# Landfill Gases at an Abandoned Open Dump: A Case Study at Udapalatha/Gampola Site in the Central Province of Sri Lanka

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***Abstract:*** *There are very limited studies on landfill gas on uncontrolled open dumps in developing countries. In this study, landfill gas samples at 1 m depth from an abandoned open dump (AOD) in the Central Province of Sri Lanka (N 7º 09', E 80º 35') were collected and the typical landfill gas composition such as $O_2$, $N_2$, $CH_4$, $CO_2$, $H_2$, $H_2S$, and $N_2O$ were measured. Buried waste samples at 1 m depth were also taken from the site and organic carbon and nitrogen contents in the residue (< 2 mm) were measured. The samples were taken from some marked plots inside the dump with waste ages of around 0.5 and 7 years ($AOD_{0.5}$ and $AOD_7$) and outside intact ($AOD_{int}$).*

*Measured $CH_4$ concentration for $AOD_{0.5}$ and $AOD_7$ ranged in 19–58 % and 0–12 %, respectively, suggesting that the dumped waste at 1 m depth was in the process to be the 'stabilization phase' at least 7 years after dumping. This is likely to be a much shorter time period to reach the phase after dumping than those in mid-latitude regions (typically in several decades). The carbon contents in the waste residue in $AOD_{0.5}$ and $AOD_7$ were 151±67 and 29±7 mg $g^{-1}$, respectively, implying that high waste decomposition and leaching of organic compounds might have been enhanced due to high temperature and precipitation at the site. A further study for the landfill gas and waste quality in the deeper layer is required to judge whether whole of the dumpsite had reached the stabilization phase rapidly.*

***Keywords:*** *Landfill gas, nutrient leaching, open dump, organic carbon, Sri Lanka*

## 1. INTRODUCTION

Haphazard dumping of the municipal solid waste is mostly observed in developing countries, where the waste is dumped in an uncontrolled manner. Such inadequate waste disposal creates serious environmental burden which affects health of humans and animals and causes serious economic and other welfare losses (Zurbrügg, 2003).

Landfill gas is an important factor which causes odor and firing and provides us information about the stability of the waste in a landfill. Figure 3 shows a conceptual model for variation in landfill gas composition over time (Rees, 1980). There are five phases of waste condition in a landfill, mentioned as follows: (I) Aerobic biodegradation phase: the organic matter in the waste is aerobically degraded by oxygen (a few hours), (II) Anaerobic acid fermentation phase: volatile organic acid, $CO_2$, and $H_2$ are generated by anaerobic decomposition of biodegradable organic matter in the waste (a few months – a few years), (III) Methanogenic phase I: the volatile organic matter changes into $CH_4$ and $CO_2$ (a few months – a few years), (IV) Mehanogenic phase II: $CH_4$ is generated by anaerobic decomposition of refractory organic matter in the waste and ranges from 45 to 60 % of the landfill gas (several decades), and (V) Stabilization phase: the organic matter in the waste decrease and $N_2$ and $O_2$ concentrations in the landfill gas increase due to the invasion of the air into the waste (more than 100 years).

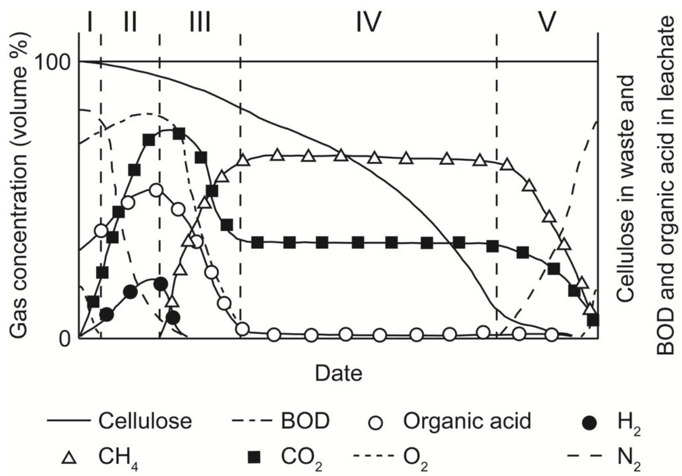


**Figure 3 Conceptual model for variation over time in landfill gas composition (Rees, 1980, modified)**

Despite the importance to observe landfill gas, there are very few studies on the uncontrolled landfills. The objective of this study is to observe typical landfill gas composition in an abandoned open dump which has different ages of dumped waste inside to evaluate time-dependent change in it. For comparison, landfill gas samples were also taken from another open dump and an engineered landfill those are under operation, in the same province.

