CHAPTER 8

Drainage Services Department

Environmental Protection Department

Treatment and disposal of sewage sludge

Audit Commission
Hong Kong
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This audit review was carried out under a set of guidelines tabled in the Provisional Legislative Council by the Chairman of the Public Accounts Committee on 11 February 1998. The guidelines were agreed between the Public Accounts Committee and the Director of Audit and accepted by the Government of the Hong Kong Special Administrative Region.

Report No. 48 of the Director of Audit contains 8 Chapters which are available on our website at http://www.aud.gov.hk.

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TREATMENT AND DISPOSAL OF SEWAGE SLUDGE

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PART 1: INTRODUCTION

1.1 This PART describes the background to the audit and outlines its objectives and scope.

Background

1.2 The Drainage Services Department (DSD) is responsible for the operation and maintenance of sewage treatment works. Based on the level of treatment, these sewage treatment works can be grouped into five categories, namely:

(a) ***Preliminary treatment.*** This is the initial stage of the sewage treatment process involving screening and de-gritting of sewage to remove large solid matters;

(b) ***Primary treatment.*** This process removes solid waste and suspended solids from sewage by sedimentation, in addition to screening;

(c) ***Chemically enhanced primary treatment (CEPT).*** This process enhances the primary treatment process by adding chemicals to the sewage to enhance the removal of suspended solids and other pollutants through sedimentation;

(d) ***Secondary treatment.*** In addition to sedimentation and screening (as done under primary treatment), secondary treatment involves biological treatment to further remove suspended solids; and

(e) ***Tertiary treatment.*** This is the highest level of treatment consisting of physical, chemical and biological processes to remove nutrients and the remaining suspended solids.

1.3 During the sewage treatment process, a large quantity of sludge is produced as a by-product. Sludge is a mixture of water and solid waste and is disposed of at landfills. Owing to its high water content, sludge is mechanically dewatered at sewage treatment works before disposal. In 2005, the DSD sewage treatment works produced an average of 838 tonnes of dewatered sludge a day, or 306,000 tonnes a year.

1.4 As at August 2006, the DSD operated 70 sewage treatment works adopting different levels of treatment (see Table 1).

Table 1

DSD sewage treatment works
(August 2006)

Level of treatment	Number	Number selected for audit review
Preliminary	23	—
Primary	2	1
CEPT	4	4
Secondary	40	7
Tertiary	1	—
Total	**70**	**12**

Source: DSD records

1.5 Of the 70 sewage treatment works in Table 1, only 12 delivered the sludge produced directly to landfills for disposal (see Figure 1). The other sewage treatment works produced small quantities of sludge which were transported to the 12 major sewage treatment works for dewatering and subsequent disposal at landfills. Therefore, this audit review focused on the sludge produced and/or dewatered by the 12 major sewage treatment works.

1.6 The Environmental Protection Department (EPD) is responsible for developing waste management strategies and managing waste disposal facilities, such as landfills. As at August 2006, there were three landfills in operation (see Table 2 and Figure 1).

Table 2

Locations of three landfills
(August 2006)

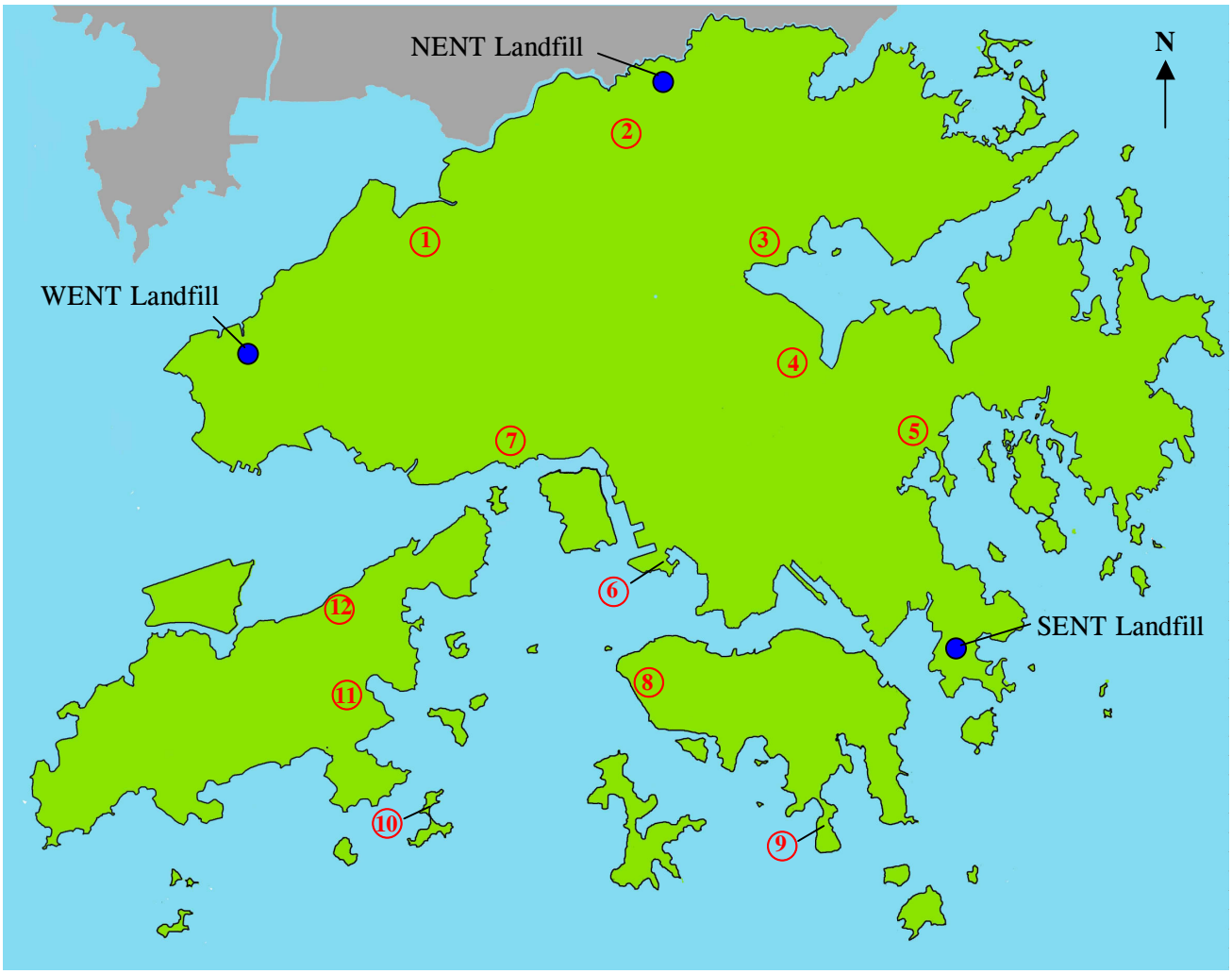
Landfill	Location	Operation commencement date
West New Territories (WENT)	Nim Wan, Tuen Mun	November 1993
South East New Territories (SENT)	Tai Chik Sha, Tseung Kwan O	September 1994
North East New Territories (NENT)	Ping Yeung, Ta Kwu Ling	June 1995

Source: EPD records

The EPD pays operation fees to the landfill operators based on the quantity of waste disposed of at the landfills. In 2005-06, the EPD paid $21 million to the operators for the disposal of dewatered sludge from the DSD sewage treatment works.

Figure 1

Location of the 12 major sewage treatment works and 3 landfills



Legend:
① Yuen Long Sewage Treatment Works
② Shek Wu Hui Sewage Treatment Works
③ Tai Po Sewage Treatment Works
④ Shatin Sewage Treatment Works
⑤ Sai Kung Sewage Treatment Works
⑥ Stonecutters Island Sewage Treatment Works
⑦ Sham Tseng Sewage Treatment Works
⑧ Cyberport Sewage Treatment Works
⑨ Stanley Sewage Treatment Works
⑩ Cheung Chau Sewage Treatment Works
⑪ Mui Wo Sewage Treatment Works
⑫ Siu Ho Wan Sewage Treatment Works

Source: *DSD and EPD records*

Audit review

1.7 The Audit Commission (Audit) has recently conducted a review to examine the economy, efficiency and effectiveness of the DSD in administering the treatment of sludge produced by sewage treatment works, and those of the EPD in administering the sludge disposal at landfills. The audit review focused on the following areas:

(a) implementation of sludge dryness requirement (see PART 2);

(b) upgrading of sludge dewatering facilities (see PART 3);

(c) administration of sludge dryness tests (see PART 4); and

(d) implementation of sewage sludge reduction plans (see PART 5).

Audit has found that there are areas where improvements can be made in the treatment and disposal of sludge, and has made a number of recommendations to address the issues.

Acknowledgement

1.8 Audit would like to acknowledge with gratitude the full cooperation of the staff of the DSD and the EPD during the course of the review.

PART 2: IMPLEMENTATION OF SLUDGE DRYNESS REQUIREMENT

2.1 This PART examines the EPD's implementation of the dryness requirement for sewage sludge disposal at landfills, and the DSD's compliance with the requirement.

Integrated Sludge Disposal Strategy Study in 1993

2.2 In June 1993, the EPD completed the Integrated Sludge Disposal Strategy (ISDS) Study. The Study found that:

(a) there would be a significant increase in the volume of sludge produced by the sewage treatment works after the commissioning of the Harbour Area Treatment Scheme (HATS — Note 1); and

(b) the increase in sludge would cause the following landfill operational problems:

(i) instability of landfill slopes;

(ii) excessive leachate (Note 2) generation; and

(iii) potential surface water contamination.

2.3 The ISDS Study concluded that a 30% dry solids content by weight was the minimum requirement for sludge disposal at landfills. As a result, the EPD determined that sewage sludge disposal at landfills should have a minimum dry solids content of 30% by weight (hereinafter referred to as the **30% dryness requirement**). To further minimise the operational problems of sludge disposal at landfills, the EPD set a landfill co-disposal ratio of 1:10 by weight (hereinafter referred to as the **1:10 co-disposal ratio**) between sludge and other solid waste (such as municipal solid waste and construction waste).

