Unconventional views to generation of greenhouse gases

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The majority of the implemented measures lowering the amount of originating greenhouse gases derive particularly from the balances targeted into power industry, transportation or heavy industry. The article summarized date shoving that the dumping of communal biodegradace wastes related to catering in many aspects competes in the creation of grenhouses gates related with the car transportation or power industry.

Key words: *greenhouse gases, natural gas, municipal waste*

Introduction

Individual countries of European Union are in the framework of Directive (EC) 1999/31/EC of 26th April 1999 concerning landfill of municipal waste required among others to implement national strategy reducing disposal of biodegradable waste to dumping grounds because of the fact that biogas containing approximately 30 % by vol. of carbon dioxide and 70 % by vol. of methane is generated as a result of running conversion effects inside dumping ground body. Both of these substances represent gases with strong contribution to greenhouse effects [1]. Required new strategy should be aimed at reduction of amount of biodegradable waste disposed to dumping grounds in a year 2009 to 50 % of amount generated in 1995 respectively in 2016 to 35 % of amount generated in 1995.

Waste considered to be biodegradable according to intention of the Directive is such waste which is subjected to degradation of microorganisms under anaerobic or aerobic conditions. For example food waste belongs among substances – i.e. waste from food production, waste from treatment of cereals, production of beer, wine and distillates, residues from processing of meat and fish, waste from kitchen and restaurants, food sale, etc. In the frame of Consultancy document to EC Directive on landfill prepared for United Kingdom there are considered as 100 % biodegradable among others substances subjected to putrefactive process including food and garden waste. Within the document newspapers, cartons and cardboards are considered to be 100 % biodegradable. Austrian Directive for separate collection of biogenous waste defines as biodegradable waste such substances which are particularly suitable for aerobic and anaerobic utilization in regard of their high content of organic, biodegradable part.

General comparison of aerobic and anaerobic processes in regard of greenhouse gases generation is showed in Tab. 1.

Tab. 1. General comparison of aerobic and anaerobic processes.

Aerobic process	**Anaerobic process**
Transformation of substances of organic waste in biogas containing carbon dioxide	Transformation of substances of organic waste in biogas containing carbon dioxide and methane
Following results from energy balance	
60 % is consumed at synthesis of new biomass 40 % is lost as a reaction heat	90 % is transformed into biogas 5 – 7 % is consumed at synthesis of new biomass 3-5 % is lost as a reaction heat
Following results from carbon balance	
50 % carbon dioxide 50 % is converted in biomass	90 % is transferred into biogas (70 % methane + 30 % carbon dioxide) 5 % is converted in biomass, 5 % is converted into in organic components

It was found that amount of biodegradable waste in the Czech Republic came to 1,51 million tonnes in 1998, amount of biodegradable waste disposed in dumping grounds came to approximately 0,79 million tonnes, respectively 52,2 % by mass in the same year based on data from Information System on Waste (ISO).

A lot of models derived from theoretical and practical data are used for evaluation of potential amount of generated dumping or reactor biogases. For example findings of Reese [2, 3], Rettenberger [4], Stegmann

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and coll. [5] can be applied for dumping processes in order to evaluate generation of dumping gas along time. Detailed comparison of individual methods is stated in a paper of Straka and coll. [6].

Theoretical relations

For example general stoichiometric formula elaborated by Symons and Buswell [7] for organic compounds with summary formula $C_xH_yO_z$, where *x,y,z* represent number of atoms of individual elements can be applied for estimation of amount of greenhouse gases generated at anaerobic decomposition of organic compounds. During evaluation of total oxidation of organic compound running according to relation

$$C_xH_yO_z + n\,O \rightarrow x\,CO_2 + y/2\,H_2O \qquad (1)$$

Where $n = 2x + y/2 - z$ (which corresponds to number of oxygen atoms necessary for oxidation of decomposed compound) these authors arrived at general stoichiometric formula of methane generation

$$C_xH_yO_z + (x - y/4 - z/2)\,H_2O \rightarrow (x/2 + y/8 - z/4)\,CH_4 + (x/2 - y/8 + z/4)\,CO_2 \qquad (2)$$

However this formula can be applied to general assessment of amount of generated greenhouse gases during disposal of waste biomaterials.