## 2. MATERIALS AND METHODS

### 2.1. Site description

The present study was conducted between 28th November and 2nd December 2011 in the Central Province of Sri Lanka. Three different types of waste disposal sites were selected as study sites (Figure ). An intensive observation was operated in an abandoned open dump (AOD) located at Udapalatha Pradeshiya Sabha (N 7º 09', E 80º 35'). The average annual rainfall is above 2000 mm with an average annual temperature of 24.7 ºC (Statistical Abstract, 2010).The samples were taken from three marked plots at regular intervals on transects along the slope (Top, Middle, and Bottom) each inside the dump with waste ages of around 0.5 and 7 years ($AOD_{0.5}$ and $AOD_7$) and outside intact ($AOD_{int}$). The samples were also taken from another open dump, Gohagoda (OOD; N 7º 19', E 80º 37') and an engineered landfill in Nuwara-Eliya (OEL; N 6º 58', E 80º 48'), those are under operation.

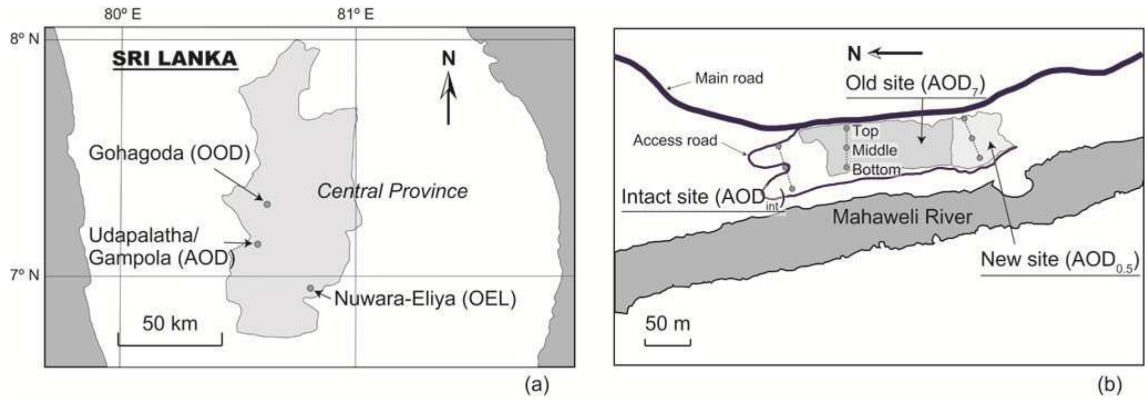


**Figure 2 (a) Location of the sites investigated, (b) Map of Udapalatha/Gampola site (AOD). The slope faces into west in this site.**

## 2.2. Sample analyses

Either perforated PVC tubes, 13.2 mm in diameter, or metal tubes, 4.1 mm in diameter, were installed at depths of 100 cm (sometimes it was shallower than 100 cm when it was failed to be installed at the depth) in each plot 30 minutes before the sampling to collect air samples from the dumped waste. The tubes were sealed by three-way cocks to allow the gas concentration in the tubes to equilibrate with the landfill gas. From each of the tubes installed, air samples (500 mL) were taken into an air-tight aluminium bag. The samples were transferred to the laboratory in Center for Environmental Science in Saitama, Japan to analyze the concentrations of typical landfill gases such as $O_2$, $N_2$, $CH_4$, $CO_2$, $H_2$, $H_2S$, and $N_2O$. $O_2$, $N_2$, $CH_4$, $CO_2$, and $H_2$ concentration in the gas samples were analysed using gas chromatography (GC) equipped with Thermal Conductivity Detector (GC-14A, Shimadzu, Kyoto, Japan and 6890 series, Agilent, Santa Clara, USA). $H_2S$ was analysed using GC equipped with Flame Photometric Detector (5890 series II, Agilent, Santa Clara, USA). $N_2O$ was analysed using GC equipped with Electron Capture Detector (Shimadzu 14B, Shimadzu, Kyoto, Japan).