Note 1: *HATS Stage 1 was fully commissioned in December 2001. It consists of: (a) a network of deep sewage tunnels for collecting sewage from the Kowloon urban area and the northeastern part of Hong Kong Island; and (b) the Stonecutters Island Sewage Treatment Works for treatment of the collected sewage. The further stages of HATS are under development.*

Note 2: *Leachate is a highly contaminated liquid formed as a result of the decomposition of waste at landfills.*

Audit observations

Need to issue technical circular to promulgate landfill requirements

2.4 In early 1993, the EPD drafted a technical circular to promulgate the 30% dryness requirement for sludge disposal at landfills. The EPD circulated the draft technical circular to the concerned government departments for comments. **In June 1993, the DSD requested the EPD to clarify whether the 30% dryness requirement referred to "an absolute minimum or an average value". In July 1993, the EPD replied that this referred to "an absolute minimum".**

2.5 Audit noted that, in December 1995, in a paper submitted to the Finance Committee (FC) of the Legislative Council (LegCo) seeking funds for upgrading the sludge dewatering facilities at sewage treatment works (see para. 3.3), the Administration stated that the EPD had laid down a requirement that all sludge disposed of at the three landfills should meet the 30% dryness requirement by mid-1997.

2.6 In November 2006, in response to Audit enquiry, the EPD informed Audit that the technical circular referred to in paragraph 2.4 had not been issued. **Audit considers that the EPD should issue the technical circular to promulgate the sludge dryness requirement for compliance by government departments.**

Need to comply with the sludge dryness requirement

2.7 In June 1996 and March 1997, the EPD informed the DSD that:

(a) with effect from 1 June 1997, any sludge which did not meet the 30% dryness requirement would not be accepted for disposal at landfills; and

(b) while it was laid down in the landfill contracts that the EPD might issue instructions to the landfill operators to accept sludge not meeting the 30% dryness requirement, such instructions would only be given in exceptional circumstances and for very small quantities of sludge.

2.8 In June 1997, at a DSD/EPD Liaison Meeting to discuss the disposal of sludge from the Shatin Sewage Treatment Works at landfills, the DSD requested the EPD to:

(a) adopt a more flexible approach to setting the minimum dryness requirement; and

(b) give consideration to the operational difficulties of both the sewage treatment works and landfill operators in order that the most cost-effective arrangement could be adopted.

In reply, the EPD said that there would be no problem to adopt a flexible approach in this case as the quantity of sludge was manageable, provided that the DSD could provide the EPD with all relevant data regularly.

2.9 However, from the DSD's records, Audit could not find details about the flexible approach mentioned in June 1997. **Audit considers it desirable for the EPD and the DSD to document details of the flexible approach agreed between the two departments.**

2.10 Audit examination revealed that, at each of the 12 major sewage treatment works, the DSD:

(a) conducted sample tests on sludge dryness every day (except Saturdays, Sundays and public holidays — Note 3);

(b) forwarded the test results to the EPD every month, together with the total quantity of sludge delivered to landfills in that month; and

(c) **did not compile reports showing the quantity of sludge not meeting the 30% dryness requirement.**

Audit examination of the DSD monthly returns to the EPD from September 2005 to August 2006 revealed that 10 of the 12 major sewage treatment works did not consistently produce sludge meeting the 30% dryness requirement (see Table 3).

Note 3: *For some small sewage treatment works, the DSD carried out sludge dryness tests every few days or weekly.*

Table 3

Compliance with sludge dryness requirement
(September 2005 — August 2006)

Sewage treatment works	Level of treatment	Quantity of sludge produced (a) (tonne)	Percentage of days not meeting 30% dryness requirement (Note) (b)	Estimated quantity not meeting 30% dryness requirement (c) = (a) × (b) (tonne)
Stonecutters Island	CEPT	218,370	0%	0
Shatin	Secondary	45,558	23%	10,478
Tai Po	Secondary	14,140	**38%**	5,373
Shek Wu Hui	Secondary	12,655	16%	2,025
Siu Ho Wan	CEPT	6,293	0%	0
Yuen Long	Secondary	3,383	7%	237
Stanley	Secondary	1,587	**100%**	1,587
Sai Kung	Secondary	1,140	21%	239
Sham Tseng	CEPT	663	3%	20
Cyberport	CEPT	445	21%	93
Mui Wo	Secondary	365	19%	69
Cheung Chau	Primary	355	**42%**	149
Total		**304,954**	**7%**	**20,270**

Source: *DSD records and Audit analysis*

Note: *This is calculated by:*

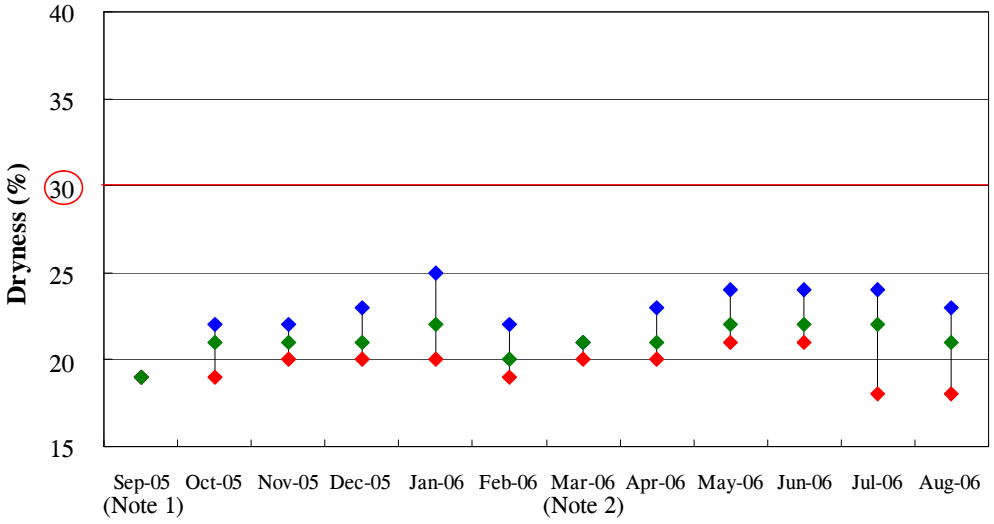
$$\frac{(\text{number of days with test results below 30\% dryness})}{(\text{number of days with test results})} \times 100\%$$

2.11 As shown in Table 3, from September 2005 to August 2006, the sewage treatment works at Stanley, Cheung Chau and Tai Po had the highest percentages of days not meeting the 30% sludge dryness requirement. An analysis of the sludge dryness of the sewage treatment works at Stanley and Tai Po (Note 4) is shown in Figures 2 and 3.

Note 4: *The Cheung Chau Sewage Treatment Works was not selected for analysis because it only produced a relatively small quantity (355 tonnes) of sludge a year.*

Figure 2

Sludge dryness of Stanley Sewage Treatment Works (September 2005 — August 2006)



Legend: Highest dryness level
Average dryness level
Lowest dryness level

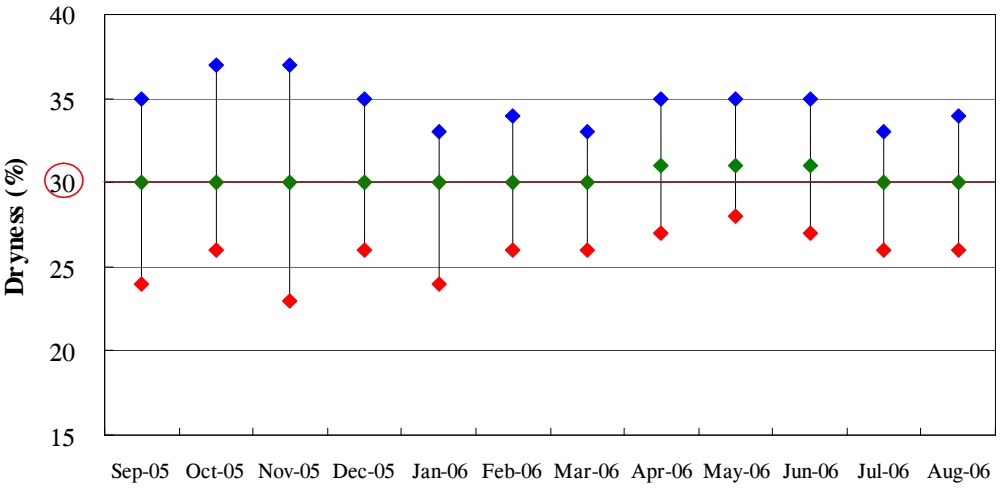
Source: *DSD records and Audit analysis*

Note 1: *In September 2005, all the tests revealed a dryness of 19%.*

Note 2: *In March 2006, both the highest and average dryness levels were 21%.*

Figure 3

Sludge dryness of Tai Po Sewage Treatment Works (September 2005 — August 2006)



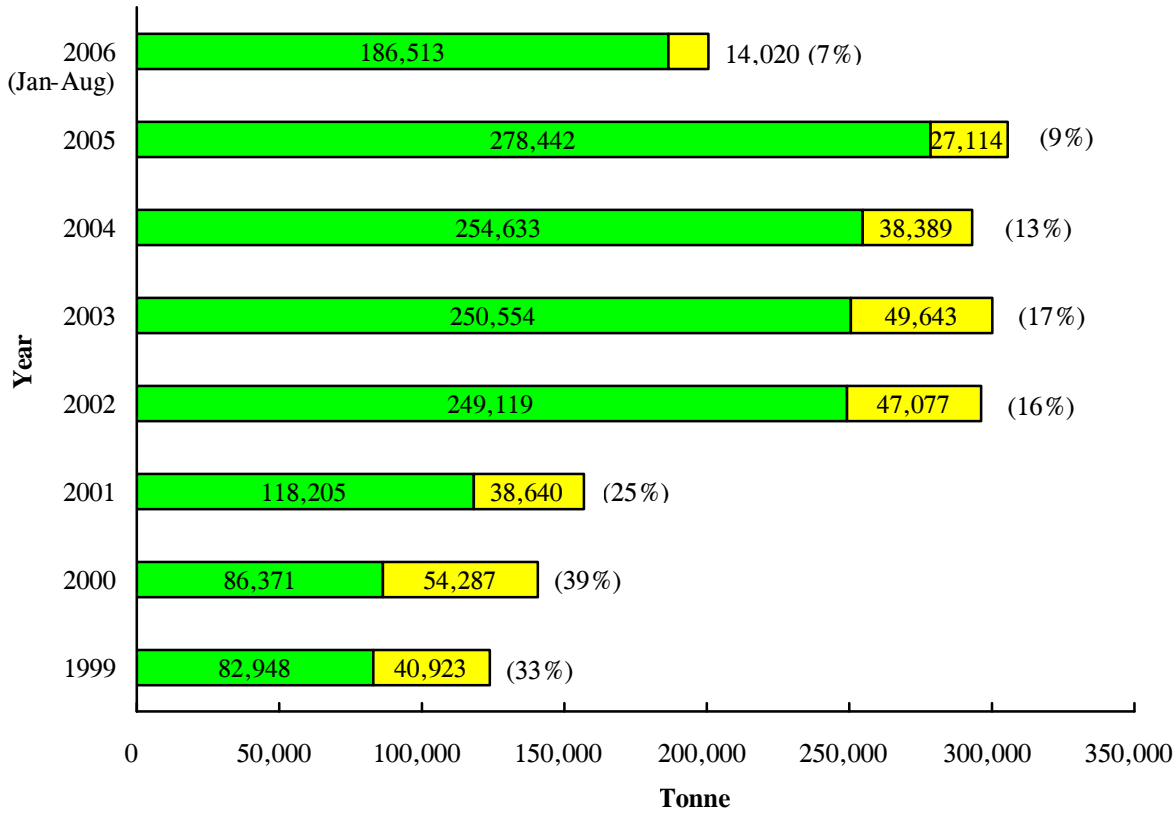
Legend: Highest dryness level
Average dryness level
Lowest dryness level

