treatment is not processed and sludge is directly used for agricultural fertilizer, the pathogenic microorganisms and parasites in sludge will pollute soil, air water, and even through skin contact and food chain to endanger health of humans, animals and plants. Therefore, if farmland use of technology of sludge is to be widely carried out, the laws and regulations of standards and corresponding of sludge as an agricultural fertilizer need to be further improved.

4.3.1 Sludge composting

Composting for agricultural use after sludge dewatering is an ongoing research and development subject in some sewage treatment plants in China. Sludge composting is an effective way of sludge treatment which utilizes appropriate bacterial types and mechanical flip. Sludge is fermented, heated and cured in a certain length of time (a few days to 10 days) which can effectively kill harmful microorganisms and pathogens in the sludge through the role of temperature. Most of the moisture content is evaporated to get an organic fertilizer in accord with the requirements of agricultural. (Qin & Wu, 2003, 9-13;

Liu & Wang, 1998, 271-273.)

This approach has an advantage that it does not consume a lot of heat energy and can achieve the purpose of reduction with the relatively low investment in equipment. The disadvantage is that the time be used is long and floor area is huge as well as high investment in order to avoid stench to contaminate the environment. This approach has a certain limit in dealing with large-scale municipal sludge.

Some measures can be used for improve the agricultural amount of sludge: First, sludge is made into organic inorganic compound fertilizer and appropriately added potash fertilizer to supply the deficiencies of potassium in the sludge fertilizer to increase the fertilizer effect and reduce the content of harmful substances. Second, the unit or individual who preferentially uses compound fertilizer is given discount in economic policies such as providing free fertilizer samples or analyzing soil nutritional status in the areas that apply sludge compound fertilizer for free. (Qin & Wu 2003, 9-13; Liu & Wang 1998, 271-273.)

4.4 Ocean dumping

The operation of ocean dumping is simple and its cost of process is lower for the coastal cities. It is the best that sludge for ocean disposal should be after digestion process. The method of ocean disposal can be piping or shipping. The area of ocean disposal should be 10km away from the coast generally. The depth is about 25m to ensure sea water dilution and self-purification.

However, with the strengthening of awareness of eco-environment, more and more people are concerned about ocean dumping of sludge for the effects on the marine eco-environment that may exist. Chinese government on February 20, 1994 stipulated requirements that industrial waste and sewage sludge cannot be disposed into the ocean. (Yu & Tian & Wang 2005, 1-6.) Ocean dumping was particularly popular in the United

Kingdom, because its costs are fairly low if compared to other methods. But the EU urban wastewater treatment law has prohibited its member countries from dumping sludge into the ocean from the end of 1998. (Werther & Ogada 1999, 55-116.)

5 SLUDGE TREATMENT AND DISPOSAL TRENDS

With the continuous progress in modern civilization, traditional techniques are no longer adapted to today's environmental requirements. Sludge treatment and disposal techniques help to find solutions for various sewage treatment plants.

5.1 Selection of sludge treatment process

Sludge treatment and disposal follows the principle of reduction, elimination of harmful effects and resource utilization. Firstly the sludge minimization is the most important problem that needs to be handled. The sludge treatment process is the first step of reduction and is the source for reducing emissions of remaining sludge.

The treatment of conventional activated sludge produces a large number of surplus sludge which creates a great burden for the sludge treatment system. There is another treatment method of conventional activated sludge which delays aeration and oxidation ditch are invented after modification. It decreases the production of surplus sludge by the method of improving its own oxidation rate. (Sun 2007, 201-202.) However, energy consumption is very large in these two methods, which limits its marketing applications.

Research has shown that the effect on reducing sludge yield is obvious by extending the sludge residence time, and there is no significant impact on the removal capacity of COD_{cr}. (Potassium dichromate was consumed as oxygen oxidizer in the acidic environment) Although the effluent NH_3-N concentration and TP concentration are both increased, by adjusting the ratio of sources of carbon, nitrogen and phosphorus, this negative impact can be eliminated. (Liu, Guo & Tian 2007, 48-50.) It can be said that this approach has prospects in developing. Of course, there are other proposals to improve techniques. All of them can reduce the emissions of the remaining sludge and are worth being researched and

promoted further.

5.2 Comprehensive utilization of sludge

The final disposal proposal of resource utilization has also been attempted except landfill, incineration and agricultural use of traditional methods of sludge disposal. Sludge comprehensive utilization include use of sludge woodland and landscape greening, the industrial utilization of sludge and other use.

The agricultural use of sludge directly related to human life, is likely to cause secondary pollution of the environment or even imperil the health of humans, animals and plants, if the protective measures and related criteria cannot be well taken and made. But the sludge used for afforestation or to fertilize forests does not threaten humans, animals and plants. This is because forests are far away from densely populated areas and the forest ecosystem is complete and stable.

