<Summary>

Research title

CDM Feasibility Study for Methane Emissions Avoidance at Waste Landfill Site in China

Research organization

Pacific Consultants Co., LTD.

1. Summary of project

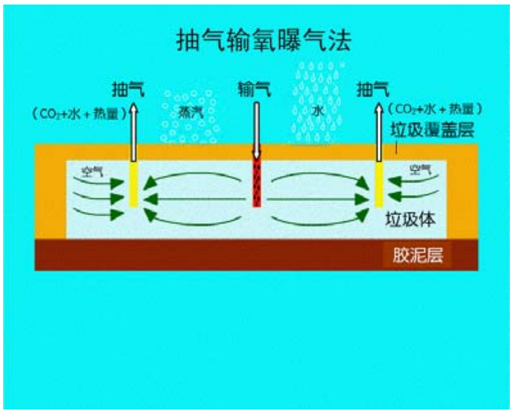
(1) Host country, region

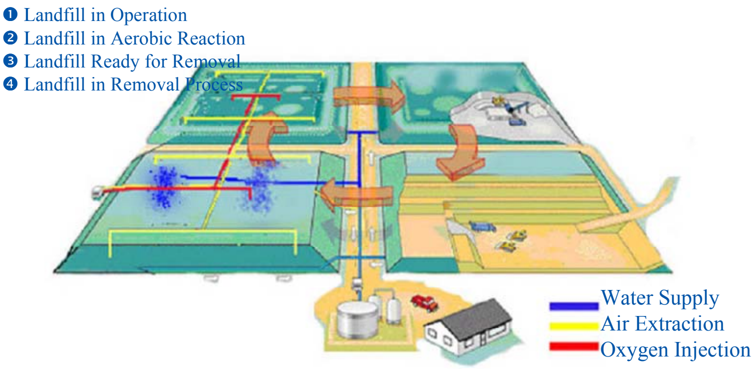
People's Republic of China, Beijing City

(2) Summary of project

The purpose of this research is realizing the project where project participants will avoid the methane emissions from municipal solid waste (MSW) landfill site in Beijing city in China as a CDM project. The target MSW landfill site is already closed from waste disposal and landfill surface is covered by soil. For avoidance of methane emissions from the degradable waste landfill body in anaerobic condition the project participants will set air injection and water circulation equipments and keep appropriate temperature of landfill body in aerobic condition.

This project will enable not only remediation of discharge water quality but also reducing of waste volume and accelerating of land utilization by facilitation of aerobic waste degradation.





2. Research descriptions

(1) Research tasks

There is no applicable approved methodology for this project so far, development of new methodology is needed with referring to similar methodology such as ACM0001 "Consolidated baseline and monitoring methodology for landfill gas project activities" and AM0025 "Avoided emissions from organic waste through alternative waste treatment processes".

Specific issues and points for new methodology could be enumerated as follows.

- When revision of AM0025 for similar project (avoidance of methane emissions from closed landfill site) was submitted to the UNFCCC, the methodology panel recommended development of a new methodology for the project because AM0025 covers alternative treatment processes for fresh waste (not for existing waste).

- As to alternative treatment processes of MSW, approved methodologies and tools such as "Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site" should be taken into account for developing realistic new methodology.
- NM0290 "Reduction of greenhouse gas emissions from landfill sites improved to be in semi-aerobic conditions" also should be taken into account because the target of this new methodology is similar to our project.
- Clarification of realistic estimation methodology of baseline methane emissions will be needed. The baseline methane emissions could be directly measured in methane capture CDM project; however this project (on-site aeration in landfill body) will prevent methane emissions themselves and direct measurement of methane emissions in the absence of project activity will be impossible.
- For estimation of baseline methane emissions, this methodology will apply the first order decay (FOD) model; however the FOD model is criticized on over estimation of methane emissions from the MSW disposal site so far.
- Clarification of realistic estimation methodology of project "residual" methane emissions will also be needed. Residual methane emissions under implementation of on-site aeration might be able to negligible; however the project participants have to certify the residual methane emissions from both of venting pipes and landfill surface.
- In case of application of the FOD model for project methane emissions estimation, the applicability should be clarified because the FOD model is basically suitable for anaerobic condition (not for aerobic condition).

(2) Research implementation framework

- The counterpart "GCE: Green Castle Environmental" has substantial knowledge and experience of waste treatment technology. GCE has past successful results of implementation of on-site aeration in MSW landfill sites in US.
- JCE inc has so substantial knowledge and experience of Chinese environmental issues and CDM projects circumstances that could be essential partner entity in this project.