Source: *DSD records and Audit analysis*

2.12 Audit estimated that, in the 12 months from September 2005 to August 2006, of the 304,954 tonnes of sludge produced by the 12 major sewage treatment works, 20,270 tonnes (7%) did not meet the 30% dryness requirement (see Table 3). Audit also estimated that the overall sludge non-compliance rates of these 12 major sewage treatment works ranged from 39% in 2000 to 7% in 2006 (see Figure 4).

Figure 4

Compliance with sludge dryness requirement (1999 — 2006)



Legend: Quantity of sludge not meeting the 30% dryness requirement

Quantity of sludge meeting the 30% dryness requirement

Source: *DSD records and Audit analysis*

Remarks: *The significant increase in the total sludge quantity in 2002 was due to the full commissioning of HATS Stage 1 in December 2001.*

2.13 Audit noted that the gradual improvements in complying with the 30% dryness requirement by the 12 major sewage treatment works from 1999 to 2006 were mainly due to the implementation of upgrading works (see PART 3) and other improvement measures by the DSD.

2.14 In September 2006 and February 2007, in response to Audit enquiry, the DSD said that:

(a) it was mentioned in an appendix to the 1993 ISDS Study Report that:

(i) dewatering sludge to a dryness of 30% might not be achievable on a consistent basis at all sewage treatment works; and

(ii) dewatered sludge from secondary sewage treatment works with a dryness of 25% to 30% could be accommodated at future landfills, although the on-site co-disposal practice might need to be modified to ensure the safety of the landfill operation;

(b) in practice, it was very difficult to dewater sludge produced by secondary sewage treatment works to a dryness of 30% consistently;

(c) the DSD had taken actions to achieve the 30% dryness requirement as far as possible, and had achieved the requirement on a monthly average basis (Note 5) for all secondary sewage treatment works, except the Stanley Sewage Treatment Works;

(d) the Stanley Sewage Treatment Works produced a small quantity of sludge that was known to be difficult to dewater to a dryness of 30%;

(e) in the case of the largest secondary sewage treatment works, i.e. the Shatin Sewage Treatment Works, the DSD could only manage to achieve a monthly average sludge dryness of 30%, with some days falling below the 30% standard; and

(f) from time to time, the DSD and the EPD had meetings and discussions on sludge quality and quantity.

Note 5: *According to the EPD, the 30% dryness requirement referred to "an absolute minimum" but not on an average value basis (see para. 2.4).*

2.15 Audit noted that, except the sewage treatment works at Stonecutters Island and Siu Ho Wan, all the other 10 major sewage treatment works did not consistently produce sludge meeting the 30% dryness requirement (see Table 3). **Audit considers that there is room for improvement in this area.**

2.16 **In the event that the DSD has operational constraints in complying with the 30% dryness requirement (which may be due to the capacity of the treatment facilities — see PART 3), Audit considers that the EPD should take proactive action to minimise the adverse effects of the disposal of sludge not meeting the 30% dryness requirement at the landfills.**

Audit recommendations

2.17 **Audit has *recommended* that the Director of Drainage Services should:**

(a) **take action to ensure that all sewage treatment works comply with the 30% sludge dryness requirement as far as possible (see para. 2.15); and**

(b) **compile periodic reports showing the quantity of sludge not complying with the 30% sludge dryness requirement for internal monitoring and submission to the EPD (see para. 2.10(c)).**

2.18 **Audit has *recommended* that the Director of Drainage Services and the Director of Environmental Protection should jointly work out mutually acceptable arrangements if some sewage treatment works cannot meet the 30% sludge dryness requirement (see para. 2.15).**

2.19 **Audit has *recommended* that the Director of Environmental Protection should:**

(a) **issue circulars to promulgate sludge disposal requirements at landfills for compliance by government departments (see para. 2.6); and**

(b) **assess the adverse effects of the disposal of sludge not meeting the 30% dryness requirement at the landfills, and take appropriate remedial action (see para. 2.16).**

Response from the administration

2.20 The **Director of Drainage Services** agrees with the audit recommendations in paragraphs 2.17 and 2.18. He has said that:

(a) the DSD will continue to liaise with the EPD to work out mutually acceptable arrangements for handling sewage sludge not meeting the 30% dryness requirement; and

(b) the DSD will liaise with the EPD to compile periodic reports to show both the daily quantity and dryness of dewatered sludge.

2.21 The **Director of Environmental Protection** accepts the audit recommendations in paragraphs 2.18 and 2.19. She has said that:

(a) the EPD will take steps to ensure that the relevant departments are fully aware of the 30% dryness requirement for the disposal of sludge at landfills;

(b) the EPD will continue to liaise with the DSD to work out and, where appropriate, document mutually acceptable arrangements for handling the 7% of sewage sludge not meeting the 30% dryness requirement; and

(c) the adverse effects of wet sludge on landfill operations have been scientifically assessed in a number of studies. The EPD will continue to closely monitor the landfill operation and conditions to identify the need for taking appropriate remedial action. In this regard, the EPD has been diverting sewage sludge with a dryness below 30% to landfills with capacity for receiving more sludge (taking into account the 1:10 co-disposal ratio) as far as practicable.

PART 3: UPGRADING OF SLUDGE DEWATERING FACILITIES

3.1 This PART examines the DSD's upgrading of the sewage treatment works for meeting the sludge dryness requirement.

DSD study to upgrade sludge dewatering facilities

3.2 In early 1993, the EPD informed the DSD that sludge disposed of at landfills should have a minimum dryness of 30%. To allow time for the upgrading works, the EPD would implement the 30% dryness requirement for sludge from 1 June 1997. In 1993, the sewage treatment works could only dewater sludge to a dryness of 10% to 22%. In view of the new requirement, in June 1993, the DSD carried out a study to evaluate the options for upgrading the sewage treatment works for meeting the sludge dryness requirement. In January 1995, the DSD completed the study and proposed that:

(a) new dewatering facilities should be installed at the five major secondary sewage treatment works at Shatin, Tai Po, Yuen Long, Shek Wu Hui and Sai Kung to upgrade the sludge dewatering facilities; and

(b) the dewatering facilities at the Stanley Sewage Treatment Works should not be upgraded. The DSD considered that it was not economical to upgrade the dewatering facilities there because it only produced a small quantity of sludge (about 1,000 tonnes a year).

Two works projects for upgrading sludge dewatering facilities

3.3 In 1995 and 1996, the Administration sought funds from the FC of LegCo for two works projects (Projects A and B — see paras. 3.4 and 3.5). **The FC was informed that the main objective of the two projects was to upgrade the sludge dewatering facilities at five major sewage treatment works so that they could produce sludge meeting the 30% dryness requirement set by the EPD.**

3.4 ***Project A.*** In January 1996, the FC approved $148 million for this project for upgrading the sludge dewatering facilities at four major secondary sewage treatment works at Tai Po, Yuen Long, Shek Wu Hui and Sai Kung. The scope of the project included:

(a) replacing all sludge dewatering equipment at the four sewage treatment works by membrane presses or centrifuges (Note 6); and

(b) providing civil engineering works, sludge reaction tanks and sludge buffer tanks.

The upgrading works for these four sewage treatment works were completed in 1997 at the cost of $119 million.

3.5 ***Project B.*** In November 1996, the FC approved $103 million for this project for upgrading the sludge dewatering facilities at the Shatin Sewage Treatment Works (the largest secondary sewage treatment works). The scope of the project included:

(a) the supply and installation of sludge dewatering facilities, including four centrifuges, sludge feeding pumps and a chemical dosing system; and

(b) construction of a sludge mixing tank and pipes.

The upgrading works for Project B were completed in 1999 at the cost of $87 million.

Audit observations

Room for improvement in achieving 30% sludge dryness requirement

3.6 Projects A and B were completed in 1997 and 1999 respectively. A comparison of the dryness of the sludge produced by the five sewage treatment works before and after the upgrading works shows that, although improvements had been made after the upgrading works, the sludge did not consistently meet the 30% dryness requirement (see Table 4).

Note 6: *According to information provided in the paper submitted to the FC, the then existing sludge dewatering facilities at three of the sewage treatment works would be near the end of their economic life by 1997.*

Table 4

Sludge dryness before and after upgrading works

Sewage treatment works	Before upgrading works (1995) (Note 1) (dryness %)	After upgrading works (September 2005 — August 2006) (Note 2) (dryness %)
Tai Po	18 – 22	23 – 37
Shek Wu Hui	18 – 22	26 – 38
Yuen Long	18 – 22	27 – 36
Sai Kung	14 – 18	24 – 38
Shatin	10	25 – 39

Source: DSD records

Note 1: These are based on the information submitted to the FC of LegCo in December 1995 and November 1996.

Note 2: These are based on the DSD's monthly returns of sludge dryness test results submitted to the EPD.