What is more, farmland lacks nutrients less than forest land and barren hill which causes the survival timing of pathogenic micro-organisms to greatly shorten and makes the sludge rich in organic matter such as nitrogen, phosphorus, potassium and other elements to be fully utilized. (Yang & Du 2002, 31-33.) But the forests are often far from the city, and transportation cost is the only limitation of this utilization. It is believed that approach will be actively developed if the problem of transport cost is resolved.

With the progress in urbanization and the improvement of living conditions of urban residents, people’s demand on the surrounding environment has also risen, and urban landscape greening is getting more attention. Sludge which is used for urban greening and ornamental plants not only gets rid of the food chain and causes a crisis for people and livestock, but also reduces transportation costs. If sludge is scientifically and rationally applied, not only composition of fertilizer and soil is saved and structure of soil is

significantly improved, but also blooming of flowers and the size of the flowers are increased and the flowering period is extend, lawn colors are more vivid and the hold time will be longer as well. (Pu & Wu 2006, 14-16.)

5.2.1 The industrial utilization of sludge

Landfill, agricultural use and incineration are mainly applied in sludge in the world. But with the industry of large-scale development, the industrial utilization of sludge is beginning to take steps.

Sludge contains a certain heat value and inorganic minerals which can be used as industrial fuel and raw materials for industrial products. It can also be used to manufacture building materials.

A mixture of sludge and coal can be incinerated in the boiler and thus produces enough heat which can save operational costs. For enterprises that need to generate heat by a large number of coal powers, it reduces the cost and decreases generated harmful gases for atmosphere from the incomplete combustion of coal while the amount of coal is reduced. (Zhang, Chen & Hu 2000, 58-61.)

The advantage of sludge used for building materials is that its heat value of sludge can be effectively utilized to reduce fuel consumption during burning. It has been reported that sludge can be utilized to make adsorbents and binders. The raw material is highly in demand in building industry which consumes a large number of sludge. That is an effective approach for sludge with low organic matter content and sludge which is not suitable for agricultural use. (Shi & Chen 2001, 45-46.) Therefore, the applying of sludge has broad prospects in developing building materials.

5.2.2 Other use

Sludge contains a lot of organic matter which provides the basic material for energy use. Energy use of sludge comprises mainly sludge energy recovery and sludge fuel. Sludge digestion can produce large amounts of methane and use the activated sludge as a binder to make the pulverized anthracite processed into shaped coal which depends on the high heat output performance of dewatering sludge. (Shi & Chen 2001, 45-46.)

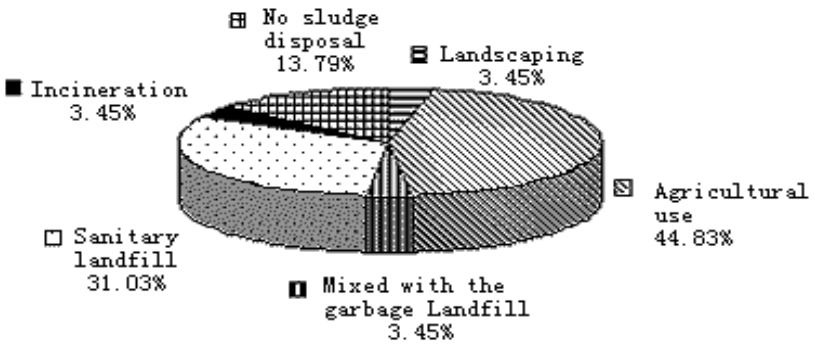
Sludge is essentially a biological fiber. Paper is processed by natural fiber material in paper making. Analysis showed that each performance indicator does not have a great impact when adding 5% of dry sludge. It can meet the requirements of the paper industry after increasing the addition and adding filter aid pharmacy. (Yin & Tan 2005, 143-145.)

Sludge contains protein, vitamins and trace elements that can be processed into protein-containing feed for the fish or mixed with other feed for feeding chickens by purified sludge or activated sludge. (Yang & Du 2002, 31-33.)

6 DESIGN OF SLUDGE DISPOSAL FOR XIAN YANG ROAD WASTEWATER TREATMENT PLANT IN TIANJIN

6.1 Status of urban sludge disposal in Tianjin

Tianjin is one of the four municipalities in China, and an important industrial and commercial city and economic trade center in the north. Sludge is used for farmland in the vicinity of suburban farms after the first sewage treatment plant, the Ji Zhuang zi sewage treatment plant, was built in the early 80's in Tianjin, China. The economy of my city is developing rapidly and the municipal government attaches great importance in urban environmental construction and protection. Not only the rate of treatment but also the technology is ranked as first in China, especially for water environmental management and improvement. (Drainage management 2008.) Thus, large amounts of sewage sludge in the urban sewage treatment process can be inevitably produced. Whether sludge can receive timely and appropriate treatment and disposal has become an important factor of affecting the normal operation of sewage treatment plants and basically increasing the environmental benefits. In China, the methods of disposing sludge are mainly composting in agricultural use, landfill, overall utilization.