It is necessary to multiple amount of methane by coefficient 23 [8] in regard of its absorption effectiveness and lifetime in the atmosphere in order to get overall influence of dumping gas containing CO_2 and CH_4 from dumping place into the atmosphere. This overall influence then will represent overall radiation intensity conversed into relative radiation intensity of carbon dioxide.

Monitored components

Monitored components in this paper are represented by biodegradable waste which can belong to category 20 00 00 respectively 20 01 08 with name “Waste from kitchen, canteens and restaurants (organically compostable waste)” according to Catalogue of waste [9]. Waste from households, waste from shops, industry and institutions or the other waste which due to its character or composition is similar to waste from household is considered as municipal waste in this category. On the other hand any other waste which is able to decompose itself under anaerobic or aerobic conditions (for example food and garden waste, paper and cardboard) can be considered as a biodegradable waste.

Following calculations will be generally structured for model simplification in the way that the whole amount of particular waste produced annually in average in the Czech Republic derived from number of inhabitants (10 469 692 in 2008) and amount of given biodegradable waste corresponding to one inhabitant of the Czech Republic according to [10] is disposed under anaerobic conditions. Amount of generated dumping gas according to model is calculated from elements composition of dry matter of given waste according to relation (2). Calculated amount of methane and carbon dioxide is consequently recalculated to overall radiation intensity of carbon dioxide according to

$$CO_{2,\Sigma} = CO_2 + 23\,CH_4 \qquad (3)$$

For a comparison this theoretical amount which would be generated during disposal under anaerobic conditions is recalculated to amount of carbon dioxide that would be generated by driving a car which consumes 5,5 litres of diesel per 100 km. Further it is recalculated to a number of family houses with average annual consumption of natural gas for heating and water heating represents volume of 2500 m^3.

Waste poultry bones

Chicken consummation in 2008 corresponds to 24 kg per inhabitant according to [10]. Amount of ash recalculated on dry mass of deposited waste was reaching 9 683 tons with a view to number of inhabitants in the Czech Republic in 2008 which was 10 469 692 and average amount of waste bones that was reaching the 6,3 % by mass.

Tab. 2. Elementary composition of deposited poultry bones - % by mass.

Parameter	C	H	N	$S_{comb.}$	O*	Ash
Value	45,4	3,4	11,6	<	12,6	27,0

**.. calculation of combustible matter up to 100 % , < .. below detection limit*

By evaluation of relation (2) with elementary composition stated in Tab. 2 according to formula

$$C_{3,78}H_{3,4}O_{0,83} + 2,5\ H_2O = 2,1\ CH_4 + 1,7\ CO_2$$

are generated methane and carbon dioxide in such amounts that are stated in Tab. 3. There is stated their overall radiation intensity in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

Tab. 3. Emission parameters of deposited poultry bones.

Quantity	Unit	Value
CH_4	m^3	7 487 977
CO_2	m^3	5 876 414
$CO_{2,\Sigma}$	m^3	68 503 026
$CO_{2,\Sigma}$	t	134 559
Passenger car	1.10^3 km	935 505
Number of family houses	pcs	27 401

Onion peelings

Onion consummation in 2008 corresponds to 11,9 kg per inhabitant according to [10]. Amount of ash recalculated on dry mass of deposited waste reached up 3 995 tons with a view to number of inhabitants in the Czech Republic in 2008 and average amount of waste onion peelings that was reaching the 3,2 % by mass.

Tab. 4. Elementary composition of deposited onion peelings - % by mass.

Parameter	C	H	N	$S_{comb.}$	O^*	Ash
Value	40,95	5,30	1,54	<	45,33	6,88

** .. calculation of combustible matter up to 100 % , < .. below detection limit*

By evaluation of relation (2) with elementary composition stated in Tab. 4 according to formula

$$C_{30,9}H_{47,8}O_{25,7} + 6,1\ H_2O = 15\ CH_4 + 15,9\ CO_2$$

are generated methane and carbon dioxide in such amounts that are stated in Table 5. There is stated overall radiation intensity of particular biogas from dumping ground in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

Tab. 5. Emission parameters of deposited onion peelings.