3.7 **As shown in Table 3 (see para. 2.10) and Table 4, in the 12 months from September 2005 to August 2006, the five major sewage treatment works did not consistently produce sludge meeting the 30% dryness requirement.** For example, on 38% of the days during the period, the Tai Po Sewage Treatment Works was unable to produce sludge meeting the requirement (see Table 3). Table 5 shows the percentages of days from 2001 to 2005 on which the five sewage treatment works did not meet the sludge dryness requirement.

Table 5

Percentages of days not meeting sludge dryness requirement
(2001 — 2005)

Year	Sewage treatment works				
	Tai Po	**Yuen Long**	**Shek Wu Hui**	**Sai Kung**	**Shatin**
2001	33%	35%	18%	49%	53%
2002	33%	25%	19%	22%	78%
2003	40%	4%	21%	21%	81%
2004	33%	9%	49%	21%	55%
2005	32%	13%	17%	23%	38%

Source: DSD records and Audit analysis

3.8 In February 2007, in response to Audit observations in paragraphs 3.6 and 3.7, the DSD informed Audit that:

(a) although the five sewage treatment works (see Table 5) did not produce sludge meeting the sludge dryness requirement of 30% on a consistent basis, between 2001 and 2006, the overall average dryness of sludge produced by these treatment works was 30.5%;

(b) in 2006, the average dryness of sludge produced by the five sewage treatment works was 31%; and

(c) since 1997, the DSD had submitted monthly reports to the EPD showing the daily sludge dryness.

3.9 As stated in paragraph 2.4, the EPD stated that the 30% dryness requirement was an absolute minimum and should not be calculated on an average value basis. **Audit considers that there is room for improvement for the five sewage treatment works in meeting the 30% sludge dryness requirement. In this connection, the audit recommendations in paragraphs 2.17 and 2.18 are relevant.**

Room for improvement in achieving sludge quantity reduction

3.10 In December 1995, in respect of Project A, the Administration informed the FC of LegCo that:

(a) consequent to increasing the sludge dryness (from the then 14% to 22%) to 30%, there would be a 50% decrease in the sludge quantity for disposal at landfills;

(b) as a result, the effective lives of the landfills would be extended; and

(c) the decrease in sludge quantity would reduce the requirement for landfill space and achieve a notional annual saving of $1.3 million in landfill development cost.

3.11 Among the four sewage treatment works involved in Project A, the sewage treatment works at Shek Wu Hui and Tai Po were the largest, accounting for over 80% of the sludge produced by the four sewage treatment works. Audit selected these two sewage treatment works to ascertain whether there had been a 50% reduction in the quantities of sludge produced after the upgrading works (see Table 6).

Table 6

Quantities of sludge produced before and after upgrading works (1996 — 2005)

Year	Shek Wu Hui Sewage Treatment Works			Tai Po Sewage Treatment Works		
	Sewage treated (a) (1,000 m^3)	Sludge produced (b) (tonne)	Sludge per 1,000 m^3 of sewage treated (c) = (b)÷(a) (tonne)	Sewage treated (d) (1,000 m^3)	Sludge produced (e) (tonne)	Sludge per 1,000 m^3 of sewage treated (f) = (e)÷(d) (tonne)
Before upgrading works						
1996	23,753	10,979	0.46	27,059	16,245	0.60
1997 (Note)	23,781	8,998	0.38	28,336	14,222	0.50
After upgrading works						
1998	22,823	7,860	0.34	28,717	12,829	0.45
1999	22,806	7,957	0.35	28,388	13,850	0.49
2000	25,252	9,417	0.37	29,786	13,039	0.44
2001	25,529	11,007	0.43	30,336	12,969	0.43
2002	26,965	11,974	0.44	28,732	12,086	0.42
2003	30,009	12,370	0.41	31,922	12,808	0.40
2004	29,673	11,402	0.38	33,428	13,261	0.40
2005	29,791	12,968	0.44	34,294	14,019	0.41

Source: DSD records and Audit analysis

Note: The upgrading works of the two sewage treatment works were completed in 1997.

3.12 At the Shek Wu Hui Sewage Treatment Works (see Table 6), on average 0.46 tonne of sludge was produced per 1,000 m^3 of sewage treated in 1996 (before the upgrading works). This sludge production rate was reduced to 0.44 tonne of sludge per 1,000 m^3 of sewage treated in 2005 (eight years after the upgrading works), representing a 4% reduction. Similarly, at the Tai Po Sewage Treatment Works, the sludge production rate was reduced by 32% from 1996 to 2005.

3.13 In February 2007, in response to Audit observations in paragraphs 3.10 to 3.12, the DSD informed Audit that:

(a) besides the volume of sewage treated, other factors would also affect the quantity of sludge produced, including:

  (i) the characteristics of the incoming sewage; and

  (ii) the arrangements for different processes during sewage treatment;

(b) the estimated 50% reduction in sludge quantity was the maximum theoretical reduction when the sludge dryness was increased from 15% to 30%. Before the upgrading works, the sludge dryness at the four sewage treatment works was 14% to 22%. After the upgrading works, the average sludge dryness was 30%;

(c) the DSD considered that the reduction in sludge quantities (see para. 3.10) had been achieved; and

(d) the notional annual saving of $1.3 million in landfill development cost (see para. 3.10(c)) was based on the designed maximum quantity of 57,000 tonnes of sludge a year for the four sewage treatment works. Between September 2005 and August 2006, these four treatment works produced 31,318 tonnes of sludge. The DSD estimated that the annual saving in landfill development cost was $0.7 million.

Audit considers that, in future submissions seeking funds for works projects from the FC of LegCo, the basis of estimating the outcome should be clearly stated.

Need to review use of chemicals for dewatering sludge

3.14 After the completion of the upgrading works at the five major sewage treatment works in 1997 and 1999, sludge meeting the 30% dryness requirement could not be consistently produced. In order to improve the efficiency of the mechanical dewatering process, the DSD added chemicals to sludge as conditioners prior to the dewatering process.

3.15 Audit selected the sewage treatment works at Shek Wu Hui and Tai Po to examine the quantity of chemicals added to the sludge before and after the upgrading works. The results are shown in Table 7.

Table 7

Quantities of chemicals added to sludge before and after upgrading works (1996 — 2005)

Year	Shek Wu Hui Sewage Treatment Works		Tai Po Sewage Treatment Works	
	Sludge produced (tonne)	Chemicals added (tonne)	Sludge produced (tonne)	Chemicals added (tonne)
Before upgrading works				
1996	10,979	142	16,245	37
1997 (Note 1)	8,998	73	14,222	627
After upgrading works (Note 2)				
1998	7,860	1,735	12,829	996
1999	7,957	1,091	13,850	1,428
2000	9,417	1,190	13,039	1,504
2001	11,007	1,199	12,969	1,567
2002	11,974	1,311	12,086	1,337
2003	12,370	1,337	12,808	1,381
2004	11,402	1,181	13,261	1,528
2005	12,968	903	14,019	1,485

Source: *DSD records*

Note 1: *The upgrading works of the two sewage treatment works were completed in 1997.*

Note 2: *According to the DSD, the main chemical used (90% of the total by weight) was ferric chloride solution (about 60% of which was water). The other chemical used was polymer in powder form.*

3.16 As shown in Table 7, there was a significant increase in the quantity of chemicals added to sludge to facilitate the dewatering process after the completion of the upgrading works in 1997. The increase is mainly due to the need to use ferric chloride, in addition to polymer, to condition the sludge in order to achieve a dryness of 30%. Prior to the upgrading works, only polymer was required. The chemicals would facilitate the dewatering process so that drier sludge would be produced. However, the chemicals added to sludge would increase the total quantity of sludge for disposal. For example, at the Tai Po Sewage Treatment Works, the quantity of chemicals used for sludge dewatering increased from 37 tonnes in 1996 (before the upgrading works) to 996 tonnes in 1998 (after the upgrading works).

3.17 In February 2007, in response to Audit observations in paragraphs 3.14 to 3.16, the DSD informed Audit that:

(a) in order to remove water from sludge to achieve a dryness of 30%, sufficient quantity of ferric chloride had to be added. In the pilot trial in 1994, it was confirmed that dosing of polymer and ferric chloride of over 10% by weight would be required to achieve the 30% dryness target;

(b) in 1996, before the upgrading of the sludge dewatering facilities, the sludge dryness was 14% to 22%. At that time, only polymer was used to dewater sludge;

(c) the DSD had carried out reviews and optimisation tests of the use of chemicals. Owing to the changing nature of sewage sludge, carrying out optimisation tests of chemical dosage was a continuous process for sludge dewatering;

(d) factors affecting the nature of sludge included the amount of solids, size of sludge particles, ratio of organic and inorganic matters, and abundance of fibrous materials. Some of these factors were unique and would be affected by the characteristics of the incoming sewage, while others depended on the performance of the treatment process. This process might be affected by the degree of the mixing achieved, the operation temperature and the presence of heavy metals; and

(e) as one of its environmental targets in 2006, the DSD had conducted two chemical reviews, one for the Stonecutters Island Sewage Treatment Works and the other for the Shatin Sewage Treatment Works. The DSD conducted the reviews to identify areas for savings in chemicals. In 2007, the DSD would conduct another two chemical reviews.

Audit considers that there is a need for the DSD to closely monitor the use of chemicals in the sludge dewatering process.

Need to provide full information about Project A to Finance Committee

3.18 In December 1995, in respect of Project A, the Administration informed the FC of LegCo that:

(a) the landfill contracts were structured such that a higher operation fee would be charged if the sludge being disposed of had a dryness below 30%;

(b) if the sludge was dewatered to a dryness of 30% or above, the Government could avoid paying the landfill operators at a higher rate; and

(c) the estimated saving was about $5.8 million a year.

3.19 Audit noted that, in 1995, while the WENT and SENT Landfill operators charged a higher operation fee for sludge with a dryness below 30%, the NENT Landfill operator in fact charged a lower operation fee for such sludge. Therefore, the information provided to LegCo as mentioned in paragraph 3.18(a) was not fully consistent with the arrangements at that time.

3.20 In February 2007, in response to Audit observations in paragraphs 3.18 and 3.19, the EPD said that, at the time of preparing a paper for the FC of LegCo for Project A:

(a) the overall sludge disposal assignment plan to various landfills had not been finalised;

(b) it was assumed that WENT Landfill would be the disposal outlet for sludge produced by the sewage treatment works; and

(c) the surcharge applicable to WENT Landfill was used for estimating the cost saving.