Waste samples were collected from 100 cm depth (if it’s not possible, shallower than 100 cm) in each plot. The samples were dried at 110 ºC for 48 hours and sieved by 2 mm sized sieves to get the residue in the Laboratory in University of Peradeniya, Sri Lanka. The residue samples were transferred to the laboratory in Saitama University, Japan to analyze the carbon and nitrogen contents in it (MT-5, Yanaco, Kyoto, Japan).

Two-way ANOVAs were carried out to judge the significance of difference in $CH_4$ concentrations in the landfill gas and carbon contents in the waste residue obtained from each waste age and slope position in AOD. The statistical analyses were conducted by R (ver. 2.11.1; R Development Core Team).

## 3. RESULTS

The measured typical landfill gas concentrations for $AOD_{0.5}$, $AOD_7$, $AOD_{int}$, OOD, and OEL were presented in Figure . Measured $O_2$ and $N_2$ concentration in the landfill gas ranged in lower values at $AOD_{0.5}$ (2-4 % and 6-58 %, respectively) and higher values at $AOD_7$ and $AOD_{int}$ (3-18 % and 65-79 %, respectively). Measured $O_2$ and $N_2$ concentration in the landfill gas for OOD and OEL ranged in similar low value as $AOD_{0.5}$ (2-3 % and 6-16 %, respectively).

Measured $CH_4$ and $CO_2$ concentration in the landfill gas ranged in higher values at $AOD_{0.5}$ (19-58 % and 19-35 %, respectively) and lower values at $AOD_7$ and $AOD_{int}$ (0-13 % and 3-20 %, respectively). Measured $CH_4$ and $CO_2$ concentration in the landfill gas for OOD and OEL ranged in similar high value as $AOD_{0.5}$ (56-57 % and 24-36 %, respectively).

Measured $H_2$ concentration in the landfill gas was very low in each plot (0.00-0.02 %).

Measured $H_2S$ concentration in the landfill gas were high (23-41 ppmv) at a few of the points which high concentrations of $CH_4$ and $CO_2$ while they were almost zero at the other points in AOD site. Measured $H_2S$ concentration in the landfill gas for OOD and OEL ranged in high values of 4-24 ppmv.

Measured $N_2O$ concentration in the landfill gas for the top and middle point in $AOD_7$ ranged in relatively high value (39-95 ppmv) while those in the other plots ranged in low (0-4 ppmv).