Quantity	Unit	Value
CH_4	m^3	1 510 745
CO_2	m^3	1 594 052
$CO_{2,\Sigma}$	m^3	14 229 376
$CO_{2,\Sigma}$	t	27 951
Passenger car	1.10^3 km	191 833
Number of family houses	pcs	5 692

Potato peelings

Potato consummation in the Czech Republic in 2008 reached up 71,4 kg per inhabitant according to [10]. During their processing an average amount of waste potato peelings reaches up 10,2 kg per inhabitant, while amount of ash recalculated on dry mass of deposited waste corresponds to 11,71 % by mass. Total production of this waste in our country corresponds approximately 106 769 tons annually. According to number of inhabitants in Prague (1 233 211) this waste represents for example mass of approximately 12 579 tons.

Tab. 6. Elementary composition of dry mass of deposited potato peelings - % by mass.

Parameter	C	H	N	$S_{comp.}$	O*	Ash
Value	40,16	5,77	2,75	<	45,32	6,0

* .. calculation of combustible matter up to 100 % , < .. below detection limit

By evaluation of relation (2) with elementary composition summarized in Tab. 6 according to formula

$$C_{17,0}H_{29,2}O_{14,4} + 2,5\ H_2O = 8,55\ CH_4 + 8,42\ CO_2$$

are generated methane and carbon dioxide in such amounts that are stated in Tab. 7. There is stated overall radiation intensity of particular biogas from dumping ground in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

As a matter of interest it could be mentioned that from deposited amount of potato peelings only in Prague would be created approximately 621 780 m^3 of methane.

Tab. 7. Emission parameters of deposited potato peelings.

Quantity	Unit	Value
CH_4	m^3	5 299 083
CO_2	m^3	5 216 602
$CO_{2,\Sigma}$	m^3	49 576 206
$CO_{2,\Sigma}$	t	97 303
Passenger car	1.10^3 km	667 809
Number of family houses	pcs	19 814

Salad cucumber peelings

Each inhabitant in the Czech Republic in 2008 consumed 7,3 kg of salad cucumber in average according to [10]. During their processing an average amount of waste cucumber peelings reaches up 1,3 kg per inhabitant, while amount of waste recalculated on dry mass of deposited waste corresponds to 18,28 % by mass. Total production of this waste in our country was estimated at approximately 13 580 tons.

Tab. 8. Elementary composition of dry mass of salad cucumber peelings - % by mass.

Parameter	C	H	N	$S_{comb.}$	O*	Ash
Value	38,21	5,65	2,45	<	50,11	3,58

* .. calculation of combustible matter up to 100 % , < .. below detection limit

By evaluation of relation (2) with elementary composition summarized in Tab. 8 according to formula

$$C_{18,7}H_{32,9}O_{18,4} + 1,29\ H_2O = 8,86\ CH_4 + 9,85\ CO_2$$

are generated methane and carbon dioxide by anaerobic decomposition inside a body of dumping grounds in such amounts which are stated in Tab. 9. There is stated overall radiation intensity of particular biogas from dumping ground in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

Tab. 9. Emission parameters of deposited salad cucumber peelings.

Quantity	Unit	Value
CH_4	m^3	914 206
CO_2	m^3	1 006 773
$CO_{2,\Sigma}$	m^3	8 652 860
$CO_{2,\Sigma}$	t	16 997
Passenger car	1.10^3 km	116 653
Number of family houses	pcs	3 461

Banana peelings

Each inhabitant in the Czech Republic in 2008 consumed 12,2 kg of bananas in average, it comes to this, that in the whole Czech Republic were consumed 127 704 tons of bananas according to [10]. During their scaling an amount of waste banana peelings was reaching 50 456 tons, while amount of dry mass of peelings corresponded to 14 400 tons.

Tab. 10. Elementary composition of dry mass of banana peelings - % by mass.

