



Research Office  
Legislative Council Secretariat

## Fact Sheet

# Management of restored landfills in selected places

FS02/18-19

## 1. Introduction

1.1 In Hong Kong, while three strategic landfills with a total area of 271 hectares are still in active operation, 13 landfills totalling 320 hectares closed during 1975-1996 are being restored for a minimum duration of 30 years. Prolonged restoration for closed landfills is necessary for management of various environmental hazards. For instance, **landfill gas** generated from waste decomposition could migrate horizontally and present odour nuisance, fire and explosion risks to the neighbourhood.<sup>1</sup> Moreover, polluting **leachate** generated from solid waste could contaminate the surrounding water bodies.<sup>2</sup> Furthermore, **ground settlement** of landfills is unsteady due to variations in waste decomposition beneath the surface, posing risks of capping rupture and slope instability. To address these environmental risks, good practice of landfill restoration first requires installation of treatment facilities upon closure of the landfills, followed by safe utilization of the sites during the aftercare period.<sup>3</sup>

1.2 In line with global practice, the Government had appointed two contractors to install restoration facilities (e.g. leachate treatment plant, landfill gas flaring plant and capping layers) in the 13 closed landfills during 1996-2006, with a total capital cost of HK\$1.3 billion. For the subsequent aftercare work, whereas these two contractors are obliged to manage the environmental impacts in the next 30 years, these sites were used as

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<sup>1</sup> More specifically, landfill gas comprises methane, a sort of greenhouse gas leading to global warming. Landfill gas took up about 3% of global greenhouse gas emissions in 2010.

<sup>2</sup> Leachate is liquid generated from moisture inside the solid waste, waste decomposition and rainwater infiltration. Untreated leachate could raise the total nitrogen level of the effluent, causing suffocation to the plant life and organisms in rivers and seas.

<sup>3</sup> As restored landfills cannot be used for building development in the next three decades due to settlement problem, they are mostly reserved for recreational usage.

recreational facilities managed by other parties.<sup>4</sup> In 2014, the Government also launched the "Restored Landfill Revitalisation Funding Scheme" valued at HK\$1 billion to support development of recreational and community facilities at the restored landfills. This notwithstanding, there have been occasional reports of malpractice in landfill management in recent years, such as substandard treatment of landfill gas and frequent discharges of untreated leachate at the Pillar Point Valley Restored Landfill ("PPVRL") during 2015-2017.<sup>5</sup> In addition, there are also concerns over a lack of progress in the conversion of landfill into open space for some 18 years at the Kwai Chung Park by mid-2018, after installation of on-site restoration facilities in September 2000.<sup>6</sup>

1.3 At the request of the Panel on Environmental Affairs, the Research Office has studied three overseas cases of good management practice in landfill restoration. The selected landfills include (a) the World Cup Park at Nanjido (蘭芝島) in **South Korea** acclaimed for its massive scale and wide public usage as an open park; (b) the Fudekeng Environmental Restoration Park (福德坑環保復育公園) in **Taiwan** for its generation of solar energy; and (c) regulatory regime on landfill operators in the private sector in **Australia** which may have implications for those places dominated by landfill contractors in the private sector. This fact sheet provides concise background information of the selected restored landfills, along with a summary table (**Appendix**).

## 2. The World Cup Park at Nanjido in South Korea

2.1 During 1990-2015, the number of landfills in South Korea had halved from 623 to 287, upon implementation of several waste reduction measures such as the volume-based waste charging in 1995. Amongst some

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<sup>4</sup> Five land licensees and the Leisure and Cultural Services Department ("LCSD") are responsible for managing the recreational facilities at the 13 closed landfills. As an illustration, the landfill at Gin Drinkers Bay is used for BMX cycling track and cricket grounds, Tseung Kwan O Landfill for football training centre and Shuen Wan landfill for golf driving range.

<sup>5</sup> Frequent complaints over substandard treatment of landfill gas and leachate at the PPVRL were lodged to the Environmental Protection Department. The contractor was convicted and fined a total of HK\$208,000 for 21 offences committed under the Water Pollution Control Ordinance between May 2016 and July 2017. The contractor had also violated contractual requirements for many times, resulting in a deduction of HK\$7.7 million from contractual payments.