(3) Research descriptions

1) Site visits

Through three time meetings with GCE and site visits to the project site, PCKK and GCE established cooperative relationship as to realization of on-site aeration technology implementation as CDM project in Beijing. GCE came up with technical information and site specific data for development of new methodology and PDD.

2) Solutions of research tasks

○ How could baseline methane emissions in the absence of project activity be certified?

- Calculate baseline methane emissions by applying the first order decay (FOD) model in the tool "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site"

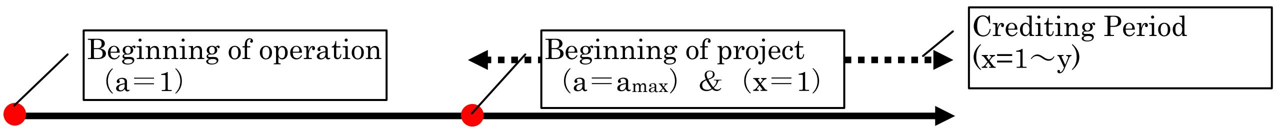
$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j (y-x)} \cdot \left(1-e^{-k_j}\right)$$

- The amount of waste type j in the year x ($W_{j,x}$) should be estimated by waste sampling such as on-site boring survey. Then classification of waste types should be limited only to degradable waste such as foods and not degradable waste such as plastics as a practical measure.

<Option A>

- The weighted average age[1] of the wastes at the start of the project considering the yearly amount of wastes deposited could be considered as average existing waste age which was disposed of in the landfill site from the beginning of the landfill operation to the project activity implementation.

$$\bar{a} = \frac{1 \cdot A_1 + 2 \cdot A_2 + 3 \cdot A_3 + \cdots + a \cdot A_a}{A_1 + A_2 + A_3 + \cdots + A_a}$$



ā : Weighted mean age of the wastes present in the SWDS prior to the project start. a : Years before project start, starting in the first year of waste disposal (a=1) up to the maximal age of the wastes (a=amax). Aa : The amount of waste deposited in each year "a". It shall be obtained from recorded data of waste disposals.

- Exponential function term "exp[-kj.(y-x+ā)]" could be applied instead of "exp [-kj.(y-x)]" in the FOD model, where x will begin from the project implementation.

$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot \boxed{e^{-k_j (y-x)}} \left(1-e^{-k_j}\right)$$

- If the recorded data of waste disposals could not be available, average waste age (ā) could be estimated as an arithmetic mean age ($\bar{a} = 0.5 * a_{max}$).

<Option B>

- Fraction of degradable organic carbon (DOCj) could be measured by waste sample laboratory analysis. And decay rate for the waste stream type j (kj) could be decided by applying the default value for Bulk waste in IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 5.

[1] AMS-III.E. Avoidance of methane production from biomass decay through controlled combustion, gasification or mechanical/thermal treatment

- Project participants could conduct waste sampling more than twice. The first sampling should be conducted before the project activity implementation for estimation of baseline methane emissions. The second sampling should be conducted before the project activity termination for confirmation of successful aerobic degradation completion.
- Recorded data of waste disposals (i.e. organic carbon decay fraction) would be unnecessary because DOC could be directly measured in the beginning of the project activity.
- Year for which methane emissions are calculated (y) in FOD model could be considered as elapsed time from the beginning of the project activity.
- In this option the biochemical parameters such as $W_{j,x}$, DOC_j and k_j could be clearly decided through waste sample laboratory analysis and the average waste characteristic in the MSW landfill site could be obtained.
- Sample size (i.e. number of existing waste samples) could be decided statistically. The existing waste samples shall be chosen in a manner that ensures estimation with 20% uncertainty at 95% confidence level. On one hand too few sample size will increase estimation uncertainty level on the other too many sample size will increase waste survey cost.

○ How could project residual methane emissions from on-site aeration be certified?

- Direct measurement of venting methane emissions during project activity by gas flow meters and gas quality analyzers set in venting wells could be defined as P_{EV}.
- Sample size (i.e. number of venting methane samples) could be decided statistically. The venting methane samples shall be chosen in a manner that ensures estimation with 20% uncertainty at 95% confidence level.
- Direct measurement of surface methane emissions during project activity by gas flow meters and gas quality analyzers attached to flux boxes could be defined as P_{ES}.
- Sample size (i.e. number of surface methane samples) could be decided statistically. The surface methane samples shall be chosen in a manner that ensures estimation with 20% uncertainty at 95% confidence level.
- The aggregation of both P_{EV} and P_{ES} could be total amount of residual methane emissions (P_E) during the project activity.

  $$P_E = \Sigma P_{EV} + \Sigma P_{ES}$$
- Inverse operation of methane emission factor (MCF) in the FOD model could be obtained by substitution of P_E to the FOD model. Then the calculated MCF might be in range of 0 (for aerobic condition) – 0.5 (for semi-aerobic condition).