Audit considers that there is room for improvement in this area. Furthermore, as the four sewage treatment works involved in Project A could not consistently produce sludge meeting the 30% dryness requirement, it is questionable whether the estimated saving mentioned in paragraph 3.18(c) could be fully achieved.

Need to provide full information about Project B to Finance Committee

3.21 Before 1996, sludge from the Shatin Sewage Treatment Works was disposed of by dumping at sea. In early 1996, in the light of international trend, the DSD discontinued this practice. Between April 1996 and the installation of the new dewatering facilities in 1999, the DSD contracted out the sludge dewatering service to a contractor, who used dewatering equipment similar to that later installed at the Shatin Sewage Treatment Works.

3.22 In November 1996, in seeking funds for Project B, the Administration informed the FC of LegCo that:

(a) the sludge dewatering facilities at the Shatin Sewage Treatment Works was only capable of dewatering sludge to a dryness of 10%;

(b) the DSD had to provide sludge dewatering facilities which could produce sludge meeting the 30% dryness requirement on a permanent basis; and

(c) as an interim measure, the DSD had contracted out the dewatering service to a contractor. **The contractor was able to achieve the 30% sludge dryness.**

3.23 However, Audit examination of the record of sludge dryness during the contract-out period (see para. 3.21) revealed that:

(a) the Shatin Sewage Treatment Works was not able to dewater sludge to 30% dryness on a consistent basis; and

(b) of the 202 days of operation from April to October 1996, the Shatin Sewage Treatment Works was only able to produce sludge meeting the 30% dryness requirement on 14 days (7%).

3.24 In February 2007, in response to Audit observations in paragraphs 3.21 to 3.23, the DSD informed Audit that:

(a) from April to October 1996, although the Shatin Sewage Treatment Works was only able to produce sludge meeting the 30% dryness requirement on 7% of the days, the sludge produced on the remaining 93% of the days was just below the dryness requirement; and

(b) the sludge dewatering performance was affected by the fluctuation in and lower-than-expected dry solids content in the incoming sludge during the period.

3.25 In October 1996, the EPD commented that the Shatin Sewage Treatment Works could not meet the 30% sludge dryness requirement on a consistent basis. **Audit considers that full and relevant information had not been provided to the FC of LegCo regarding the performance of the Shatin Sewage Treatment Works in dewatering sludge when seeking funds for the upgrading works in November 1996.**

Audit recommendations

3.26 **Audit has *recommended* that the Director of Drainage Services should:**

(a) **conduct a post-implementation review of the two works projects for upgrading the sludge dewatering facilities of the five major sewage treatment works to identify areas for improvement (see paras. 3.9, 3.13 and 3.20);**

(b) **conduct a review of the use of chemicals in the sludge dewatering process with a view to optimising the quantity of chemicals to be applied (see para. 3.17); and**

(c) **in seeking funds from the FC of LegCo for works projects in future:**

(i) **conduct thorough examination of the expected benefits of the projects for inclusion in the submissions (see paras. 3.13 and 3.20); and**

(ii) **provide the Committee with full and relevant information (see paras. 3.19 and 3.25).**

Response from the Administration

3.27 The **Director of Drainage Services** agrees with the audit recommendations in paragraph 3.26. He has said that the DSD has started the post implementation review of the two works projects in conjunction with the EPD.

3.28 The **Director of Environmental Protection** has said that, in future submissions seeking funds from the FC of LegCo for works projects, the basis of estimated outcome will be presented.

PART 4: ADMINISTRATION OF SLUDGE DRYNESS TESTS

4.1 This PART examines the administration of sludge dryness tests conducted at sewage treatment works and landfills.

Classification of waste at landfills

4.2 The EPD has outsourced the operation of landfills. As laid down in the landfill contracts, the EPD has classified waste into the following three categories:

(a) ***Permitted Waste Type 1.*** This refers to waste which is generally accepted for disposal at landfills. It includes dewatered sludge with a dryness of 30% or above;

(b) ***Permitted Waste Type 2.*** This refers to waste which is not generally accepted for disposal at landfills. Landfill operators could accept such waste for disposal only under the EPD's instructions. It includes dewatered sludge with a dryness of 20% to 29% at SENT Landfill and WENT Landfill, and 15% to 29% at NENT Landfill. In the case of WENT Landfill, the contract specifies that such sludge is not expected to be accepted for disposal under normal circumstances, except when so instructed by the EPD under special circumstances, e.g. due to typhoons or accidents which have affected the disposal facilities for such waste; and

(c) ***Unpermitted Waste.*** This refers to waste which is not accepted for disposal at landfills. It includes dewatered sludge with a dryness below 20% at SENT Landfill and WENT Landfill and below 15% at NENT Landfill.

In June 1996, the EPD informed the DSD that, while the EPD might instruct the landfill operators to accept sludge not complying with the 30% dryness requirement as Permitted Waste Type 2, such instructions would only be given under exceptional circumstances and only for very small quantities of sludge.

Audit observations

Room for improvement in administering landfill admission tickets

4.3 The EPD has implemented a landfill admission ticket system to control the disposal of waste (such as dewatered sludge) which required special handling and co-disposal arrangements. The procedures for disposal of dewatered sludge were as follows:

(a) usually, every six months, the DSD applied to the EPD for admission tickets for landfill disposal of dewatered sludge produced by the 12 sewage treatment works;

(b) the DSD estimated in the application the quantity and the dryness percentage of the dewatered sludge produced by each sewage treatment works in the coming six months;

(c) in granting the approval, the EPD issued an admission ticket for each sewage treatment works for six months stating the estimated sludge dryness (see Table 8); and

(d) the landfill operators would accept the sludge on production of the admission tickets issued by the EPD.

Table 8

Sludge dryness stated in admission tickets
(April 2006 — September 2006)

Landfill	Sewage treatment works	Estimated sludge dryness (%)
SENT	Stonecutters Island	32%
	Shatin	25–30%
WENT	Stonecutters Island (Note)	30%
	Sham Tseng	20%
	Yuen Long	20%
	Siu Ho Wan	Not specified
	Mui Wo	Not specified
	Cheung Chau	Not specified
NENT	Stanley	30%
	Cyberport	30%
	Shek Wu Hui	20%
	Tai Po	15%
	Sai Kung	15%

Source: DSD records

Note: The Stonecutters Island Sewage Treatment Works disposed of its sludge at both SENT Landfill and WENT Landfill.

The estimated sludge dryness was not specified in the landfill admission tickets for the sewage treatment works at Siu Ho Wan, Mui Wo and Cheung Chau. **Audit considers that there is a need for specifying the estimated sludge dryness in the admission tickets.**

4.4 As shown in Table 8, the estimated dryness of sludge produced by the sewage treatment works at Tai Po and Sai Kung was 15%, and that by the sewage treatment works at Sham Tseng, Yuen Long and Shek Wu Hui was 20%. As laid down in the landfill contracts, such sludge was classified as Permitted Waste Type 2, the disposal of which was subject to the EPD's approval (see para. 4.2(b)). **The EPD approved the DSD's disposal of sludge as Permitted Waste Type 2 on an on-going basis instead of under special circumstances. Audit considers there is room for improvement in this area.**

Room for improvement in administering sludge dryness tests

4.5 At each sewage treatment works, DSD staff conducted sludge dryness tests every day (see para. 2.10). As the test results would not be available at the time of sludge deliveries, the DSD did not provide the test results to the landfill operators. It provided these test results in monthly returns to the EPD.

4.6 On the other hand, for facilitating the operations at the landfills (such as preparing tipping faces and determining appropriate mixing with other waste) and for charging landfill operation fees (Note 7), the landfill operators conducted their own sludge dryness tests. The frequencies of tests varied among the landfill operators. They selected samples from the sludge deliveries for dryness tests, which were conducted at on-site laboratories (for SENT Landfill and NENT Landfill) or the Government Laboratory (for WENT Landfill). The laboratories reported the test results to the landfill operators and the EPD.

4.7 Table 9 shows a comparison between the results of sludge dryness tests conducted by the landfill operators and those by the DSD.

Note 7: *Different rates of operation fee were charged for Permitted Waste Type 1 and Type 2, depending on the terms stated in the landfill contracts. The terms differed among the three landfill contracts.*

Table 9

Sludge dryness test results of landfill operators and DSD
(September 2005 — August 2006)

Landfill/ Sewage treatment works	Sludge produced at sewage treatment works (tonnes)	Estimated number of sludge deliveries (No.)	Dryness test conducted by landfill operators (No.)	Landfill operators' test samples not meeting 30% dryness (Note 4) (% of no. of tests)	DSD's test samples not meeting 30% dryness (Note 4) (% of no. of tests)
SENT Landfill					
Stonecutters Island	96,083	4,800	0	N/A	0%
Shatin	45,558	4,800	**12**	36%	23%
WENT Landfill					
Stonecutters Island (Note 1)	122,287	6,000	**720**	0%	0%
Siu Ho Wan	6,293	360	180	**72%**	**0%**
Yuen Long	3,383	480 (Note 2)	204	**95%**	**7%**
Sham Tseng	663				**3%**
Mui Wo	365	70 (Note 3)	0	N/A	19%
Cheung Chau	355				42%
NENT Landfill					
Tai Po	14,140	1,440	**12**	**91%**	**38%**
Shek Wu Hui	12,655	1,320	**12**	**70%**	**16%**
Stanley	1,587	360	**12**	82%	100%
Sai Kung	1,140	120	**12**	**67%**	**21%**
Cyberport	445	60	0	N/A	21%

Source: *DSD and EPD records, and Audit analysis*

Note 1: *The DSD delivered sludge produced by the Stonecutters Island Sewage Treatment Works to both SENT Landfill and WENT Landfill for disposal.*

Note 2: *The DSD delivered sludge produced by the Yuen Long Sewage Treatment Works and the Sham Tseng Sewage Treatment Works together to WENT Landfill for disposal.*

Note 3: *The DSD delivered sludge produced by the Mui Wo Sewage Treatment Works and the Cheung Chau Sewage Treatment Works together to WENT Landfill for disposal.*

Note 4: *This is calculated by:*

$$\frac{(\textit{number of sludge dryness test samples not meeting 30\% dryness})}{(\textit{number of dryness tests conducted})} \times 100\%$$

4.8 As shown in Table 9, the landfill operators did not conduct sludge dryness tests for sludge delivered from the following sewage treatment works:

(a) the SENT Landfill operator, for sludge delivered from the Stonecutters Island Sewage Treatment Works;

(b) the WENT Landfill operator, for sludge delivered from the sewage treatment works at Mui Wo and Cheung Chau; and

(c) the NENT Landfill operator, for sludge delivered from the Cyberport Sewage Treatment Works.