GRAPH 1. The proportion of several sludge disposal technologies in my city.

Ultimate sludge disposal in China has serious problems. According to planned objectives, in 2010 the rate of sewage treatment will not be less than 70% in my city which will surely generate a lot of sludge. From the Graph can see 13.79% of sludge is still not disposed which will bring enormous environmental harm. (Tianjin research report 2008.) In fact, the data from the figure above will be greatly changed, because the treatment and disposal are estimated under certain conditions. As it can be seen, sludge treatment and disposal are still lagging behind compared to other countries. In the long run, sludge can be processed into a biological sludge compound fertilizer or a compound fertilizer, and utilization of agricultural forest land as major effective use should be considered for a large agricultural country like ours.

Generally speaking, the source of sludge includes three aspects in Tianjin:

- Dewatering sludge from the Ji Zhuangzi sewage treatment plants, the Xian Yang road sewage treatment plant, the Eastern Suburbs sewage treatment plant and the Bei Cang sewege treatment plant. The final disposal methods for these four large-scale sewage treatment plants are outbound transportation and stockpiling. These four sewage treatment plants produce 869 tons sludge totally per day. (75% water content)
- Dredged sludge from the drains in Tianjin about 475 m^3 /day (75% water content)
- Sludge by the river. The daily output is 5381 m^3, 75% water content. (Drainage management 2008.)

In Tianjin, the main places that municipal sludge is going to be divided into three types:

- Random dumping without fixed places;
- To select the river beach under jurisdiction as a temporary storage;
- Leasing abandoned land from farmers as a storage field. (Tianjin research report 2008.)

Although the medium temperature anaerobic digestion and mechanical dewatering methods are used for sludge treatments since the Ji Zhuangzi and eastern suburb sewage treatment plants were built in 1984 and 1993 in Tianjin, the situation of the final disposal of sludge is

still open. (Tianjin research report 2008.)

With the rapid development of economy and the increasing tension of consuming water in Tianjin, wastewater regeneration and reuse of the scale have expanded, which result the sludge landfill site was reduced. That means shortening the life expectancy of the storage field. Therefore, the method of disposing sludge produced in the four sewage treatment plants is a serious issue to be considered and resolved.

6.2 Sludge disposal design for the Xian yang road sewage treatment plant

The Xianyang road sewage treatment plant is supposed to establish a sludge disposal site with a scale of 720 m^3/d and design life of 7 years covering about 20 hectares (sludge water content is considered $\leq 75\%$). Apart from dissolving dewatering sludge from the Xianyang road sewage treatment plant, the sludge disposal site accepts the sludge from the expansion of the Ji Zhuangzi and other sewage treatment plant. (Xian Yang road yearbook 2008.)

What follows is a design and analysis of sludge disposal at the Xianyang road sewage treatment plant respectively based on land use, landfill and incineration which all have unique features, are the most commonly used method and the most mature techniques in China.

6.2.1 Analysis of land use

6.2.1.1 Sludge use for farmland

Whether the sludge can be used for farmland is dependent on two factors. One is the content of the sludge in harmful substances and the other is the current status of farmland soil

environment. The major pollution factors to restrict the application of sludge farmland are heavy metals and pathogens. Combining the sludge status of four sewage treatment plants, the heavy metal content of sludge in the Xianyang road sludge disposal sites is certainly in accordance to analysis of the materials if compared to the GB4284-84 pollutants control standards for sludge of agricultural as shown in the figure. (Xian Yang road yearbook, 2008.)

TABLE 3. Contents of heavy metals and comparison table in sludge, mg / kg dry sludge

Categories	Cu	Zn	Pb	Cd	Hg	As	Ni	Cr
Sludge content	609.9	1663	322.6	13.0	7.6105	17.2	141.4	947.0
Standards permissible value	500	1000	1000	20	15	75	200	1000

From the Table, it can be seen that the sludge is not suitable for agriculture, because contents of Cu, and Zn in sludge have exceeded the standard permissible value, and contents of Cd, Ni, Cr and other elements are close to standard values.

In addition, Tianjin began to use wastewater to irrigate farmland since 1958 and a large sewage irrigated area was formed due to the lack of water. What is more, the inorganization of agricultural use in sewage treatment plants has caused significant contamination of agricultural soils in recent years. Irrigation of sewage and using of sludge are the major sources of pollution in agricultural soils and crops in Tianjin. The farmland that is polluted by heavy metal in my city is more than 1700,000 mou which exceeds the total area of the secondary standard farmland by 40,000 mou. From the contamination degree, the field for vegetable is greater than rice paddy and the field for rice paddy is greater than cornfield. The area which is fertilized by sludge is most seriously polluted and next is the upstream zone in sewage irrigation area. (Management handbook 2008.) Pollution of heavy metals has been

very serious in agricultural soils and there is no environmental capacity that can be fertilized by sewage sludge. The area which is available for qualified sludge application is very limited even if it is uncontaminated farmland. The comprehensive analysis above shows that the site for sludge of the Xianyang Road sludge disposal site is not suitable for agricultural use.