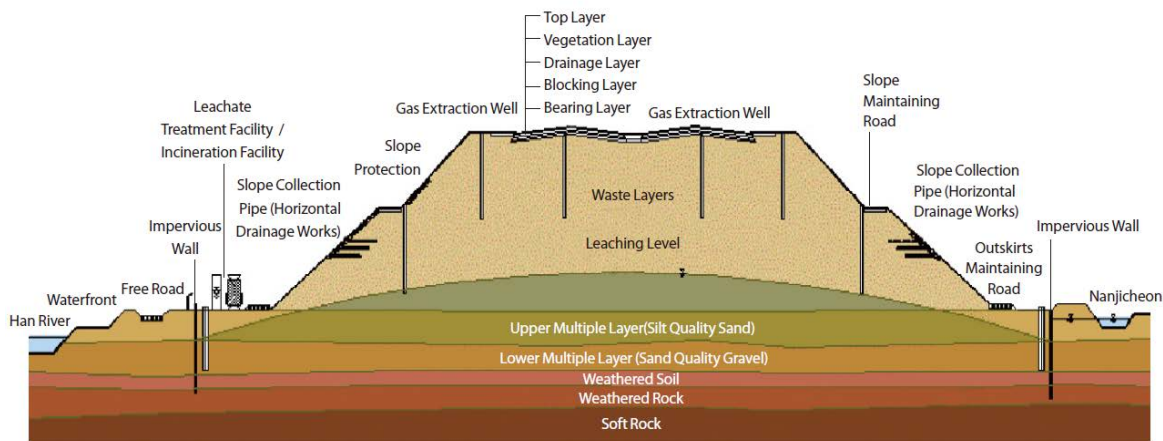
<sup>6</sup> Audit Commission (2018).

300 landfills which were closed over the past three decades or so, the restoration of the large dumping site at **Nanjido in Seoul** since 1996 is possibly the most noteworthy.<sup>7</sup> This is not only because of its massive area straddling 180 hectares, but also its subsequent transformation into a large open park for hosting the World Cup tournament in 2002.

2.2 The Seoul Metropolitan Government ("SMG") is responsible for landfill restoration at Nanjido and construction of World Cup Park, spending a total of 223.2 billion Won (HK\$1.4 billion). Similar to global practice, SMG has taken the following measures to manage the environmental hazards from landfills:

- (a) **Landfill gas:** Landfill gas at the World Cup Park is collected by 106 collection wells and transferred through a pipe network with a total length of 14 000 metres (**Figure 1**). The collected gas is used for district heating for over 16 000 households, 36 office buildings and three public buildings nearby;<sup>8</sup>

**Figure 1 – Cross section of World Cup Park at Nanjido in South Korea**



Source: Seoul Metropolitan Government (2017).

<sup>7</sup> Nanjido is an island located on a branch of Han River and was used as the sole landfill of Seoul during 1978-1992, taking up a total of 92 million cubic metres of solid wastes. After its closure in 1992, a Landfill Recovery Project was launched in 1996, with a view to restoring the ecosystems of the island. It was subsequently converted into the World Cup Park (comprising five smaller parks) which completed in May 2002.

<sup>8</sup> The total amount of landfill gas used for district heating during 2002-2013 was 232 million cubic metres, equivalent to a financial saving of about 8.2 billion won (HK\$58.2 million).

- (b) **Leachate:** Impervious walls and low permeability layers were erected and installed to prevent leakage of leachate to the slopes, bottom part of the landfill and outside the landfill. A total of 31 collection wells were installed as part of the leachate collection system underground. There is also an on-site leachate treatment facility which handles over 1 600 tonnes of leachate on daily basis;
- (c) **Capping system:** Compound materials (e.g. drainage and blocking layers) with a thickness of 5.4 metres were placed above the landfill as a protection layer. Besides, about 540 000 trees together with the vegetation layer were planted as part of the capping system to enrich the biodiversity of the World Cup Park; and
- (d) **Regular monitoring:** A total of 12 monitoring wells were set inside and outside of the World Cup Park for inspection of landfill gas migration and underground water contamination. In addition, investigations of settlement and slope stability are carried out regularly to minimize rainwater penetration and its corresponding leachate problem.