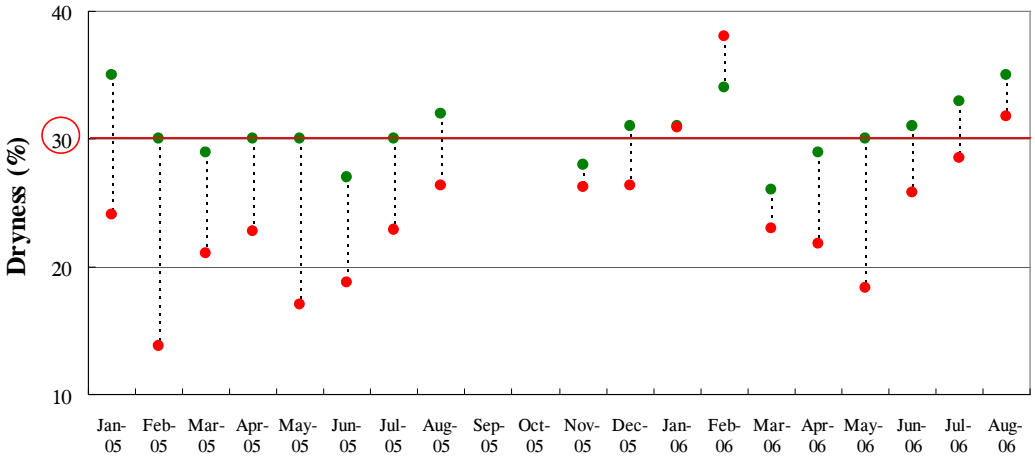
4.9 Furthermore, Table 9 shows that the WENT Landfill operator conducted 720 sludge dryness tests in 12 months (i.e. 60 tests a month) for sludge delivered from the Stonecutters Island Sewage Treatment Works. However, both the SENT and NENT Landfill operators each only conducted 12 sludge dryness tests in 12 months (i.e. 1 test a month) for sludge delivered from the sewage treatment works at Shatin, Tai Po, Shek Wu Hui, Stanley and Sai Kung. **Audit considers that there is a need to review the variations in the test frequencies among the landfill operators.**

4.10 As shown in Table 9, there were significant variances between the results of the tests carried out by the landfill operators and those by the DSD. For example, between September 2005 and August 2006, for the sewage treatment works at Siu Ho Wan, Yuen Long, Sham Tseng, Tai Po, Shek Wu Hui and Sai Kung, 67% to 95% of the landfill operators' test samples did not meet the 30% dryness requirement. However, for these sewage treatment works, only 0% to 38% of the DSD's test samples did not meet the requirement during the same period. A comparison between the landfill operators' monthly test results and the DSD's monthly test results for the sewage treatment works at Shek Wu Hui and Sai Kung is shown in Figures 5 and 6 (Note 8).

Note 8: *For these two sewage treatment works, the landfill operators conducted sludge dryness tests once a month. Audit selected the tests conducted by the DSD on the same days for comparison.*

Figure 5

Sludge dryness test results at Shek Wu Hui Sewage Treatment Works (January 2005 — August 2006)



Legend: ● DSD's test results

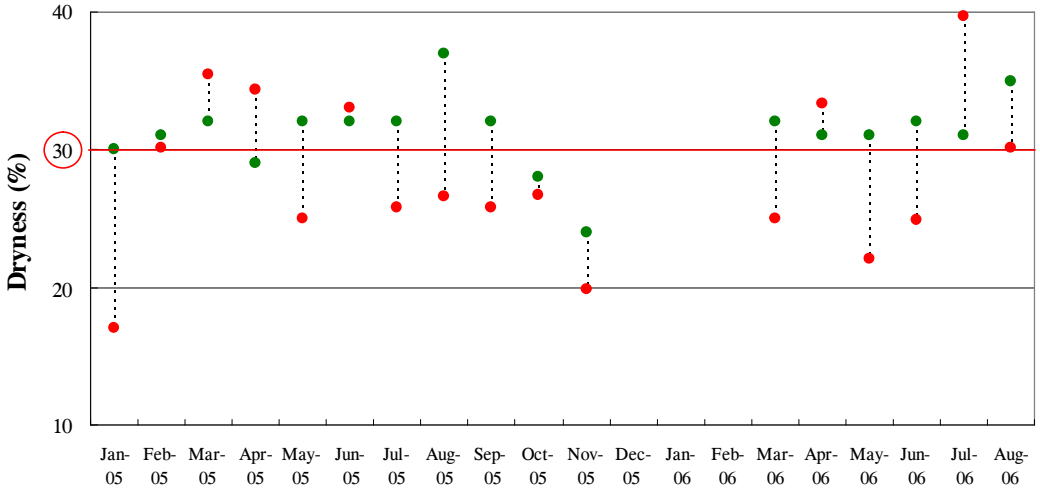
● Landfill operator's test results

Source: *DSD and EPD records*

Remarks: *Landfill operator's test results for September and October 2005 are not available.*

Figure 6

Sludge dryness test results at Sai Kung Sewage Treatment Works (January 2005 — August 2006)



Legend: ● DSD's test results

● Landfill operator's test results

Source: *DSD and EPD records*

Remarks: *Landfill operator's test results from December 2005 to February 2006 are not available.*

4.11 Figures 5 and 6 show that there were significant variances between the test results of the landfill operators and those of the DSD. **In view of the potential operational problems of disposing wet sludge at landfills (see para. 2.2(b)), the EPD and the landfill operators need to closely monitor the sludge dryness. Audit considers that the EPD and the DSD should take measures to improve the accuracy of the sludge dryness information.**

Room for improvement in transporting and storing dewatered sludge

4.12 The DSD delivered sludge to landfills for disposal by:

(a) land transport (for all the three landfills); and

(b) marine transport (for WENT Landfill only).

4.13 At sewage treatment works, the dewatered sludge was loaded into containers which were transported by trucks or barges to the landfills. While the sewage treatment works at Stonecutters Island and Siu Ho Wan used **purpose-built sealed containers** for sludge storage and transportation (see Photograph 1), the other sewage treatment works used **open-top containers** with tarpaulin covers (see Photograph 2).

Photograph 1

A purpose-built sealed container for transporting sludge

Source: *Photograph taken by Audit in October 2006*

Photograph 2

An open-top container with a tarpaulin cover for transporting sludge

Source: *Photograph taken by Audit in October 2006*

4.14 Audit noted that, in an advisory note attached to the application form for an admission ticket for sludge delivery, the EPD said that:

(a) a shelter should be provided to ensure that no additional liquid would mix with the sludge prior to and during the loading operation; and

(b) the waste collection vehicle should have a proper cover to prevent rain water from seeping into the sludge during transport to the landfills.

4.15 The three landfills opened every day for waste disposal. Their opening hours were as follows:

(a) SENT Landfill: 8:00 a.m. — 11:00 p.m.;

(b) WENT Landfill: 8:00 a.m. — 8:00 p.m.; and

(c) NENT Landfill: 8:00 a.m. — 6:00 p.m.

While the three landfills closed at night, the DSD sewage treatment works operated 24 hours a day. The dewatered sludge produced at night was stored in containers for delivery to the landfills on the following day.

4.16 **Audit considers that there are merits for the DSD to consider replacing open-top containers by purpose-built sealed containers.** The use of sealed containers for overnight storage and for transporting sludge to the landfills helps:

(a) avoid seepage of rainwater into the sludge. Open-top containers with a tarpaulin cover are not as reliable as sealed containers for preventing rainwater seepage;

(b) minimise the absorption of moisture;

(c) obviate the spillage of sludge onto roads during transportation; and

(d) reduce odour nuisance during transportation.

Audit recommendations

4.17 **Audit has *recommended* that, regarding the sludge dryness test results of the landfill operators and those of the DSD, the Director of Drainage Services and the Director of Environmental Protection should jointly:**

(a) **conduct a review to find out the reasons for the variances between the two sets of test results and take appropriate improvement measures (see para. 4.11); and**

(b) **conduct periodic comparisons between the two sets of test results (see para. 4.11).**

4.18 **Audit has *recommended* that the Director of Drainage Services should:**

(a) **specify the estimated sludge dryness in the applications for landfill admission tickets for sludge produced by the sewage treatment works at Siu Ho Wan, Mui Wo and Cheung Chau (see para. 4.3); and**

(b) **consider using sealed containers for storage and transportation of dewatered sludge to the landfills for disposal (see para. 4.16).**

4.19 **Audit has *recommended* that the Director of Environmental Protection should:**

(a) **conduct a review of the practice of approving the disposal of sludge as Permitted Waste Type 2 at landfills on an on-going basis (see para. 4.4); and**

(b) **conduct a review to determine an appropriate sludge dryness test frequency for adoption at landfills (see para. 4.9).**

Response from the Administration

4.20 The **Director of Drainage Services** agrees with the audit recommendations in paragraphs 4.17 and 4.18. He has said that:

(a) the DSD and the EPD have started to review the variances between the sludge dryness test results of the landfill operators and those of the DSD, and will conduct periodic comparisons between the two sets of test results;

(b) the DSD has now stated the estimated dryness of sludge produced by all sewage treatment works when applying for the landfill admission tickets; and

(c) the DSD has commenced an in-house study to look into the feasibility of using sealed containers for storing and transporting dewatered sludge for disposal.

4.21 The **Director of Environmental Protection** agrees with the audit recommendations in paragraphs 4.17 and 4.19. She has said that:

(a) the dryness of sludge could change with time and environmental conditions (e.g. temperature and humidity). The EPD and the DSD have started to study the variances between the sludge dryness test results of the landfill operators and those of the DSD, and will make periodic comparisons between the two sets of test results;

(b) the EPD will review the acceptance of sludge classified as Permitted Waste Type 2 at the landfills from time to time; and

(c) the sludge dryness tests conducted at different landfills have different operational purposes (e.g. for operation planning and for determining operation fees). Therefore, the measurement frequencies would be different among them. Nevertheless, the EPD will consider conducting a review to identify areas for improving the consistency in conducting sludge dryness tests among the landfills.

