

Supplementary Report of ALGAS Project: (3)

**The Estimation of Methane Emission
from Man-made Waste (Garbage) of 46 Cities in China**

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CH₄ emission from man-made waste

City trash is man-made waste, during buried, methane bacteria make organic matter produce anaerobic decomposition. These waste produce methane 30-70Tg/year that occupies 6-18 in global. The organic waste is decomposed firstly under condition of needing oxygen and then becomes gas and short-chain organic compound (H₂, CO₂, CH₃COOH, HCOOH, and CH₃OH). This creates the condition for production of methane bacteria and results in producing CO₂ about 50% and CH₄ about 50% (volume ratio). Because of the dissolving of CO₂ in water, the content of CO₂ is low. Based on this study, we must pay more attention to the methane emissions of buried field and disposal plant of city man-made waste. Otherwise, it will be an important resource of GHGs that we can't omitted it.

In short, there are a lot of influence facts in producing methane from man-made waste. We can classified them generally into two types: physical and chemical factor and management factor.

The physical and chemical factor includes waste component, humidity, pH value and nourishment. The management factor includes waste sorts, density and grain size of waste, open dumping and sanitary bury.

The urban man-made waste occupies a large amount of waste in all kinds of waste. For majority areas, the urban man-made waste of developing country is mainly composed of trash foods and that of developed country is mainly paper production that contains much carbon then foods. The paper and its production produce methane more than that of foods. Therefore, The disposal method of man-made waste should adopt the combustion in developed countries and buried (open burying and sanitary bury) in developing countries.

1. Methane emission from man-made waste of 46 main cities in China

In this paper, according to the format of “Table 6” in the IPCC guideline for GHG inventory, the lowest values of solid waste (man-made waste) are estimated for China in the years of 1990, 1992 and 1994.

Format of Table 6 in the IPCC guideline (6A waste: bury)

!1 Resource kinds	Acting data		Emission estimate	Total emission factors	
	A	B		D	E
Waste kinds (man-made waste)	Urban total waste kg/year	Urban waste bury quantity kg	C CH4 emissions kg	D Emission factors CH4 kg/urban waste kg bury kinds	E CH4 recycle quantity CH4 kg
				f0 D=C/B	
Bury kinds					

Another approach used by making the estimation is Orlich experience estimation method that was used by IPCC in discussing meeting of global methane emission in 1990.

Orlich hypothesizes that every body produces waste 1 kg/day in developed area and 0.5 kg/day in developing area. The one ton waste in developed area produces methane 86 kg and 21.5 kg in developing area. The difference is resulted from waste disposal (such as pressing or non-pressing), components (vegetable or paper), as well as area, custom, climate, temperature, humidity etc. In present days in the 46 main cities of China, as comprehensive emission factors, it is suitable that each ton waste produces methane 32 kg. Orlich only uses urban population as estate objection. Because big amount dumping has no anaerobic condition of producing methane, according Orlich’s estimation, the dumping produces methane 31.5 Tg in 1985. The methane emissions of 46 main cities of China are listed in following tables (Table 1, Table 2 and Table 3 are based on the data of 1990, 1992 and 1994 separately)

2 Chinese waste characteristic of main cities

Table 1 The Sanitary Fill Emissions of Methane in China (46 main cities, 1990)