6.2.1.2 Sludge use for forestry

Sludge in the Xianyang Road sludge disposal site is not suitable for agricultural use from the above analysis shown. But the sludge with healthy fertilizer can be treated for the gardens and forests. There are huge areas of forest land, green land, reed land and saline-alkali wasteland available for fertilization in the Tianjin area. Composting sludge is one of the important ways for sludge stabilization and safe disposal. After being composted in high temperature, not only environmental odor pollution is eliminated but also pathogenic bacteria and eggs are slain and the toxic organic compounds are significantly degraded as well.

In 1998, the Tianjin Wastewater Treatment Research Institute completed the Tianjin science and technology project, Municipal sludge composting and garden green application of technological research - municipal sludge composting research that used digested sludge from Ji Zhuangzi as composting test material. The appearance of the sludge fertilizer is brown, loose, non-odor and has 40-50% moisture content based on the test results on composting sludge. The results of fertilizing laboratory were TN 2.33%, TP 2.89% and TK 0.35% with a very high value of the content of fertilizer applications. The heavy metal content can be seen from Table 4. Except Zn, other values reached agricultural sludge standards relatively. Ascaris eggs mortality rate is over 95% and coliform value decreased by 2 to 5 orders of magnitude. (Ji Zhuang Zi yearbook 2007.)

TABLE 4. Contents of heavy metals in sludge composting compared to the standard value

Unit: mg/kg

Item	Cd	Pb	Cu	Zn	Ni	Cr	As	Hg
Ji Zhuangzi Sludge	5.24	286.3	455.8	1300	103.9	466.8	28.0	7.88
Sludge composting	5.55	277.7	422.6	1271.6	94.5	359.7	31.1	8.06
The national standard of agricultural sludge	20	1000	500	1000	200	1000	75	15

Sludge composting for agricultural use should be one of the important methods of the safe disposal of sludge, but agricultural standards and background values of heavy metals in soil fertilization as well as market demands should be also considered. The gardens and forests cannot be fertilized by applying a sludge fertilizer without limitations for long term. To avoid gardens and forests to be composted by sludge for long-term which causes the excessive accumulations of heavy metals in soil, the maximum pollution load of soil as well as life of application should be determined to strictly control according to heavy metals contents in sludge. Many countries have set the maximum allowable concentration of heavy metals in agricultural soils. China has constituted national soil environmental quality standards, with the main basis of preventing soil pollution and protecting the ecological environment in which Grade 3 standard suitable for gardens and forests. (Hang et al. 2005, 11-14.) According to the soil background values of the corresponding metals elements in Tianjin, and the contents of heavy metals in forest is soil background values were assumed, so the number of years of sludge for application in forest land can be calculated. The results are shown in Table 5.

TABLE 5. The cumulative effects of forest land application of sludge

Items		Cu	Zn	Pb	Cd	Hg	As	Ni	Cr
Soil background contents in Tianjin(mg/kg)		27.50	63.90	20.50	0.086	0.044	10.85	30.15	98.20
Soil inlet per year （mg/kg）		8.13	22.17	4.30	0.173	0.1015	0.229	1.89	12.63
Soil contents After a few years	1 year	35.63	86.07	24.80	0.259	0.146	11.08	32.04	110.83
	2 year	43.76	108.24	29.10	0.432	0.247	11.31	33.93	123.46
	3 year	51.89	130.41	33.40	0.605	0.348	11.54	35.82	136.09
	5 year	68.15	174.75	42.00	0.951	0.552	11.99	39.60	161.35
	10 year	108.80	285.60	63.50	1.916	1.059	13.14	49.05	224.50
	15 year	149.45	396.45	85.00	2.681	1.566	14.28	58.50	287.65
	20 year	190.19	507.30	106.5	3.546	2.074	15.43	67.95	350.80
Grade 3 Soil Environmental quality Standard （mg/kg）		400	500	500	1.0	1.5	40	200	300

Obviously, the Cd in soil exceeds the critical value. If the technology of application for five years continuously, Hg, Cr exceeds the critical value after successive being applied for 15 years. Apart from three above-mentioned kinds of elements, Zn also exceeds the critical value, if sludge use is applied continuous for 20 years for gardens and forests in the Xianyang Road sludge disposal site. Thus the longest life span of this project is five years in order to ensure that forest land is not polluted.

In addition, occupation of land, contamination on the surrounding environmental and transportation also create problems if composting sludge is used for forest in the Xianyang Road sludge disposal site.