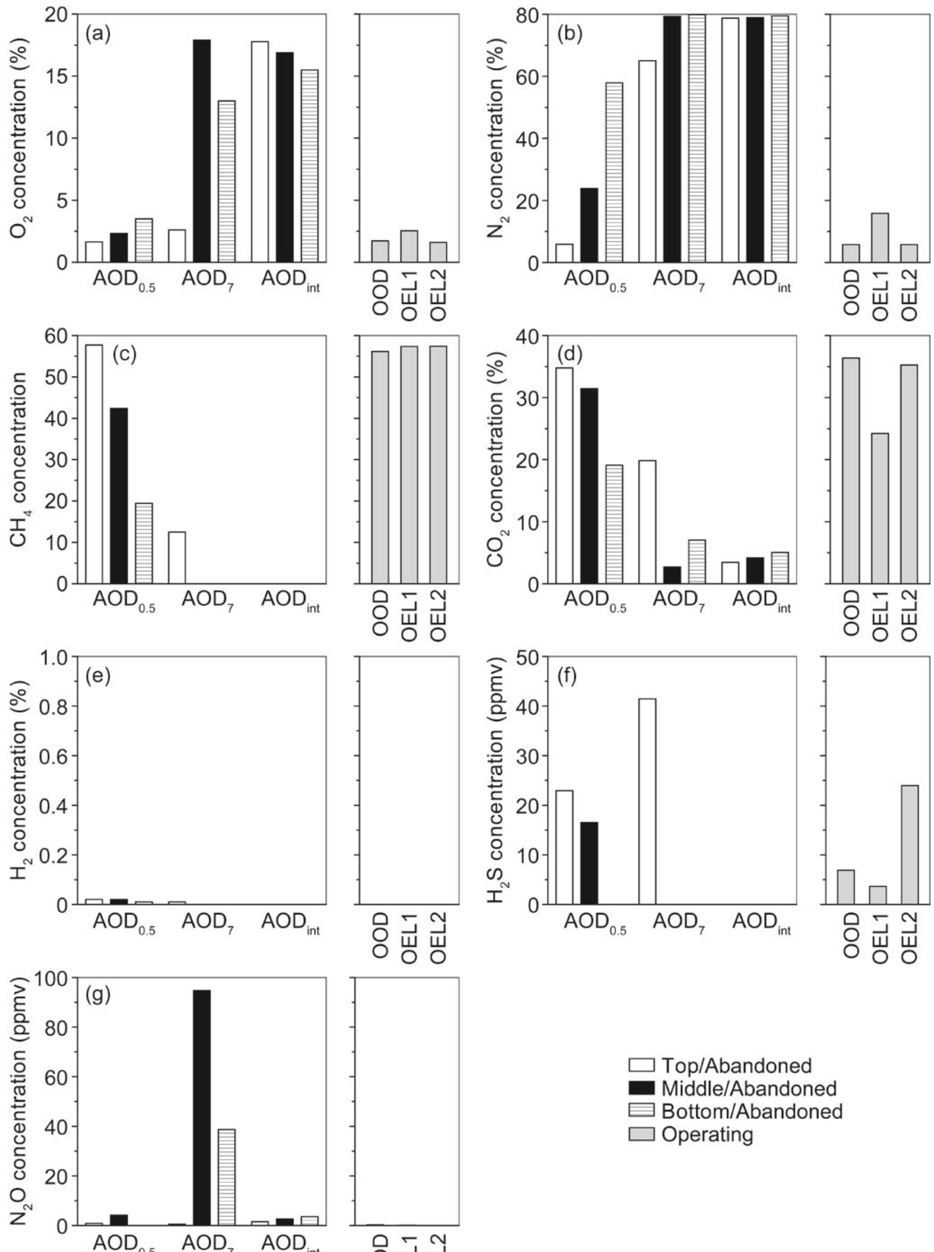


**Figure 3 (a) $O_2$, (b) $N_2$, (c) $CH_4$, (d) $CO_2$, (e) $H_2$, (f) $H_2S$, (g) $N_2O$ concentration in the landfill gas in AOD, OOD, and OEL sites.**

Measured carbon and nitrogen content in the waste residue ranged in higher values at $AOD_{0.5}$ (93-224 and 8-14 mg $g^{-1}$, respectively; Figure ) and lower values at $AOD_7$ and $AOD_{int}$ (5-37 and 0-3 mg $g^{-1}$, respectively). Measured carbon and nitrogen content in the waste residue for OOD and OEL ranged in 30-79 and 3-7 mg $g^{-1}$, respectively. Calculated CN ratio in the waste residue ranged in 6-16 and there was no site specific tendency.