!1 Source	Municipality or City	Population (thousand)	Activity Data (T)	Methane Emissions (T)	Aggregated Emissions Factors	Waste amount per capita (T)	Methane emission per capita (T)
Waste type	Beijing	6,995	3,445,000	110,240	0.032	0.493	0.0158
	Tianjin	5,771	2,172,000	69,504	0.032	0.376	0.0120
	Shijiazhuang	1,319	390,000	12,480	0.032	0.296	0.0095
	Qinghuangdao	501	326,000	10,432	0.032	0.651	0.0208
	Taiyuan	1,964	950,000	30,400	0.032	0.484	0.0155
	Huhehaote	886	380,000	12,160	0.032	0.429	0.0137
	Shenyang	4,538	2,081,000	66,592	0.032	0.459	0.0147
	Dalian	2,396	702,000	22,464	0.032	0.293	0.0094
	Changchun	2,110	1,048,000	33,536	0.032	0.497	0.0159
	Haebing	2,827	1,500,000	48,000	0.032	0.531	0.0170
	Shanghai	7,835	2,786,000	89,168	0.032	0.356	0.0114
	Nanjing	2,498	608,000	19,455	0.032	0.243	0.0078
	Lianyungang	521	151,000	4,832	0.032	0.290	0.0093
	Nantong	457	99,000	3,168	0.032	0.330	0.0069
	Hangzhou	1,339	486,000	15,552	0.032	0.363	0.0116
	Ningbo	1,085	311,000	9,952	0.032	0.287	0.0092
	Whenzhou	562	211,000	6,752	0.032	0.275	0.0120
	Hefei	1,002	190,000	6,080	0.032	0.190	0.0061
	Fuzhou	1,292	347,000	11,104	0.032	0.269	0.0086
	Xiamen	603	230,000	7,360	0.032	0.381	0.0122
	Nanchang	1,354	187,000	5,984	0.032	0.138	0.0044
	Jinan	2,322	620,000	19,840	0.032	0.267	0.0085
	Qingdao	2,053	508,000	16,256	0.032	0.247	0.0079
	Yantai	805	156,000	4,992	0.032	0.194	0.0062
	Weihai	257	52,000	1,664	0.032	0.202	0.0065
	Zhengzhou	1,706	603,000	19,296	0.032	0.353	0.0113
	Wuhan	3,751	1,416,000	45,312	0.032	0.378	0.0121
	Changsha	1,321	290,000	9,280	0.032	0.220	0.0070
	Guangzhou	3,579	1,052,000	33,664	0.032	0.294	0.0094
	Zhanjiang	1,060	214,000	6,848	0.032	0.202	0.0065
	Shenzhen	395	256,000	8,192	0.032	0.648	0.0207
	Zhuhai	366	138,000	4,416	0.032	0.377	0.0121
Shantou	856	218,000	6,976	0.032	0.255	0.0081	

	Nanning	1,070	171,000	5,472	0.032	0.160	0.0051
	Beihai	200	57,000	1,842	0.032	0.285	0.0091
	Haikou	370	144,000	4,608	0.032	0.389	0.0125
	Chengdu	2,808	619,000	19,808	0.032	0.220	0.0071
	Chongqing	2,984	400,000	12,800	0.032	0.134	0.0043
	Guiyang	1,532	513,000	16,416	0.032	0.335	0.0107
	Kunming	1,525	492,000	15,744	0.032	0.323	0.0103
	Lasha	123	10,000	320	0.032	0.081	0.0026
	Xi an	2,757	580,000	18,560	0.032	0.201	0.0087
	Lanzhou	1,507	460,000	14,720	0.032	0.305	0.0098
	Xining	650	236,000	7,552	0.032	0.363	0.0116
	Yingchuan	480	210,000	6,720	0.032	0.438	0.0140
	Wulumiqi	1,157	760,000	2,430	0.032	0.657	0.0210
Total		83,489	28,775,000	898,943	Average	0.330	0.0106

Table 2 The Sanitary Fill Emissions of Methane in China (46 main cities, 1992)