6.2.2 Use of sludge for landfill

Sludge landfill technology is to make the sludge dissolved safely and to gradually achieve disposal effects of full stability and environment sound thorough project methods and environmental protection measures while using natural metabolic function. (Pu & Wu 2006, 14-16.) Sludge landfill disposal is one of the most convenient and direct methods. The costs of construction and operating are low, operation is relatively simple, and the occupied land has reuse value. The disadvantage is that the area occupied is large, resource utilization is low and length of service is fixed. The biological organic matter of sludge is decomposed; leachate is discharged and foul smell and biological emissions are generated after landfill, which lead to secondary environmental pollution problems. (Li & He 2005, 101-103.)

In the Xianyang Road sludge disposal site, the first overall layout is divided into the sludge sanitary landfill area (including leachate and gas collection and emission systems), the drying soil field, the sludge drying treatment area and the production supporting facilities. The total area is 20 hectares. The landfill area is the core of sludge disposal. Depending on the landfill area, disposal ability and requirements of length of service, and combined analysis of the situation of foundation bearing capacity and groundwater depth, the principle

of digging deep and heaping high is determined to use, and project investment, operating costs and other composite factors must be considered. The pile body is dug by 1.5m and the height of pile body above the ground is 30m. (Xian Yang road yearbook 2008.)

The landfill area will be reduced to 13 hectares because the plant site is adjusted in the Xianyang Road sewage treatment plant. The form of the heap body and service life will be changed if the disposal ability is not changed. (Xian Yang road yearbook 2008.) Excavation should not be further deepened from security considerations. Otherwise the possibility of leachate contamination of groundwater will be greatly increased which will result in the increase of insecurity factors. To ensure that the heap body is stable and landfill operations smooth, the height of the heap body cannot be increased because of the restrictions for requirements of the heap body and sludge intensity.

To timely eliminate the flammable gases in the heap and to prevent the landfill gas (mainly methane) from gathering, vertical exhaust pipes are set up in the landfill area. This will cause fire hazards of the landfill gas being directly discharged into the atmosphere. The main components of landfill gases are CH_4 and CO_2, some NH_3, H_2S and other organic gases. (Li & He 2005, 101-103; Drainage management 2008.) The gas composition and the main physical properties are seen in the Table 6.

TABLE 6. The composition of sludge landfill gases and physical properties

Compon-ent	CH_4	CO_2	N_2	O_2	NH_3	H_2	H_2S	CO	micro compone-nt
Volume (%)	40-70	20-40	2-5	0.1-1.0	0-0.2	0-0.2	0-1.0	0-0.2	0.01-0.6
Relative weight(air = 1)	0.555	1.520	0.967	1.033	/	0.069	1.190	0.967	/
Combustib-le	Combus-tible			Comb-ustibl-e		Combus-tible	Combusti-ble		
explosion ratio (%)	5-15	/	/	/	/	4-75.6	4.3-45	12.5-74	/
Odor	None	None	None	/	/	None	Have	None	None
toxicity	None	None	None	/	/	None	Have	Have	None

CH_4 is a flammable and explosive gas whose critical explosion concentration is 5-15% in the air. Although the landfill gas cannot be intensively discharged, the scale of disposal site is still relatively large. A large number of landfill gases may be produced and assembled at the venue which not only causes air pollution but also may result in fire. Across the river is the first coal-gas plant in Tianjin. Once marsh gas or coal gas starts to leak, combustible gas concentrations in the air is not easily evacuated. Thus fatalness is greatly high.

In addition, the operator in the disposal venue who absorbs landfill gas in the air for a long time feel discomfortable and health is impaired. It is proposed that landfill gas is led to designated direction and landfill gas is collected. The gas is let out or reused after harmless treatment.

Two 50 t / h of USFilter sludge drying machines were introduced to the Xianyang Road sewage treatment plant. They can make solid content with a drying rate 50-90% in sludge, and the product’s grain diameter is 1-4 mm. Dried sludge can be used as a fertilizer, and it

can be used as addition for sludge landfill. The addition proportion and economical efficiency need to be further studied. (Management handbook 2008.)

In short, the sludge landfill can be one of the methods of sludge disposal in Xianyang Road sludge disposal site especially in the near future. It is not proper to consider it as the only long-term approach, because it is not a comprehensive approach to solve secondary pollution after all. It just delays the time of contamination due to leachate problems because the sludge containing a variety of toxic and hazardous substances pollute the groundwater by the rain erosion and leakage. (Li & He 2005, 101-103.) Especially at present, our economic strength is limited. The sludge landfill is still one of the ways for sludge disposal in Xianyang Road sludge disposal site in this case which is impossible to invest a lot of money into sludge incineration.