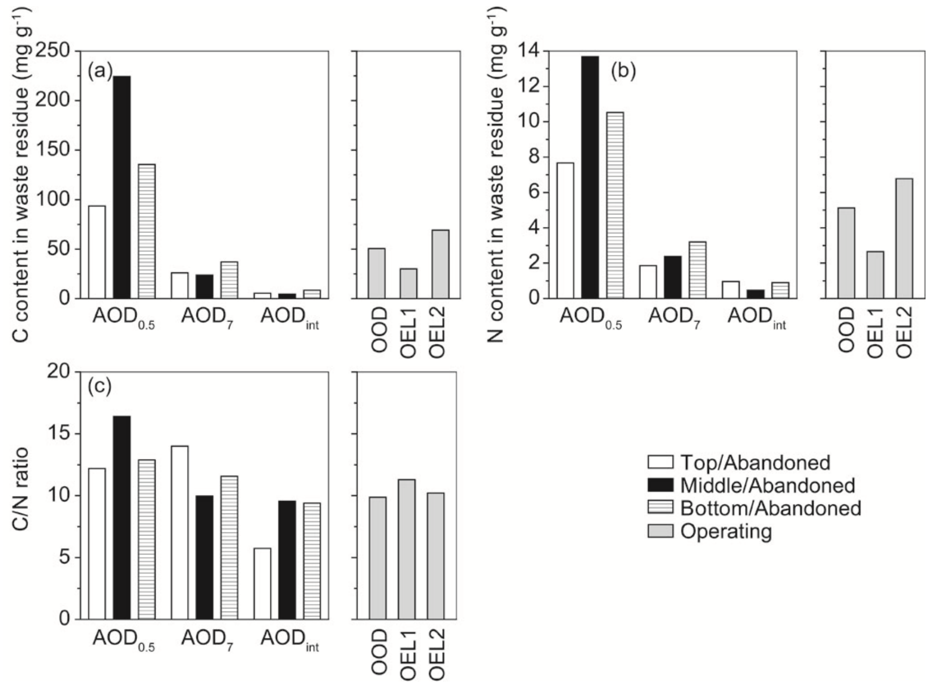


**Figure 4 (a) Carbon and (b) nitrogen content and (c) C/N ratio of the residue of waste in AOD, OOD, and OEL sites.**

## 4. DISCUSSION

The 2-way ANOVA for $CH_4$ concentration in the landfill gas revealed that there is a significant variation in the $CH_4$ concentration among the sites those have different age of waste ($P < 0.02$; Table 1), indicating temporal-dependent decrease of it (Figure c). The $CH_4$ concentrations of the landfill gas for $AOD_7$, at which seven years old of waste is buried, were lower than theoretical $CH_4$ concentration in 'Methanogenic phase II', which is said to continue for several decades (Rees, 1980). This would be due to high waste decomposition and leaching rate of organic compounds enhanced by high temperature and precipitation at the site ($P < 0.02$; Figure a, Table ). Additionally, high concentration of $O_2$ and $N_2$ in the landfill gas at $AOD_7$ (Figure a, b) implies invasion of the air into the waste. The $CH_4$ concentrations in the landfill gas were high and the $N_2$ and $O_2$ concentration were low in the other waste disposal sites under operation (OOD and OEL; Figure a, b, c), indicating $CH_4$ was continuously generated using flesh organic matters in anaerobic condition in those sites. These indicates that the buried waste at 1 m depth in $AOD_7$ had already been in lack of organic matter that could be changed to $CH_4$ and had reached 'stabilization phase' nevertheless it had passed only 7 years since the stopage of dumping. However, we investigated only the surface layer of the open dump, where the oxidization is easier than that in deeper layers. A further study for the landfill gas and waste quality in the deeper layer is required to judge whether whole of the dumpsite had reached the stabilization phase rapidly.

The effect of slope position on $CH_4$ concentration in the landfill gas was not significant (Table 1). However, there is a tendency that higher $CH_4$ concentration in the landfill gas was observed at upper slope (Figure c). Lohila *et al*., (2007) suggested that the higher emissions from the summit area are due to the uncovered surface and the daily deposited new waste. Although the studied site has no difference in cover treatment between the summit area and slope area and no daily deposited new waste, the waste buried in deeper layers may act some role which effect on the above phenomenon. A further investigation in the deeper layer will help us obtain valuable information on it.

**Table 1 The ANOVA Table for $CH_4$ concentration in the landfill gas in AOD.**

| | SS | d.f. | MS | F value | P value |
|---|---|---|---|---|---|
| Waste age | 36455 | 2 | 18228 | 11.56 | 0.02 |
| Slope position | 2728 | 2 | 1364 | 0.87 | 0.49 |
| e | 6305 | 4 | 1576 | - | - |
| Total | 45489 | 8 | 5686 | - | - |

**Table 2 The ANOVA Table for carbon contents in the waste residue in AOD.**

| | SS | d.f. | MS | F value | P value |
|---|---|---|---|---|---|
| Waste age | 2877 | 2 | 1439 | 13.90 | 0.02 |
| Slope position | 430 | 2 | 215 | 2.08 | 0.24 |
| e | 414 | 4 | 103 | - | - |
| Total | 3721 | 8 | 465 | - | - |

Besides, relatively high values of $N_2O$ concentration were observed in some plots at $AOD_7$ (Figure g), suggesting that nitrification was stimulated due to time-dependent aerobic conditioning in the 1 m depth (measured $O_2$ concentration for the plots ranged in 13–18%). This indicates that nutrient leaching through runoff and surface water might give an impact to groundwater environment at open dump sites even in the ’stabilization phase’. Long term observation would be required to assess the environmental impacts of an open dump.

## 5. CONCLUSION

Observation for the typical landfill gas composition in an abandoned open dump located at the Central Province, Sri Lanka reveals that the surface layer of the dumped waste reached ‘stabilized phase’ only seven years after the disposal. A further investigation in deeper layer of the dump site is required to judge whether whole of the dumpsite had reached the stabilization phase rapidly. Furthermore, long term observation on nutrient leaching from an open dump is required even after reaching ‘stabilized phase’ because invasion of the air will enhance nitrification inside of the waste.

## 6. ACKNOWLEDGMENTS

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