!1 Source	Municipality or City	Population (thousand)	Activity Data (T)	Methane Emissions (T)	Aggregated Emissions Factors	Waste amount per capita (T)	Methane emission per capita (T)
Waste type	Beijing	7,050	3,960,000	126,720	0.032	0.562	0.0180
	Tianjin	5,809	2,300,000	73,600	0.032	0.396	0.0127
	Shijiazhuang	7,862	3,010,000	96,320	0.032	0.383	0.0123
	Qinghuangdao	1,337	420,000	13,440	0.032	0.314	0.0101
	Taiyuan	514	320,000	10,240	0.032	0.623	0.0199
	Huhehaote	1,983	930,000	29,760	0.032	0.469	0.0150
	Shenyang	896	420,000	13,440	0.032	0.469	0.0150
	Dalian	4,576	1,970,000	63,040	0.032	0.431	0.0138
	Changchun	2,416	710,000	22,720	0.032	0.294	0.0094
	Haebing	2,132	1,030,000	32,960	0.032	0.483	0.0155
	Shanghai	2,844	1,610,000	51,520	0.032	0.566	0.0181
	Nanjing	2,522	700,000	22,400	0.032	0.278	0.0089
	Lianyungang	531	140,000	4,480	0.032	0.264	0.0084
	Nantong	539	90,000	2,880	0.032	0.167	0.0042
	Hangzhou	1,350	510,000	16,320	0.032	0.378	0.0121
	Ningbo	1,095	270,000	8,640	0.032	0.247	0.0079
	Wenzhou	566	410,000	13,120	0.032	0.724	0.0232
	Hefei	1,024	210,000	6,720	0.032	0.205	0.0066
	Fuzhou	1,308	270,000	8,640	0.032	0.206	0.0066
	Xiamen	614	250,000	8,000	0.032	0.407	0.0130
	Nanchang	1,371	240,000	7,680	0.032	0.175	0.0056
	Jinan	2,346	550,000	17,600	0.032	0.234	0.0075
	Qingdao	2,072	540,000	17,280	0.032	0.261	0.0083
	Yantai	816	140,000	4,480	0.032	0.172	0.0055
	Weihai	265	60,000	1,920	0.032	0.226	0.0072
	Zhengzhou	1,732	420,000	13,440	0.032	0.243	0.0078
	Wuhan	3,792	720,000	23,040	0.032	0.190	0.0061
	Changsha	1,350	510,000	16,320	0.032	0.378	0.0121
	Guangzhou	3,620	1,250,000	20,000	0.032	0.345	0.0110
	Zhanjiang	1,080	230,000	7,360	0.032	0.213	0.0068
	Shenzhen	432	690,000	22,080	0.032	1.597	0.0511
	Zhuhai	279	130,000	4,160	0.032	0.456	0.0149
	Shantou	873	270,000	8,640	0.032	0.309	0.0099
	Nanning	1,086	200,000	6,400	0.032	0.184	0.0059
Beihai	206	70,000	2,240	0.032	0.340	0.0109	
Haikou	387	170,000	5,440	0.032	0.439	0.0141	
Chengdu	2,842	870,000	27,840	0.032	0.306	0.0098	
Chongqing	3,011	1,000,000	32,000	0.032	0.332	0.0106	

	Guiyang	1,561	620,000	19,840	0.032	0.397	0.0127
	Kunming	1,557	450,000	14,400	0.032	0.289	0.0092
	Lasha	124	20,000	640	0.032	0.161	0.0052
	Xi an	2,789	650,000	20,800	0.032	0.233	0.0075
	Lanzhou	1,532	500,000	16,000	0.032	0.326	0.0104
	Xining	656	360,000	11,520	0.032	0.549	0.0176
	Yingchuan	491	220,000	7,040	0.032	0.448	0.0143
	Wulumiqi	1,175	590,000	18,880	0.032	0.502	0.0161
Total		84,412	31,000,000	972,000	Average	0.373	0.0119

Table 3 The Sanitary Fill Emissions of Methane in China (46 main cities, 1994)