6.2.3 Incineration of sludge

Incineration as the core is the most thorough method for sludge disposal, which can take solid rate is 15-35% of dehydrated sludge into incinerator, and organic matter will be directly combusted into CO_2, NO, and inorganic substances. This method can kill the pathogens and minimize the sludge volume to completely achieve sludge reduction, harmless disposal and resource utilization of sludge in order to achieve zero emissions of pollutants. However, it affects and limits the use and smoke need to be treated and incineration ash needs to be retreated, because investment in equipments and operation costs is high and organic matter being burnt produces toxic dioxins and other substances. (Yang & Du 2002, 31-33.)

However, drying or incinerating sludge at the temperature is between 200-900 ° C, malodorous gases and waste water will be inevitably produced in the process. Smoke needs washing and waste water achieves the emission standards after oxidation, bleaching, deodorization and filtration. (Yang & Du 2002, 31-33.) Environmental technology in the process of sludge disposal is a prerequisite for sludge treatment.

Sludge disposal technology in Japan and Europe is more advanced today. There is the sludge incineration process and the sludge melting process. Tianjin Drainage Company conducted sludge incineration project research work cooperating with a foreign company in 2001. This company compared techniques and economy of sludge incineration and sludge melting for sludge disposal. (Drainage management 2008.)

The result has shown that a melting furnace and an incinerator can effectively remove organic pollutants from sludge disposal which makes the sludge harmlessness and able to recycle ashes or slag. A melting furnace produced more slag and less ash. Because the generated slag is glassy after melting, the dissolution of heavy metal substances is less, and the property is stable. An incinerator can be directly used as to pave the way without unnecessary retreatment. It will not cause pollution to the environment and will produce certain economic benefits. Flying ash from the incineration still contains many heavy metals.

It should be handled as hazardous waste according to state regulations. It still needs applying more equipment if reuse it. (Yang & Du 2002, 31-33; Drainage management 2008.)

Due to the high temperature (1300-1400 ° C) from the melting furnace chamber, the level of heat recovery value is high and sludge pollutant treatment is more thorough. Meanwhile, generation of dioxin, and other toxic and harmful gases is inhibited. Molten slag obtained from sludge will not deteriorate after melting where the property is stable and can open up a variety channels for effective use. (Drainage management 2008.) However, the melting furnace costs are high and fuel consumption is more and capital costs and operating costs higher than for incinerators.

If the Xianyang Road sewage treatment plant applies this program to deal with sludge, the sludge disposal of this project must include a new sludge disposal workshop and its corresponding ancillary projects. The sludge disposal facility in this project should include the corresponding civil works, process, electrical, acquisition and installation of instrumentation. The total investment is 53,649,000 euro for melting furnace program which processes 200t daily. The total investment is 43,380,000 euro for incinerator program which processes daily capacity of 300 t. (Drainage management 2008.) An estimate of the total costs shows that the sludge incinerator and melting processing are very expensive.

6.2.4 Remarks

Sludge can be treated by the combination disposal of forest use, landfill, incineration and melting in Xianyang Road sludge disposal site if the operability and the impact on the environment, safety, economy and other aspects are considered.

Four recommendations are presented as follows according to the above design assumption.

Firstly, the sludge can be used for the gardens and forests for 3-5 years after composting treatment, and sludge fertilizer of woodland will be traced and monitored.

Secondly, a good process of impermeable layer and flood control, landfill gas process should be valued to avoid secondary pollution.

Thirdly, small-scale sludge incineration or melting processes can be tried to use, and explore and create out a thorough treatment for sludge based on the urgency, thoroughness and model of the sludge disposal in Tianjin,

Fourthly, national preferential policies for environmental protection should be used well, for this far-reaching and benefit project of the living environment needs the support from governments, particularly in policy matters. (Management handbook 2008.)

6.3 Factors of constrainting sludge treatment and development of disposal technology in Tianjin

Although sludge treatment technology has been gradually perfected in recent years in TianJin, there are still some problems:

Firstly, sludge treatment rate is low and process is not complete in my city. Sewage treatment plants where the sludge was processed by concentration, digestive stability and drying dehydrated account for only a small number indicates most of the sewage treatment plants do not have the complete the sludge treatment process.

Secondly, sludge treatment technology and equipment are backward. Current sludge treatment technologies that we are using in Tianjin have been discarded by developed

country, and processing techniques do not fit the sludge characteristics in China. The sludge treatment equipment is also left behind. Its performance is poor, efficiency low, energy consumption high, professional equipment is lacking and standardization and seriation cannot be matched which limits the improvement and development of sludge processing technology. (Sun 2007, 201-202.)

Thirdly, sludge treatment and management are at a low level. The facilities of sludge treatment which have been built cannot operate normally. The level of management is also an important factor besides the technical degree. Managers and operators lack experience in management in most of the sewage treatment plant, so they cannot effectively organize production. There are fewer technicians which make some of the sludge treatment system idle for a long-term.