PART 5: IMPLEMENTATION OF SEWAGE SLUDGE REDUCTION PLANS

5.1 This PART examines the Government's implementation of measures for reducing the quantity of sewage sludge for disposal at landfills.

Sludge for disposal at landfills

5.2 In 1993, in the light of the ISDS Study findings, the EPD set a landfill co-disposal ratio of 1:10 by weight between sludge (at a dryness of 30%) and other solid waste (see para. 2.3). In addition to sewage sludge produced by DSD sewage treatment works, the following types of waste also require co-disposal at landfills:

(a) sludge from water treatment works;

(b) sludge from private/commercial/industrial operations;

(c) grease trap waste from restaurants and food processing factories; and

(d) abattoir and livestock waste.

5.3 In 1999, in respect of the disposal of waste at landfills, the EPD completed the Sludge Treatment and Disposal Strategy (STDS) Study for formulating an integrated strategy for sludge management. The Study found that:

(a) there would be an increase in the quantity of sewage sludge due to the implementation of the upgrading programmes for sewage treatment works;

(b) on the other hand, there would be a decrease in the quantity of solid waste due to the implementation of waste reduction measures; and

(c) therefore, the co-disposal ratio of 1:10 between sludge and solid waste would not be maintained by 2008.

Audit observations

Need to attain co-disposal ratio at landfills

5.4 Audit examination revealed that there had been a significant decrease of the sludge/solid waste co-disposal ratio over the past ten years. The ratio had fallen below 1:10 in the first eight months of 2006 (see Table 10).

Table 10

Sludge and solid waste disposed of at landfills
(1997 — 2006)

Year	Average quantity of solid waste (Note 1) (a) (tonne/day)	Average quantity of sludge			Sludge/ solid waste co-disposal ratio (e) = 1:(a)÷(d)
		Sewage sludge (Note 2) (b) (tonne/day)	Other sludge (Note 3) (c) (tonne/day)	Total (d)=(b)+(c) (tonne/day)	
1997	15,157	307	92	399	1: 38.0
1998	15,765	356	97	453	1: 34.8
1999	17,164	335	289	624	1: 27.5
2000	16,810	352	349	701	1: 24.0
2001	15,708	404	361	765	1: 20.5
2002	19,624	779	398	1,177	1: 16.7
2003	16,169	828	396	1,224	1: 13.2
2004	15,883	836	409	1,245	1: 12.8
2005	15,933	902	455	1,357	1: 11.7
2006 (Jan–Aug)	13,603	923	466	1,389	**1: 9.8**

Source: EPD records

Note 1: This included municipal solid waste and construction waste.

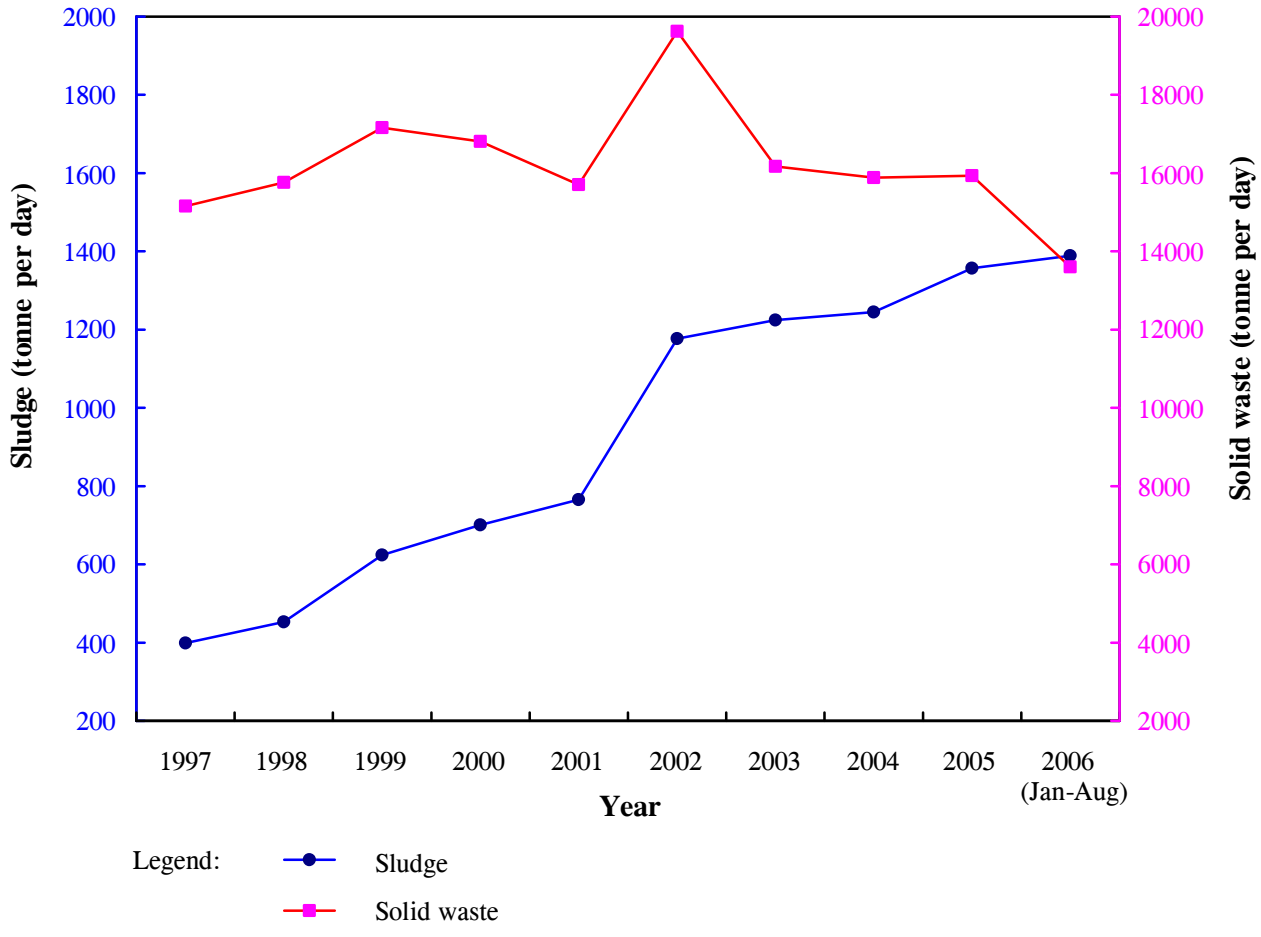
Note 2: This included sewage sludge from the DSD sewage treatment works and that from private sewage treatment works.

Note 3: This included other types of waste requiring co-disposal at landfills (see para. 5.2).

5.5 As shown in Table 10, over the past ten years, the average quantity of solid waste disposed of at landfills decreased from 15,157 tonnes a day in 1997 to 13,603 tonnes a day in 2006. On the other hand, the average quantity of sludge for disposal increased significantly from 399 tonnes a day in 1997 to 1,389 tonnes a day in 2006 (representing an increase of 248% over the period — see Figure 7).

Figure 7

Sludge and solid waste disposed of at landfills (1997 — 2006)



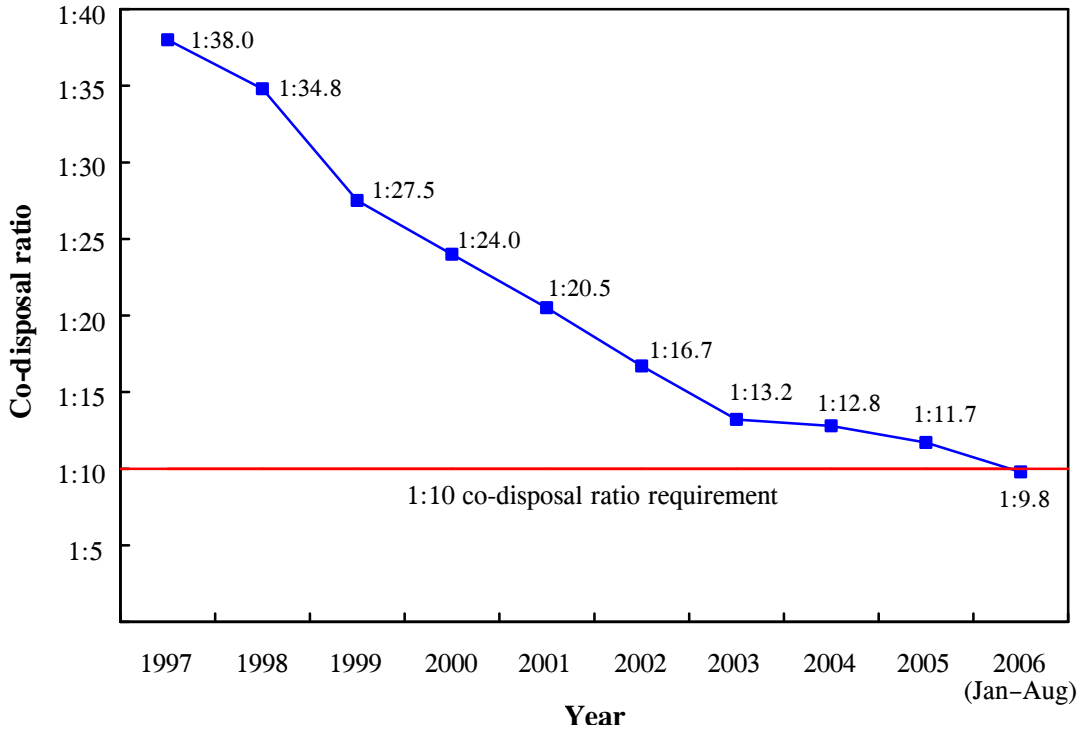
Source: *EPD records*

Remarks: *The scale showing the quantity of sludge is different from that for the quantity of solid waste.*

5.6 As a result of the significant increase in the quantity of sludge for disposal at landfills over the past ten years, the sludge/solid waste co-disposal ratio had decreased rapidly (see Figure 8).