!1 Source	Municipality or City	Population (thousand)	Activity Data (T)	Methane Emissions (T)	Aggregated Emissions Factors	Waste amount per capita (T)	Methane emission per capita (T)
Waste type	Beijing	10,620	4,250,000	136,000	0.032	0.400	0.0128
	Tianjin	8,950	2,090,000	66,880	0.032	0.234	0.0075
	Shijiazhuang	12,990	3,580,000	114,560	0.032	0.276	0.0088
	Qinghuangdao	8,360	450,000	14,400	0.032	0.054	0.0017
	Taiyuan		290,000	9,280	0.032		
	Huhehaote	2,770	940,000	30,080	0.032	0.339	0.0108
	Shenyang	1,440	450,000	14,400	0.032	0.313	0.0100
	Dalian	6,620	2,080,000	66,560	0.032	0.314	0.0101
	Changchun	5,320	740,000	23,680	0.032	0.139	0.0045
	Haebing	6,580	1,060,000	33,920	0.032	0.161	0.0052
	Shanghai	5,130	2,040,000	65,280	0.032	0.384	0.0123
	Nanjing	5,180	750,000	24,000	0.032	0.145	0.0046
	Lianyungang		160,000	5,120	0.032		
	Nantong		110,000	3,520	0.032		
	Hangzhou	5,980	630,000	20,160	0.032	0.105	0.0034
	Ningbo	5,230	230,000	7,360	0.032	0.044	0.0014
	Wenzhou		470,000	15,040	0.032		
	Hefei	4,030	220,000	7,040	0.032	0.055	0.0017
	Fuzhou	5,550	440,000	14,080	0.032	0.079	0.0025
	Xiamen	1,190	230,000	7,360	0.032	0.193	0.0062
	Nanchang	3,890	440,000	14,080	0.032	0.113	0.0036
	Jinan	5,370	550,000	17,600	0.032	0.102	0.0033
	Qingdao	6,790	580,000	18,560	0.032	0.085	0.0027
	Yantai		180,000	5,760	0.032		
	Weihai		80,000	2,560	0.032		
	Zhengzhou	5,760	560,000	17,920	0.032	0.097	0.0031
	Wuhan	7,000	1,650,000	52,800	0.032	0.236	0.0075
	Changsha	5,590	550,000	17,600	0.032	0.098	0.0031
	Guangzhou	6,370	1,990,000	63,680	0.032	0.312	0.0100
	Zhanjiang		300,000	9,600	0.032		
	Shenzhen	940	700,000	22,400	0.032	0.745	0.0238
	Zhuhai		170,000	5,440	0.032		
Shantou		300,000	9,600	0.032			
Nanning	2,690	260,000	8,320	0.032	0.097	0.0031	
Beihai		190,000	6,080	0.032			
Haikou	460	300,000	9,600	0.032	0.652	0.0208	
Chengdu	9,600	980,000	31,360	0.032	0.102	0.0033	

	Chongqing	15,120	1,040,000	33,280	0.032	0.069	0.0022
	Guiyang	1,660	550,000	17,600	0.032	0.331	0.0106
	Kunming	3,710	400,000	12,800	0.032	0.108	0.0034
	Lasha	380	50,000	1,600	0.032	0.132	0.0042
	Xi an	6,390	670,000	21,440	0.032	0.105	0.0033
	Lanzhou	2,660	500,000	16,000	0.032	0.188	0.0060
	Xining	1,070	360,000	11,520	0.032	0.336	0.0108
	Yingchuan	880	220,000	7,040	0.032	0.250	0.0080
	Wulumiqi	1,400	650,000	20,800	0.032	0.464	0.0149
Total			35,430,000	1,133,760			

Based on investigation of urban waste component in China, we can conclude that the urban waste has both analogy and uncertainty. The citizens lived in North of China are accustomed to store Chinese cabbage. During seasonal change of autumn and winter, the cabbage leaves are seasonal wastes. With the changing of accustom of citizen, the component of waste changes. There are also a lot of factors of producing the uncertainty of classify. For example, pollution of plastic bag becomes more and more serious in China. The urban areas are different with suburban areas. There is also difference among big, middle and small cities. Moreover, waste-collected waste is not yet collected classify. However, China is a developing country, the waste classification has changed totally. At present time, reform makes more population flow. Surplus labor power is rush into 46 main cities, the population of cities increase sharply and man-made waste increases sharply too. But the average amount of methane emission of each person has the trends of decreasing. At same time, we must point out that with the living quality changes, the flow of population is no longer existence in the future. It is only a temporary phenomenon.

3. Automatic and man-control measure of methane emission of man-made waste

Automatic measure of methane emission of man-made waste has is practical phrase. CRAES has build up a set of equipment that temperature and humidity are consistent and simulation experiment in liberation and automatic equipment. From bury column of man-made waste-aerobic fermentation-anaerobic fermentation to producing gas, has realize automatic monitor. The temperature, humidity and pH value are recorded by three probe-heads of translate sense instrument that are buried in there. In addition, gases of CH₄, CO₂, NH₃, H₂S etc. are pumped by gas analyses monitor. Penetrate liquid is collected at the same time and the data are collected by the computer. So far, this equipment is used only in laboratory. If possible, it can be used in burring of man-made waste. Generally, man-control measures are limited to waste buried field. Certainly, if there is no automatic measures in laboratory, man-control measure should be used.

4. Method of making list of Chinese cities waste

According to “Country GHG emission list” volume 1-3, IPCC, and handbook of GHG table work, we estimate waste buried quantity. At that time, urban population is 301.91 millions (from “Chinese Environment Data Compilation”, 1990, page 45). Waste productivity and bury are listed in Table 4-1.