Parameter	C	H	N	$S_{comb.}$	O^*	Ash
Value	43,37	5,21	1,43	<	36,57	13,42

*.. calculation of combustible matter up to 100 % , < .. below detection limit

By evaluation of relation (2) with elementary composition summarized in Tab. 10 according to formula

$$C_{36,1}H_{52,1}O_{22,9} + 11,62\ H_2O = 18,84\ CH_4 + 17,26\ CO_2$$

are generated methane and carbon dioxide in such amounts that are stated in Tab. 11. There is stated their overall radiation intensity in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

Tab. 11. Emission parameters of deposited banana peelings.

Quantity	Unit	Value
CH_4	m^3	7 147 941
CO_2	m^3	6 543 023
$CO_{2,\Sigma}$	m^3	66 325 805
$CO_{2,\Sigma}$	t	130 283
Passenger car	1.10^3 km	894 159
Number of family houses	pcs	26 530

Pineapple peelings

Each inhabitant in the Czech Republic in 2008 consumed 2,2 kg of pineapple in average, it comes to this, that in the whole Czech Republic were consumed 22 945 tons of pineapples according to [10]. During their processing before consummation an amount of waste pineapples peelings was reaching 8 719 tons, while amount of dry mass of peelings corresponded to 1 557 tons.

Tab. 12. Elementary composition of dry mass of pineapple peelings - % by mass.

Parameter	C	H	N	$S_{comb.}$	O^*	Ash
Value	42,67	5,77	1,77	<	44,30	5,5

*.. calculation of combustible matter up to 100 % , < .. below detection limit

By evaluation of relation (2) with elementary composition summarized in Table 12 according to formula

$$C_{28,2}H_{45,8}O_{22} + 5,74\ H_2O = 14,3\ CH_4 + 13,9\ CO_2$$

are generated methane and carbon dioxide in such amounts that are stated in Tab. 13. There is stated their overall radiation intensity in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

Tab. 13. Emission parameters of deposited pineapple peelings.

Quantity	Unit	Value
CH_4	m^3	642 406
CO_2	m^3	621 630
$CO_{2,\Sigma}$	m^3	5 594 480
$CO_{2,\Sigma}$	t	11 774
Passenger car	1.10^3 km	80 807
Number of family houses	pcs	2 398

Residues from grapes

Each inhabitant in the Czech Republic in 2008 consumed 4,8 kg of grapes in average, it comes to this, that in the whole Czech Republic were consumed 50 061 tons of grapes (production of wine was not included) according to [10]. During their consummation an amount of waste stems represented 995 tons, while amount of dry mass of residues corresponded to 245 tons.

Tab. 14. Elementary composition of dry mass of grape stems - % by mass.

Parameter	C	H	N	$S_{comb.}$	O^*	Ash
Value	43,95	5,31	1,48	V	40,97	8,29

* .. *calculation of combustible matter up to 100 % , < .. below detection limit*

By evaluation of relation (2) with elementary composition summarized in Tab. 14 according to formula

$$C_{34,7}H_{49,9}O_{24,3} + 1,08\ H_2O = 17,56\ CH_4 + 17,13\ CO_2$$

are generated methane and carbon dioxide in such amounts that are stated in Tab. 15. There is stated their overall radiation intensity in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

Table XV Emission parameters of deposited grape stems

Quantity	Unit	Value
CH_4	m^3	101 401
CO_2	m^3	98 882
$CO_{2,\Sigma}$	m^3	946 942
$CO_{2,\Sigma}$	t	1 860
Passenger car	1.10^3 km	12 765
Number of family houses	pcs	379

Orange peel

Total consumption of oranges in the Czech Republic in 2008 was approximately reaching 142 455 tons (12,3 kg oranges per inhabitant) according to [10]. An amount of 2 992 tons of dry peel out of this total consumption was deposited on dumping grounds as a result of their consummation. Elementary composition of this dry matter is stated in Tab. 16.

Tab. 16. Elementary composition of dry mass of orange peel - % by mass.

Parameter	C	H	N	$S_{comb.}$	O^*	Ash
Value	41,03	5,94	0,69	<	52,34	0,62

* .. *calculation of combustible matter up to 100 % , < .. below detection limit*

By evaluation of relation (2) with elementary composition summarized in Tab. 16 according to formula

$$C_{68,4}H_{117,8}O_{65,4} + 6,25\ H_2O = 32,6\ CH_4 + 35,8\ CO_2$$

are generated methane and carbon dioxide in such amounts that are stated in Tab. 17. There is stated their overall radiation intensity in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

Tab. 17. Emission parameters of deposited orange peel.