Figure 8

Sludge/solid waste co-disposal ratios (1997 — 2006)



Source: EPD records

5.7 **As shown in Figure 8, for the first eight months in 2006, the sludge/solid waste co-disposal ratio fell below 1:10.** In fact, in 1999, the EPD predicted that the sludge/solid waste co-disposal ratio of 1:10 would not be maintained by 2008 (see para. 5.3(c)). Some landfill operational problems (such as instability of landfill slopes, excessive leachate generation and potential surface water contamination — see para. 2.2 (b)) may arise as a result of the non-attainment of the 1:10 ratio. **Audit considers that there is a need for the EPD to take appropriate measures to improve the situation.**

5.8 Audit examination of the sludge/solid waste co-disposal ratios of the three landfills revealed that the ratios were different (see Table 11):

Table 11

Sludge/solid waste co-disposal ratios of three landfills (2003 — 2005)

Year	Landfill		
	SENT	**WENT**	**NENT**
2003	1:13.1	**1:7.6**	1:19.7
2004	1:16.4	**1:7.6**	1:14.8
2005	1:16.0	**1:7.6**	1:10.1

Source: EPD records

5.9 Table 11 shows that, while both SENT Landfill and NENT Landfill exceeded the co-disposal ratio of 1:10 from 2003 to 2005, WENT Landfill attained only a co-disposal ratio of 1:7.6, which was considerably below 1:10. **Therefore, there is a need for the EPD to focus its attention on WENT Landfill with a view to attaining the 1:10 co-disposal ratio.**

5.10 Audit examination revealed that one of the reasons for WENT Landfill not attaining the 1:10 co-disposal ratio was that it received a large proportion of sewage sludge from the Stonecutters Island Sewage Treatment Works (see Table 12), which produced the largest quantity of sludge.

Table 12

Waste disposed of at landfills
(2005)

Landfill	Solid waste (a) (million tonnes)	Sludge			
		From Stonecutters Island Sewage Treatment Works (b) (tonne)	From other DSD sewage treatment works (c) (tonne)	Other (d) (tonne)	Total (e)=(b)+(c)+(d) (tonne)
SENT	2.78	81,000	48,000	44,000	173,000
WENT	2.04	**139,000**	10,000	121,000	270,000
NENT	0.98	0	30,000	67,000	97,000
Total	**5.80**	**220,000**	**88,000**	**232,000**	**540,000**

Source: EPD records

5.11 As shown in Table 12, in 2005, SENT Landfill received 2.78 million tonnes of solid waste and 173,000 tonnes of sludge (including 81,000 tonnes of sludge from the Stonecutters Island Sewage Treatment Works), resulting in a sludge/solid waste co-disposal ratio of 1:16. However, during the same period, WENT Landfill received 2.04 million tonnes of solid waste and 270,000 tonnes of sludge (including 139,000 tonnes of sludge from the Stonecutters Island Sewage Treatment Works), resulting in a sludge/solid waste co-disposal ratio of 1:7.6, i.e. below 1:10.

5.12 Audit noted that, in 2005, of the 220,000 tonnes of sewage sludge produced by the Stonecutters Island Sewage Treatment Works, 139,000 tonnes (63%) were delivered to WENT Landfill for disposal, and 81,000 tonnes (37%) to SENT Landfill (see Table 12). SENT Landfill's co-disposal ratio was 1:16, but WENT Landfill's ratio was only 1:7.6 (i.e. below 1:10). **Audit considers that there are merits for the EPD and DSD to explore the feasibility of diverting some sludge produced by the Stonecutters Island Sewage Treatment Works from WENT Landfill to SENT Landfill for disposal. This would help improve WENT Landfill's sludge/solid waste co-disposal ratio.**

Recycling of sewage sludge

5.13 In 1999, the EPD completed the STDS Study and found that:

(a) due to the progressive increase in sewage sludge and decrease in solid waste for disposal at landfills, it was necessary to examine alternative methods for sludge disposal; and

(b) one option for sewage sludge disposal was recycling (e.g. for agricultural use). However, the high chloride content of sewage sludge, the lack of markets for compost and the need for a large area for the related operations had rendered this option not feasible.

5.14 In January 2000, when the Advisory Council on the Environment (ACE — Note 9) was consulted on the STDS Study findings, the Council requested the Government to continue to explore the opportunities for reusing dewatered sewage sludge.

Audit observations

Need to explore opportunities for recycling sewage sludge

5.15 According to the EPD, due to the use of seawater for flushing, sewage sludge in Hong Kong has a high chloride content. This has affected the reuse of sewage sludge as compost or soil conditioner. Audit notes that, while 80% of the households use seawater for flushing, households in some districts still use fresh water for flushing. These districts include the Peak, Southern District, Sai Kung, North District and Yuen Long. Thus, sludge produced by the sewage treatment works at Stanley, Yuen Long and Shek Wu Hui has a relatively low chloride content. **There are merits for the EPD, in collaboration with the DSD, to explore the opportunities for recycling the sludge produced by these sewage treatment works. In doing so, the EPD and the DSD need to find sites for the recycling process and to find markets for the recycled products.**

Note 9: *The ACE advises the Government on appropriate measures for combating pollution, and protecting and sustaining the environment.*

Sludge incineration proposal

5.16 In 1999, the EPD completed the STDS Study and found that thermal treatment (such as incineration) was more suitable for sludge disposal in Hong Kong because this treatment could:

(a) remove water from sludge to avoid causing operational problems at landfills; and

(b) reduce the sludge volume by up to 90% which would help save landfill space. The remaining ash would be disposed of at landfills.

5.17 The STDS Study recommended that:

(a) all sewage sludge and waste of similar properties (e.g. grease trap waste) should be dewatered and incinerated prior to final disposal at landfills;

(b) a centralised treatment facility for incinerating sewage sludge and grease trap waste was the preferred option; and

(c) other types of sludge (see para. 5.2) would continue to be dewatered before disposal at landfills.

5.18 In December 1999 and January 2000, the ACE was consulted on the findings of the STDS Study. The ACE agreed that incineration would be the right direction if sludge production was unavoidable.

5.19 Between 2000 and 2003, the EPD conducted feasibility studies for sludge incineration at a centralised sludge treatment facility. The EPD:

(a) found that the sludge incineration proposal was technically feasible;

(b) proposed that a centralised sludge treatment facility should be built mainly for incinerating sewage sludge from the Stonecutters Island Sewage Treatment Works and ten regional sewage treatment works; and

(c) proposed that the facility would treat 2,000 tonnes of dewatered sewage sludge at 30% dryness a day.

5.20 In 2004, the EPD commissioned consultants to carry out an engineering and environmental feasibility study for developing a sludge treatment facility. The study reviewed the following:

(a) various sludge treatment options (including composting, drying and incineration);

(b) engineering, environmental and health-risk assessments;

(c) solid waste management;

(d) sewage treatment; and

(e) environmental pollution controls (including air emission controls).

As at December 2006, the EPD was finalising the study and was drawing up an implementation programme for the sludge treatment facility, adopting incineration as the treatment methodology.

Audit observations

Need to implement sludge reduction proposals

5.21 **In view of the sludge disposal challenges mentioned in paragraphs 5.4 to 5.12, Audit considers that there is a need for the EPD to expedite action to implement the proposed sludge treatment facility, adopting incineration as the treatment methodology which the EPD has considered to be the best option.**

5.22 In addressing concerns over air pollution resulting from sludge incineration, the EPD said that it would adopt the most stringent emission standards of overseas countries for the proposed facility.

5.23 The Government has acknowledged that there is room for improvement in the air quality in Hong Kong and has taken initiatives to make improvements. The initiatives include:

(a) in November 2005, the Government launched the Pearl River Delta Regional Air Quality Monitoring Network in cooperation with the Mainland;

(b) in July 2006, the Government launched the Action Blue Sky Campaign; and

(c) in November 2006, the Government signed the Clean Air Charter initiated by the business sector.

5.24 **In view of public concerns over air pollution associated with incineration, Audit considers that the EPD needs to take measures to minimise the impact on air quality due to incineration of sludge. There is also a need for the EPD to conduct wide public consultations on the proposed sludge treatment facility.**

Audit recommendations

5.25 **Audit has *recommended* that the Director of Environmental Protection should:**

(a) **closely monitor the disposal of sludge at landfills and take appropriate measures with a view to attaining the 1:10 co-disposal ratio, particularly at WENT Landfill (see paras. 5.7 and 5.9);**

(b) **in collaboration with the Director of Drainage Services, explore the feasibility of diverting some sludge produced by the Stonecutters Island Sewage Treatment Works from WENT Landfill to SENT Landfill for disposal (see para. 5.12);**

(c) **explore the opportunities for recycling sewage sludge with a low chloride content (such as that produced by the sewage treatment works at Stanley, Yuen Long and Shek Wu Hui — see para. 5.15);**

(d) **expedite action to implement the proposed sludge treatment facility (see para. 5.21);**

(e) **implement measures to minimise the impact on air quality due to incineration of sludge (see para. 5.24); and**

(f) **conduct wide public consultations on implementing the proposed sludge treatment facility (see para. 5.24).**

Response from the Administration

5.26 The **Director of Environmental Protection** agrees with the audit recommendations in paragraph 5.25. She has said that:

(a) the EPD will continue to closely monitor the disposal of sludge and similar waste at landfills, and will take appropriate measures to attain the 1:10 co-disposal ratio at WENT Landfill;

(b) subject to satisfactory environmental assessments, the EPD will consider diverting sludge from one landfill to another;

(c) the EPD will, in collaboration with the DSD, consider reviewing the feasibility of recycling sewage sludge produced by the sewage treatment works at Stanley, Yuen Long and Shek Wu Hui; and

(d) the EPD will carry out an environmental impact assessment (including an air-quality impact assessment) to ascertain the environmental feasibility of the proposed sludge treatment facility. The public will be consulted during the assessment.

5.27 The **Director of Drainage Services** has said that the DSD will continue to collaborate with the EPD to explore the feasibility of delivering less sludge produced by the Stonecutters Island Sewage Treatment Works to WENT Landfill for disposal.

Appendix

Acronyms and abbreviations

ACE	Advisory Council on Environment
Audit	Audit Commission
CEPT	Chemically enhanced primary treatment
DSD	Drainage Services Department
EPD	Environmental Protection Department
FC	Finance Committee
HATS	Harbour Area Treatment Scheme
ISDS	Integrated Sludge Disposal Strategy
LegCo	Legislative Council
NENT	North East New Territories
SENT	South East New Territories
STDS	Sludge Treatment and Disposal Strategy
WENT	West New Territories