Table 4-1 Proposal components and produce data of every area waste

Area	MSW bury ratio	DOC share of MSW	Waste productivity (Kg/p/D)	waste productivity (Kg/p/y)
Developing country	0.8	0.15	0.5	182

Take the data listed above into Table 4-2 of “work handbook of GHG report Table” of IPCC. We can get “MSW buried quantity of every year”, “actually fallen and dissolved potation” in man-made waste buried, and “C-CH₄/C” from “work-hand of GHG report table”, “DOC portion” from “GHG emission list” of Tsinghua University, September 1993 (internal information).

Then, fill above data into “Work Report Table 5-1”, and get net methane emission 394.90-789.78 (Gg).

Table 4-2 Work Handbook of GHG Report Table of IPCC

consist waste subconsist report table table		Methane emissions of being buried 4-2		
A population (urban population) (classify) 10 ⁶ person	B waste productivity (GgMSW/10 ⁶ person/year)	C Waste (GgMSW)	D Buried share	E buried MSW (GgMSW)
		$C=(A \times B)$		$E=(C \times D)$
301.91	182	54947.62	0.8	43958.096
301.91	182	54947.62	0.4	21979.048

Table 5-1 Work Report

Step 1	Step 2					Step 3				
A	B	C	D	E	F	G	H	I	J	K
buried MSW a year classify	DOCsh are (GgDO C/GgM SW)	Doc share a year (Gg)	actually degra- dated share	emissive carbon share (Gg)	c- CH ₄ /total C	carbon of methane a year	Conver- sion factor (16/12)	methane emissions (Gg)	recovery methane (Gg)	methane net emissions (Gg)
		$C=(A \times B)$		$E=(C \times D)$		$G=(E \times F)$		$I=(G \times H)$		$K=(I \times J)$
43958.096	0.035	1538.53	0.77	1184.67	0.5	592.34	16/12	789.78	0.0	789.78
21979.048		769.27		592.34		296.17		394.90	0.0	394.90

5. Test of methane emission factors urban man-made

China is a large country, from east to west and south to north, the custom is different widely. The temperature and the humidity are also different, so the components of man-made are differ. The methane emission factors of man-made change with region and can not take a uniform value. In order to estimate methane emission of 46 cities of China, we adopt a synthesis emission factors as 0.032, although the uncertainty is exist. The comparing emission is listed and the result is satisfactory. For example, if buried ratio is 40%, relative error is small than 10% as showed in table 6.

Table 6 Compare methane emissive list of urban waste to main cities accurate emission

compare two statistic ways	population 10 ⁶ ,1990	methane net emissions Gg,1990	methane net emissions per person Gg/10 ⁶ ,1990	Methane net emissions per Person weighted mean Gg/10 ⁶ , 1990	relative error (\pm %)
methane emission list of being buried 40%	301.91	394.90	1.31	1.22	$\pm 7.38\%$
methane emissions of 46 main cities	81.37	92.08	1.13	1.22	$\pm 7.38\%$
methane emission list of being buried 80%	310.91	789.78	2.620	1.875	$\pm 39.73\%$
methane emissions of 46 main cities	81.37	92.08	1.13	1.875	$\pm 39.73\%$

Conclusion

- (1) Because of the wide area of China, from east to west and from south to north, the custom is different. The temperature and the humidity are different. The components of man-made are differ. The methane emissive factors of man-made couldn't be uniform value. In order to estimate methane emissive of 46 cities of China, we adopt a synthesis emissive factors 0.032, although the uncertainty is exist. In the data of synthesis investment, we gave a variable rang of data .as a reference.
- (2) According to statistic result of rubbish production from 1992-1994,the total urban man-made waste amount of China is 8000million to one billion ton. Methane emissions are about 240 to 320 million tons.
- (3) Based on the estimation of person share from table 1 to table 3, the waste production rate per person deduced from 0.35ton in 1990-1994 to 0.19. Methane of person share deduced from 0.011ton to 0.006 ton. This is because urban people flowed to village.
- (4) It is discovered from matching way of urban man-made waste that bury share of MSS will affects directly the accurate.
- (5) We think at present, bury level of China is lower and bury quantity is much lower. It is suitable to bury 40%. The observable data show that the relative error both data and result is less than 10%.

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