Quantity	Unit	Value
CH_4	m^3	3 692 417
CO_2	m^3	4 017 350
$CO_{2,\Sigma}$	m^3	84 925 591
$CO_{2,\Sigma}$	t	17 450
Passenger car	1.10^3 km	119 762
Number of family houses	pcs	3 553

Kiwi fruit peelings

Total consumption of kiwi fruit in the Czech Republic in 2008 was approximately reaching 8 374 tons (0,8 kg per inhabitant) according to [10]. An amount of 8 817 tons of kiwi fruit peelings out of this total consumption was deposited on dumping grounds as a result of kiwi fruit consummation. Recalculation on dry matter corresponded to amount of 459 tons. Elementary composition of this dry matter is stated in Tab. 18.

Tab. 18. Elementary composition of dry mass of kiwi fruit peelings - % by mass.

Parameter	C	H	N	$S_{comb.}$	O^*	Ash
Value	45,01	5,46	1,23	<	43,00	5,30

** .. calculation of combustible matter up to 100 % , < .. below detection limit*

By evaluation of relation (2) with elementary composition summarized in Tab. 18 according to formula

$$C_{41,6}H_{60,6}O_{29,94} + 11,5\ H_2O = 20,9\ CH_4 + 20,7\ CO_2$$

are generated methane and carbon dioxide in such amounts that are stated in Tab. 19. There is stated their overall radiation intensity in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

Tab. 19. Emission parameters of deposited kiwi fruit peelings.

Quantity	Unit	Value
CH_4	m^3	196 423
CO_2	m^3	194 210
$CO_{2,\Sigma}$	m^3	1 837 020
$CO_{2,\Sigma}$	t	3 608
Passenger car	1.10^3 km	24 765
Number of family houses	pcs	735

Tea

Total consumption of tea in the Czech Republic in 2008 was approximately reaching 4 186 tons (0,4 kg of tea per inhabitant) according to [10]. An amount of 4 056 tons of mass resulting from this total consumption was deposited on dumping grounds as a result of tea consummation. Analytical data of this waste are stated in Tab. 20.

Tab. 20. Elementary composition of tea waste - % by mass.

Parameter	C	H	N	$S_{comb.}$	O^*	Ash
Value	47,30	5,75	3,50	<	40,33	3,12

** .. calculation of combustible matter up to 100 % , < .. below detection limit*

By evaluation of relation (2) with elementary composition summarized in Tab. 20 according to formula

$$C_{15,77}H_{23,0}O_{10,1} + 4,97\ H_2O = 8,39\ CH_4 + 7,54\ CO_2$$

are generated methane and carbon dioxide in such amounts that are stated in Tab. 21. There is stated their overall radiation intensity in this Table as well respectively recalculation of this amount of carbon dioxide to corresponding distance of model journey by passenger diesel car respectively to number of family houses utilizing natural gas.

Tab. 21. Emission parameters of deposited tea waste.

Quantity	Unit	Value
CH_4	m^3	2 003 915
CO_2	m^3	1 831 504
$CO_{2,\Sigma}$	m^3	18 591 525
$CO_{2,\Sigma}$	t	36 519
Passenger car	1.10^3 km	250 637
Number of family houses	pcs	7 437

Conclusion

Performed modeling comparison demonstrates that it is necessary to reduce an amount of deposited municipal biodegradable waste due to the fact that an amount of generated green house gases is very significant.

The biggest amounts of green house gases coming from municipal waste usually deposited on dumping grounds are generated from poultry bones followed by banana peelings and potato peelings (representatives of 10 selected typical kinds of municipal waste). Overall radiation intensity of green house gases generated from deposition sites of these 10 typical kinds of municipal waste recalculated to a number of family houses (each with annual consumption of natural gas in amount of 2 500 m^3) corresponds approximately to 97 000 family houses, which is almost one tenth of all family houses in the Czech Republic.

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