2.3 While the environmental measures taken in the restored landfill at Nanjido seem to be broadly similar to those taken in Hong Kong, it is globally acclaimed for several reasons. Reflecting an improved ecosystem, biodiversity of Nanjido has significantly improved after restoration, with a doubling in species of plants from 271 to 582 during 2000-2013. Meanwhile, there were 80% growth in terrestrial insects and 50% growth in wild birds. So far, there has been no report in the public domain on major incident on leakage of leachate and landfill gas from the World Cup Park. The World Cup Park has also become a landmark facility in Seoul, attracting around 10 million visitors each year (equivalent to at least one per capita visit for citizens of Seoul annually). In October 2010, the SMG was presented an award by the United Nations on its achievement in landfill restoration at Nanjido. It also attracts over 3 000 public officials and delegates from other places to learn from its successful restoration experience every year (**Figure 2**).

**Figure 2 – World Cup Park at Nanjido in South Korea**



Source: Seoul Metropolitan Government (2017).

### **3. The Fudekeng Environmental Restoration Park in Taiwan**

3.1 The number of landfills in Taiwan has also sharply fallen over the past two decades, upon implementation of several waste reduction initiatives and increasing waste incineration as a waste disposal measure. Amongst the 378 landfills in Taiwan at end-2016, as many as 196 landfills or 52% were being restored. While a majority of them are used for recreational purposes, the **Fudekeng Environmental Restoration Park** is particularly noteworthy because of its additional usage for generation of renewable energy.

3.2 The landfill at Fudekeng has a total area of 37 hectares, taking up some eight million cubic metres of solid waste in the 1980s and 1990s. It was closed in 1994 and then transformed into a park after completion of restored work in 2003.<sup>9</sup> In July 2016, the Taipei City Government ("TCG") entered into an agreement with an enterprise to build a photovoltaic power station on a three-hectare site at the park, which is also named as Taipei Energy Hill (台北能源之丘).<sup>10</sup> In January 2017, the project at Fudekeng commenced generation of solar energy, upon installation of 8 000 solar panels on-site. This scale is noticeably bigger than the sum of about 5 000 solar PV

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<sup>9</sup> Fudekeng Environmental Restoration Park provides fields for grass skiing, cycling and flights of remote control aircrafts. In the future, facilities for leisure, entertainment and education will be added, making it a more attractive spot for citizens and tourists.

<sup>10</sup> This is one of the initiatives taken by TCG to meet the policy objective of generating 10% of total power from renewable energy by 2025. For the public-private partnership at Fudekeng, it requires the contractor to provide and maintain the solar panels for the following 20 years, while TCG can receive 10% of the revenue made from electricity generated in return.

panels installed in three places in Hong Kong (i.e. Siu Ho Wan Sewage Treatment Works, Shek Pik Reservoir and Plover Cove Reservoir).<sup>11</sup>

3.3 TCG is responsible for landfill restoration at the Park during the aftercare period. Based on limited information available, it appears that the following safety measures taken in Fudekeng are similar to other advanced places:

- (a) **Landfill gas:** Collection pipes and biogas generation facilities were installed to gather and utilize landfill gas for electricity generation. It provides 3.5 million kWh of power for 1 000 households every year;
- (b) **Leachate:** After collection from pumping wells, leachate goes through biological and chemical treatment procedures before discharge. To maintain the water quality, external consultants are appointed to conduct surveys from monitoring wells along the river course twice a year;
- (c) **Capping system:** Multiple layers of impermeable barriers, coarse sand and soil were used to cover and protect the surface of the closed landfill; and
- (d) **Regular monitoring:** There are regular inspections on leachate, underground water, air quality and vector as reference for subsidy provision by the Government.

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<sup>11</sup> In Hong Kong, Drainage Services Department set up a solar plant in Siu Ho Wan Sewage Treatment Works in December 2016. With 4 237 solar panels, this is the largest solar farm in Hong Kong. Meanwhile, Water Supplies Department installed solar PV panels on the surface of the Shek Pik Reservoir in February 2017 and Plover Cove Reservoir in October 2017, with 352 solar panels each. Altogether, these three projects have a total of 4 941 solar panels, generating 1.34 million kWh of electricity which is sufficient to meet the needs of 302 households each year.