Fourthly, the level of sludge treatment design is low. It is seen that practical experience and design experience are lacking in sludge treatment, particularly in the low overall degree of sludge treatment system relatively. Its operation is poor and cannot guarantee long-time running for sludge treatment facilities in sewage treatment plants that have been built. Technical reconstruction is applied after many factory installations are completed resulting in tremendous waste of human and material resources. (Sun 2007, 201-202.)

Lastly, technical support and financial input are not enough. China's current sludge treatment and disposal technology both in technology and capital inputs are relatively left behind if compared to foreign countries. The investment in sludge treatment and disposal is only 20-50% of the total investment in sewage treatment plant (Hang et al. 2005, 11-14.). It can be said that the short of capital investment restricts normal construction and operation for sludge treatment and disposal.

7 CONCLUSIONS

To sum up, the main technology for sludge is incineration or comprehensive utilization after drying, concentration, digestion and conditioning. The comprehensive utilization is mainly used for building materials, sludge that cannot be processed or used will be processed for landfill or disposal finally. Sludge resource utilization is the future trend of developing an economic and effective way. Sludge as an inevitable product in the end of treatment of industry which get more and more attention, and its use and processing technology have gradually matured.

Although there is a variety of municipal sludge treatments, sludge should be analyzed concretely according to the specific situations such as the amount of sludge, sludge nature and heavy metal content, just as the analysis of the above design for sludge disposal for the Xianyang road wastewater treatment plant. Must take the eco-environment, economic efficiency, handling costs, technology trends and other factors into account, and also explore some new methods, new technologies, and new processes of sludge treatment actively.

China is a large agricultural country whose economic foundation needs to be strengthened. Sludge resource utilization, especially agricultural use cannot only save lots of costs in sludge final disposal, but also add organic matter for the farmland of low fertility to improve fertility, promote the development of agricultural production and to implement positive cycle of agricultural ecological environment. Therefore, the sludge resource utilization has been developing in accord with sludge disposal of China's national condition.

From a long-term point of view, to do a good job in sludge treatment and disposal and waste as renewable resources to utilize effectively are common important issues in each country in the world.

Scientific research on the aspects of sludge land-use should be carried out from principles of

economics, safety, reasonability, effectiveness and benefits from the use of sludge to take full advantage of such resources and to reduce environmental pollution. The following points bring enormous economic, social and ecological benefits into full play.

(1) To get to know the status of sludge and harm it brings out. To study properties and categories of the sludge is conducive to use this new resource which turns waste into treasure.

(2) To choose economical and rational sludge processing technology according to the characteristics and nature of the sludge reduces the sludge hazards to the surrounding environment and human.

(3) To use sludge to produce eco-cement which broadens the sources of raw materials, reduces consumption of natural resources and reduces the cost of cement production which is conducive to the sustainable development of cement industry.

(4) Using sludge should meet strict sanitation standards, and new environmental hazards should not be created because there are potential risks in the use of sludge.

(5) To choose the best option when given consideration to the balance of environmental and ecological benefits, social benefits and economic should consider the actual situation in own country and region when facing the diverse experience of use of sludge in each country.

(6) Exploration of sludge treatment and disposal should implement diversification disposal, together with related financial support so that sludge disposal will really go a benign development.

In short, development of sludge treatment and disposal in the future does not just rely on the final treatment and disposal. Firstly, the source of the remaining sludge must be controlled

which is to introduce the concept of cleaner production into the area of sludge treatment and disposal. With the capital investment, technical support and regulatory policies, only by reducing the amount of surplus sludge generation, adding the final process of harmless treatment and utilization of resource disposal and vigorously developing a variety of techniques of sludge treatment and disposal and the use, changing waste into valuable in the future.

If a mature, appropriate treatment technology and disposal methods are chosen, sludge will be able to have access to safe treatment and disposal.

REFERENCES

Cao, J-L. 2006. Municipal wastewater treatment plant sludge disposal study and Fuzhou municipal sewage sludge disposal recommendations (in Chinese). Fujian Chemical Industry 3, 63-66.

Chen, S. and Sun, L-N. 2006. Municipal sewage sludge treatment and disposal technologies and resource utilization research (in Chinese). Ecological sciences 25, 1-6.

Chen, T-B. Huang, Q-F. and Gao, D. 2003. China's urban sludge of heavy metals and changes in trends (in Chinese). Journal of Environmental Science 23, 561-569.

Dai, Y-Q. 2007. Sewage treatment plant sludge disposal environmental constraints analysis (in Chinese). Zhejiang Construction 24, 57-59.

Dang, Z-G. 2007. Sludge treatment and disposal research (in Chinese). Guangzhou Chemical Industry 35, 1-6.

Expansion project environmental impact yearbook of Ji Zhuangzi sewage treatment plant in Tianjin. 2007. Tianjin Environmental Impact Assessment Center (in Chinese).