3. Project implementation

(1) Project boundary and baseline scenario

1) Project boundary

The spatial extent of the project boundary encompasses the physical delineation of closed landfill site where existing wastes are aerobically treated by on-site aeration and discharge water circulation, and on-site electricity consumption and/or generation for activating of equipments and machines.

2) Baseline scenario

The baseline scenario is identified as partial or total atmospheric release of LFG generated from anaerobic degradation process of municipal solid organic waste at the closed landfill site without any capture and/or combustion of methane (i.e. business-as-usual scenario).

3) Application of a baseline and monitoring methodology

Proposed new methodology "Avoidance of methane emissions from closed landfills by on-site aeration of existing wastes" is applied to this project.

This methodology applies the same approach as ACM0001 and AM0025 from the aspect of estimating baseline emissions based on the FOD model. However this methodology proposed on-site aeration technique to avoid methane emissions from closed landfills by remediation of anaerobic condition in landfill body instead of methane capture and/or combustion.

4) Leakage

No leakage effects need to be accounted under this methodology because on-site aeration is implemented within the closed landfill site and any treated waste will not transferred across project boundary.

5) Emission reductions

Baseline emissions are identified as methane emissions from the closed landfill site in the absence of the project activity.

Otherwise residual methane emissions should be taken into account as project emissions during the project activity in case of incompletion of aerobic degradation treatment process.

At the same time project emissions from the electricity consumption for activating of equipments and machines should be taken into account.

Emission reductions are calculated as follows.

Emission reductions	=	Methane emissions in the absence of project activity	—	Residual methane emissions in the project activity	—	Project emissions from the electricity consumption

○ Baseline methane emissions in the absence of the project activity

The amount of methane generated from the landfill ($BE_{CH4,SWDS,y}$) could be estimated by FOD model applied in "Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site". In ex-ante estimation the amount of waste type j in the year x ($W_{j,x}$) could be estimated based on recorded data of waste disposals and waste type j could be estimated by simple method of waste sampling.

Based on default values of the tool and site specific data, the amount of methane generated from the landfill ($BE_{CH4,SWDS,y}$) during 2010 - 2016 could be estimated as follows.

Year	2010	2011	2012	2013	2014	2015	2016
$BE_{CH4,SWDS,y}$	151,290	136,893	123,866	112,079	101,413	91,726	83,030

Parameters in the FOD model, applied values and sources of data are as follows.

$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j (y-x)} \cdot \left(1-e^{-k_j}\right)$$

parameter	value	source of data used
φ = Model correction factor to account for model	0.9	default value of the tool
f = Fraction of methane captured at the SWDS and flared, combusted or used in another manner	0	no regulation or law
GWP_{CH4} = Global Warming Potential of methane, valid for the relevant commitment period	21	IPCC 2006 GNGGI
OX = Oxidation factor	0.1	IPCC 2006 GNGGI
F = Fraction of methane in the SWDS gas	0.5	default value of the tool
DOC_f = Fraction of degradable organic carbon that can decompose	0.5	IPCC 2006 GNGGI
MCF = Methane correction factor	1	IPCC 2006 GNGGI
x = Year during the operation periods: x runs from the first year of the operation period (x = 1) to the year y for which avoided emissions are calculated (x = y)	1995 - 2016	project participants
y = Year for which methane emissions are calculated	2010 - 2016	project participants
j = Waste type category	-	index of the tool
$W_{j,x}$ = Amount of organic waste type j disposed of in the SWDS in the year x (tons)	289,150	project participants
DOC_j = Fraction of degradable organic carbon (by weight) in the waste type j	0.266	project participants
k_j = Decay rate for the waste type j	0.10	IPCC 2006 GNGGI

○ Residual methane emissions in the project activity

Theoretically no methane generation would occur from landfill body in aerobic condition by on-site aeration. However project participants should confirm the complete avoidance of methane emissions, and should take into account residual methane emissions in the case of incomplete aerobic condition during project activity. However for ex-ante estimation, the project participants could neglect the residual methane emissions by assuming the methane correction factor “MCF” in the FOD model to be 0 in aerobic condition.

○ Project emissions from the electricity consumption ($PE_{EC,y}$)

The yearly amount of electricity generated in an on-site fossil fuel fired power plant or consumed from the grid as a result of the project activity is estimated as 636MWh/year.