3.4 Taipei Energy Hill is hailed as a successful experiment for renewable energy development in Taiwan (**Figure 3**). The photovoltaic power station can generate two million kWh of electricity per annum (equivalent to annual electricity consumption of 573 households), creating some NT\$1 million (HK\$262,000) of annual revenue to TCG. As a matter of fact, Taipei Energy Hill has won the Special Award of 2018 FIABCI-Taiwan Real Estate Excellence Award for its accomplishment in green energy development. In the light of this successful precedent in Fudekeng, TCG is committed to building "Taipei Energy Hill 2.0" by early 2019 at Shanshuilu Ecological Park, another restored landfill located in Nangang District (南港區) of Taipei.<sup>12</sup>

**Figure 3 – Fudekeng Environmental Restoration Park in Taiwan**



Source: Taipei City Government (2017).

## 4. The Chains of Parks in Australia

4.1 As landfills in Australia are largely built to meet the needs of local governments and serve a population of less than 5 000, their sizes are mostly smaller compared to those in Seoul and Taipei.<sup>13</sup> Moreover, operation of landfills (including those in use and the closed ones) in Australia are usually outsourced to landfill contractors in the private sector, which are increasingly dominated by large enterprises. This poses a challenge for the regulatory authorities in Australia to ensure that the contractors can meet the environmental and safety standards throughout the life cycle of landfills.

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<sup>12</sup> Taipei Energy Hill 2.0 comprises a solar power system with 1MW of installation capacity, covering about 1 hectare of the Shanshuilu Ecological Park. The expected annual electricity generation is around 1 million kWh, about half of that at Fudekeng.

<sup>13</sup> Waste Management Association of Australia (2013).

4.2 More specifically on landfill restoration, the state governments have taken steps to tighten respective regulations and introduce guidelines for the operators of closed landfills since the 1990s. Taking the state government in Victoria as an illustration, it published the "**Closed Landfill Guideline**" ("CLG")<sup>14</sup> in 2012 and the "**Best Practice Environment Management – Siting, Design, Operation and Rehabilitation on Landfills**" ("BPEM")<sup>15</sup> in 2015, ensuring that operators of 560 closed landfills within the state can comply with the requirements. Furthermore, under a licence programme for post-closure landfills, operators of such landfills may be subject to a fine of up to AU\$387,000 (HK\$ 2.2 million) if they contravene a requirement stipulated by the regulatory authority, and AU\$193,000 (HK\$ 1.1 million) on daily basis if the offence continues.<sup>16</sup> Apart from the penalty, a special provision of financial assurance under the licence programme also enables the Government to clean up a landfill funded by the prepaid deposit when the operator fails to do so.

4.3 In Victoria, there are more than 30 active and closed landfills covering 261 hectares in the Kingston's Green Wedge close to Melbourne, with an average area of only 9 hectares per landfill. The City Government of Kingston is redeveloping all the landfills within its Green Wedge into "**Chain of Parks**" by phases in the coming decades. After the planning amendments in October 2015, while all waste businesses (including landfill operation) will be phased out gradually, all closed landfills will be rezoned as public open space, with pedestrian and bicycle trails as inter-links between them (**Figure 4**).

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<sup>14</sup> In CLG, it provides guidance to landfill operators for meeting the requirements of rehabilitation and aftercare management for closed landfills. Operators are required to conduct environmental audit and submit such reports to the authority regularly.

<sup>15</sup> BPEM stipulates the best practice of landfills in Victoria, taking into account the risks that landfills pose to the environment.

<sup>16</sup> Post-closure pollution abatement notice ("PC PAN") has been used as statutory tool to manage the risks from closed landfills in Australia since the 1990s. See Environment Protection Authority Victoria (2018c).



**Figure 4 – The Chain of Parks in Australia**



Source: City Council of Kingston (2018).

4.4 As regards environmental hazards arising from landfill restoration, the following measures based on aforementioned CLG/BPEM will be taken in the Chain of Parks:

- (a) **Landfill gas:** Landfill gas treatment equipment and extraction wells will be installed at closed landfills so as to control gas concentration levels. Depending on the amount of landfill gas, different technologies will be adopted for gas utilization;<sup>17</sup>
- (b) **Leachate:** Leachate collection system (consisting of drainage layer, collection pipes and sump) will be installed as an integral component of the landfill liner system. Landfill operators have to carry out hydrogeological assessment to identify maximum leachate levels allowed before obtaining the licence;
- (c) **Capping system:** Long-term stable barriers comprising low-permeability clay, geo-membrane, soil and collection systems for gas and leachate are needed in order to separate waste from the environment. Capping materials will be selected based on its ability to withstand stress from large differential settlement; and

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<sup>17</sup> If the generation of landfill gas is at a high level (i.e. over 1 000 cubic metres per hour), operators will be recommended to utilize gas for combined heat and power generation. If the generation rate is low, flaring or discharging methods will be preferred.