Hang, S-J. Chen, J-N. Zheng, X-C. Wang, K-J. and Wang, H-C. 2005. Misunderstanding of sludge treatment and disposal and control measures (in Chinese). China Environmental Protection Industry 3, 11-14.

J Werther and T Ogada. 1999.Sewage sludge combustion. Progress in Energy and Combustion Science 25, 55 - 116.

Li, B-G. 2002. Municipal sludge on degraded forest ecosystems of artificial ripening of Soil Research (in Chinese). Journal of Applied Ecology 13, 159-162.

Li, J-H. and He, Q-B. 2005. European Sludge Disposal and Treatment (in Chinese). China Water & Wastewater 21, 101-103.

Li, Y-X. Chen, T-B. and Luo, W. 2003. China's urban sludge organic matter and nutrient content and land use. (in Chinese). Journal of Ecology 23, 246-247.

Liu, W. Guo, G-Y. and Tian, D-J. 2007. Sludge retention time on the yield of excess sludge (in Chinese). Chemical engineer 138, 48-50.

Liu, Y-D. and Wang F. 1998. The resources of municipal sewage sludge and control measures (in Chinese).Conservation of resources 14, 271-273.

Operation and management handbook of Xianyang Road sewage treatment plant in Tianjin. 2008 (in Chinese).

Project environmental impact yearbook of Xianyang road sewage treatment plant in Tianjin. 2008. Tianjin Environmental Impact Assessment Center (in Chinese).

Pu, T-H. and Wu, X-W. 2006. Comprehensive urban sewage treatment plant sludge treatment technology applications (in Chinese). Guangzhou Environmental Science 12, 14-16.

Qiao, X-L. Luo, Y-M. and Wu, S-C. 2000. Sludge land use and its environmental impact (in Chinese). Journal of Soil 1, 1-6.

Qiu, Y-R. and Wu, Q-T. 2007. municipal sewage sludge drying research (in Chinese). Ecology environment 16, 1-6.

Qin, Z-S. and Wu, W-X. 2003. The research development of municipal sewage sludge composting technology (in Chinese). Sichuan Environment 22, 9-13.

Shen, Y-L. 2004. Aerobic sludge digestion treatment process research (in Chinese). Suzhou Institute of Urban Construction Environment Journal 7, 55-64.

Shi, X-L. and Chen, S-W. 2001. Municipal Sewage Sludge Disposal and Utilization. (in Chinese). Environment protection 3, 45-46.

Sun, G-F. 2007. Both environmental and efficiency-Sewage treatment sludge reduction (in Chinese). Resources and Environment 7, 201-202.

The research report of municipal sludge treatment methods and ways of planning in Tianjin. 2008 (in Chinese).

Wang, J. 2006. Sewage treatment plant sludge treatment technology (in Chinese). Liaoning Urban and Rural Environmental Science and Technology 26, 1-6.

Wang, S-Y. Cui, Y-B. and Wang, C-L. 2000. Sludge Treatment Technology Outlook (in Chinese). Jilin Construction Engineering College 3, 25-28.

Xue, W-Y. 2002. Municipal Sewage Sludge Treatment and Disposal means (in Chinese). China Water & Wastewater 8, 41-46.

Xu, L-L. Sun, S-L. and Ren, Y-Z. 2007. Sludge treatment and process status at home and abroad (in Chinese). Modernization construction 3, 509.

Yang, Q. and Liu, G-L. 1999. Sludge treatment and new progress of disposal technology (in Chinese). Shanghai Environmental Science 18, 1-6.

Yang, X-W. and Du, Y-H. 2002. Sludge Treatment and Utilization of the program options (in Chinese). China Water & Wastewater 18, 31-33.

Drainage Management. 2008. Yearbook of Drainage Management Office in Tianjin (in Chinese).

Yin, J. and Tan, X-J. 2005. Sewage sludge treatment and disposal in resource utilization (in Chinese). Beijing: Chemical Industry Press 8, 143-145.

Yu, J. Tian, N-N. and Wang, K-J. 2005. Sludge treatment and disposal of technology policy in China (in Chinese). China Water & Wastewater 8, 1-6.

Zhang, Q-M. Chen, W-P. and Hu, G-C. 2000. Sludge effective use of research (in Chinese). Agriculture environmental protection 19, 58-61.

Zhang, S-H. and Hua, Y-M. 2004. Enhanced anaerobic digestion treatment technology (in Chinese). Environmental protection Science 30, 13-15.

Zhang, Z-J. Lin, R-C. and Jin, R-L.1996. Drainage Works (Third Edition) (in Chinese). Beijing: China Building Industry Press 8, 296-299.

Zhao, L-J. Zhang, D-Q. and Chen, B-Z. 2001. Sludge treatment and disposal of technological progress (in Chinese). China Water & Wastewater 17, 23-25.