In this project activity the carbon emission factor for electricity consumption (CEF_{elec} = 0.9928tCO_2/MWh) based on “2008 Baseline Emission Factors for Regional Power Grids in China” is applied. As a result project emissions from the electricity consumption are estimated as 631 tCO_2/year.

(2) Monitoring plan

○ Existing organic waste sampling

The baseline emissions of anaerobic methane generation could be calculated based on the FOD model. The characteristics of existing wastes such as the different waste type j with respectively different decay rates kj and different fractions of degradable organic carbon (DOCj) could be identified based on the existing organic waste sampling.

The waste samples could be obtained by open excavation survey and/or on-site boring survey, and project participants could conduct waste sample laboratory analysis.

The existing waste samples should be statistically analyzed in a manner that ensures the representativeness of waste characteristics for the landfill body which has certain extend and depth with 20% uncertainty at 95% confidence level.

○ Monitoring of residual methane emissions

The amount of landfill gas emissions from each venting pipes could be measured (in m^3, by using a gas flow meter) monthly or at least quarterly. And the fraction of methane in the LFG should be measured with a continuous gas analyzer (in tCH_4/m^3, by using a flame ionization detector). The average amount of landfill gas emissions from each surface capping area and the methane concentration could be measured by using flux box survey (with a gas flow meter and a flame ionization detector attached a flux box, and a recording data logger) monthly or at least quarterly.

Simultaneously monitoring of temperature and pressure of the LFG are required to determine the amount of the LFG and the density of methane gas in the LFG. However no separate monitoring of temperature and pressure is necessary when using gas flow meters that automatically measure both temperature and pressure.

(3) Emission reductions

Based on both baseline methane emissions in the absence of the project activity and project emissions from the electricity consumption, summary of the ex-ante estimation of emission reductions are determined as follows.

Year	2010	2011	2012	2013	2014	2015	2016
$BE_{CH4,SWDS,y}$	151,290	136,893	123,866	112,079	101,413	91,763	83,030
$PE_{EC,y}$	631	631	631	631	631	631	631
Total	150,659	136,262	123,235	111,448	100,782	91,131	82,399

(4) Duration of the project activity / crediting period

The beginning of project activity is scheduled as April 1st 2010. And the crediting period is planned as 7 years from October 2010 to September 2016.

(5) Environmental impacts

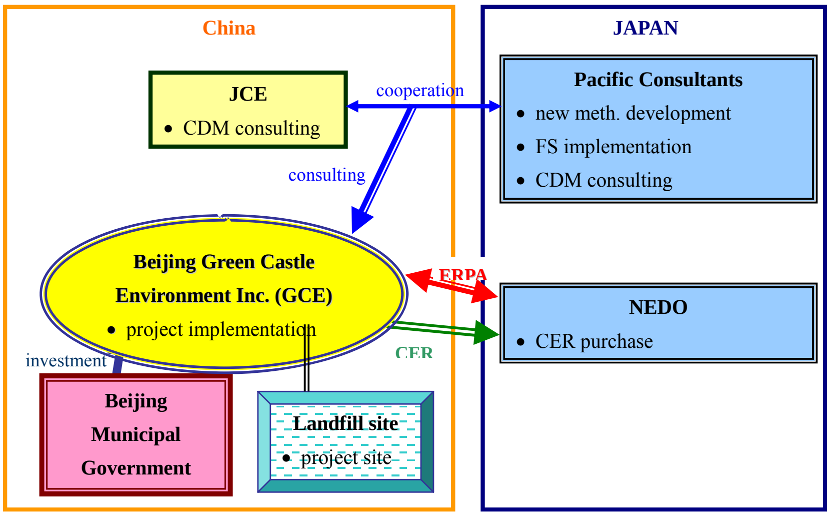
Discharge water from the closed landfill site should be collected and circulated by the on-site aeration technique applied in this project. Then quality of discharge water should be kept in appropriate condition and be prevented from water contamination.

At the same time State Environmental Protection Administration of China (SEPA) does not have any law or regulation as to operational modification of closed MSW landfill site for additional environmental impact assessment such as discharge water quality evaluation.

(6) Stakeholders' comments

First and foremost new methodology should be submitted with draft-PDD. Then project participants should take place the stakeholders' meeting for correction of comments and/or requirement from residents living in the vicinity of the landfill site before the PDD validation.

(7) Project implementation framework



(8) Funding plan

This project is planned to be realized with both Beijing city's subsidy and the People's Bank of China's investment except CER revenues.