- (d) **Regular monitoring:** Operators need to devise an environmental monitoring programme, demonstrating their compliances with landfill gas concentrations, leachate levels, groundwater quality and air quality. The state government will also appoint environmental auditors to assure that the operators comply with the requirements of CLG and BPEM.

## 5. Concluding remarks

5.1 While restoration of landfills in Hong Kong is generally in line with global practice, there are occasional reports of malpractice in management of leachate and landfill gas. Whereas the selected landfill at World Cup Park in South Korea is globally acclaimed for its massive scale of restoration, the one at Fudekeng in Taiwan is renowned for solar power generation. For the selected landfills at the Chain of Parks in Australia, they can serve as a model for public regulation of private contractors in landfill restoration.

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## Environmental measures of selected landfills under restoration

	Hong Kong	South Korea	Taiwan	Australia <sup>(1)</sup>
<b>1. Selected landfill under restoration</b>				
- Selected landfill under restoration	Shuen Wan Golf Course	World Cup Park	Fudekeng Park	Kingston's Chain of Parks
- Size of the landfill (hectare)	55	180	37	9 <sup>(2)</sup>
- Total waste received (million tonne)	15	143	-	-
- Year of usage as landfill	1973-1995	1978-1993	1985-1994	-
<b>2. Usage of the landfill</b>				
- Restoration period after closure	1996-1997	1996-2002	1996-2003	-
- Aftercare period (number of years)	30	30	-	30
- Major usage	Golf course	Park	Solar energy and park	Park
- Total restoration cost	HK\$167.7 million	223.2 billion won (HK\$1.4 billion)	NT\$460 million (HK\$104.4 million)	-
- Annual operation cost in 2016	HK\$4.1 million	-	NT\$6.2 million <sup>(3)</sup> (HK\$1.6 million)	-
- Managing party	Government and Contracting party	Government	Government	Government and Contracting party
<b>3. Landfill gas management</b>				
- Usage of landfill gas	Towngas generation	District heating	Electricity generation	Depending on output level
- Collection well and pipe	✓	✓	✓	
- On-site gas utilization plant	✓	✓	✓	

Notes: (1) As the project of Chain of Parks is still in the developing stage, information for Australia is based on the requirements specified in the "Closed Landfill Guideline" ("CLG") and "Best Practice Environment Management – Siting, Design, Operation and Rehabilitation on Landfills" ("BPEM").

(2) The reported figure is the average area of some 30 active and closed landfills in Kingston's Green Wedge.

(3) The reported figure reflects the annual management cost of Fudekeng Park in 2008.

(-) Not applicable or not available.

## Environmental measures of selected landfills under restoration

	Hong Kong	South Korea	Taiwan	Australia <sup>(1)</sup>
<b>4. Leachate management</b>				
- Collection of leachate by pump station and draining facilities	✓	✓	✓	✓
- Surface water and drainage	✓	✓	✓	✓
- Leachate treatment	Off-site <sup>(4)</sup>	On-site	On-site	On-site
<b>5. Capping system</b>				
- Low permeability lining	✓	✓	✓	✓
- Soil and vegetation	✓	✓	✓	✓
<b>6. Monitoring and maintenance</b>				
- Landfill gas	✓	✓	✓	✓
- Leachate and groundwater	✓	✓	✓	✓
- Settlement	✓	✓	✓	✓
- Capping system	✓	✓	✓	✓
- External monitoring and assurance	✓	✓	✓	✓

Notes: (1) As the project of Chain of Parks is still in the developing stage, information for Australia is based on the requirements specified in the "Closed Landfill Guideline" ("CLG") and "Best Practice Environment Management – Siting, Design, Operation and Rehabilitation on Landfills" ("BPEM").

(4) Leachate from the Shuen Wan Landfill is collected and delivered to the adjacent Tai Po Sewage Treatment Works of the Drainage Services Department for treatment.

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