Project participants could not make any direct revenues by methane emissions avoidance project itself with on-site aeration technique. However If applicable, the project participants should consider revenues by land use after the project activity. Because this project will enable not only remediation of waste degradation condition but also reducing of waste volume and accelerating of land utilization by facilitation of aerobic waste degradation. The land use revenues will be estimated by considering both the city plan and the average neighborhood land value.

The Bei Tian Tang landfill site is placed at suburban village in Beijing where land use is planned as public area such as green space and sports park, and construction of high building is prohibited by land use planning in Bei Tian Tang district. Thus commercial uses such as residential development, commercial establishment will be unreal social and economic scenarios.

(9) Investment analysis

If applicable, the project participants should consider revenues by land use after the project activity. As Table below indicates, although internal rate of return (IRR) without CDM credits will be only 1.2%, that with CDM credits will be improved even 36.2%. Besides the project participants will be able to recover the investment costs at early year with CDM credits. Therefore CDM credits will become important financial incentive to realize the proposed project activity. Under the benchmark analysis, the IRR of the project activity should be compared with a reasonable benchmark. The selected benchmark is the interest rate of credit for investment by commercial banks in China. That value at the time of the PDD completion is 5.94–7.72% in March 2009, according to the open-to-public website by the People's Bank of China, the China's central bank.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Investment costs	35.8									
Operation costs		5.6	5.6	5.6	5.6	5.6	5.6			
CDM credits	15.1	13.6	12.3	11.1	10.1	9.1	8.2			
Land use revenues								25.0	25.0	25.0
Summary with CDM	-20.7	8.0	6.7	5.5	4.5	3.5	2.6	25.0	25.0	25.0
IRR (with CDM credits) = 36.2%										
Summary without CDM	-35.8	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	25.0	25.0	25.0
IRR (without CDM credits) = 1.2%										

(10) Assessment and demonstration of additionality

Project participants could not make any direct revenues by methane emissions avoidance project itself with on-site aeration technique. There is no law or regulation to stipulate for application of on-site aeration technique in closed landfill site in China. Considering that investment costs would stand even 35.8 in millions of RMB, it would not realistic that this project could be realized without CER revenues.

○ **Identification of alternatives to the project activity**

- Case A: The atmospheric release of LFG generated from anaerobic degradation process of organic waste matter at the landfill site (business-as-usual).
- Case B: The retrofitting with landfill gas collection and combustion system to comply with laws and regulations or contractual requirements.
- Case C: The composting treatment of existing wastes excavated from the landfill for recycling or re-disposing.
- Case D: The project activity (on-site aerobic treatment of existing wastes) without registration as a CDM project activity.

Case B, Case C and Case D are all technically feasible, however economically unattractive. Meanwhile Case A is compliant with current national/local mandatory laws and regulations and economically feasible. Therefore the only Case A (business as usual) is identified as the most likely baseline scenario for the proposed project activity.

○ **Common practice analysis**

Under current situation in China, in general, closed landfill sites are dealt with as follows:

- Untreated landfill sites where the atmospheric release of LFG generated from anaerobic degradation process dominate almost all actual landfill sites since no mandatory laws and regulations stipulate for control and/or treatment of LFG from closed landfills;
- All cases where the retrofitting with landfill gas collection is employed or the composting treatment of existing wastes is employed are realized by using CDM incentives and/or other public funds;
- On-site aerobic treatment of existing wastes is not employed anywhere in Beijing.

○ **Conclusion**

As mentioned above untreated landfilling is common practice and the project activity without CER revenues or other public fund is implausible. Therefore the proposed project activity is additional and is eligible as a CDM project.

(11) Issues and expectations for project implementation

The China government and the Beijing authority accept the possible good effect of this project; however, this project is the first case to apply this technology in China so far. This technology is applied only in the US. Therefore, this project should be a demonstration case. In addition proper landfill management with co-benefits is most acceptable to Chinese authority. Therefore the realization of this project as a CDM project will contribute to proper landfill management technique as well as contribute to environmental improvement and sustainable development in both urban and local communities in China.

5. Prospective co-benefits in host country

The project activity will bring about both environmental and socioeconomic good effects in community areas as follows:

- The methane gas generation through anaerobic decomposition of the landfilled municipal solid wastes will be avoided at the root;
- The toxic elements elution from the existing waste materials under aerobic condition in the landfill body will be also avoided at the root;
- The chemical oxygen demand level and contamination of drainage leachate from the landfill will be highly reduced;
- The stability of landfill site will be achieved in relatively short period of time and land use such as green space will be facilitated.