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NOMOGRAMA of a Landfill (msw)—Setting *m* Parameter Values

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Abstract

MSW wastes depositing on a landfill in accordance with the national environment protection legislation means a (msw) waste conglomerate which generates greenhouse effect gas, especially CH_4 on an active lifetime of the deposit, but, in the same time, after the waste depositing quit too. As a consequence it is absolutely necessary to estimate gas emission quantities, mainly CH_4 annually. This thing can be done by quantitative waste degraded estimation, annually also. This paper describes the adequate technique to be used for the -*m*- parameters values establishing having in mind that -*m*- represents the number of months when a certain quantity of msw is degraded, annually, during the lifetime of the msw deposit (landfill). Nevertheless the establishing of the -*m*- values means, in fact, set up of the msw landfill NOMOGRAMA itself. The wastes agglomeration on a landfill can be expressed through a mathematical equation, whose analyze lead to the -*m*- values establishing. The waste (msw) will be degraded in time under the specific environmental factors of every region.

Keywords

Municipal Solid Waste (msw), Wastes Degradation, Mathematical Equation, Conglomerate, Nomograme

1. Introduction

The anthropic activities regarding the msw deposit management are subjected and are generators of greenhouse effect gas, especially CH_4 having potentially hazardous effects over the environment and especially on climate, as well. There are really concerns on the temperature rising, globally, due to the anthropic activities and it is provided that, up to 2020, Member States of UNFCCC-United

Nations Framework Convention on Climate Change [1] will have to reduce the global warming with at least 1.5˚C.

The diminishing measures are in accordance with DOHA agreements and amendments of the Kyoto Protocol provisions [2] and are referring to the 2013 ÷ 2020 period. These measures open the way for a new global climate changes agreement having the goal—a great global diminishing of the greenhouse gas effect to be mandatory by the year 2020.

It is well known that, through DOHA modification and agreements on the Kyoto Protocol [3], 38 developed countries agreed that the greenhouse gas effect will be minimum 18% with respect to the 1990 year level.

Within the new global climate agreement stated in Paris [4] a new action plan for global warming limitation was approved and this is more under 2˚C, for the 2020 ÷ 2030 period.

With respect to the msw wastes which have been eliminated through depositing after sorting, researchers from different countries are looking to find out a calculus relation (formula) in order to be able to estimate, quantitatively, the greenhouse gas emission CH_4, particularly. The formula will be applied both for conforming and nonconforming wastes deposits (landfills) [5].

Degree of uncertainty is great due to the various climate conditions, cultural diversification as well as the diversification of waste types and increasing of generated wastes quantity.

Within the present article (paper) I'm applying for a new concept regarding the management of msw wastes stated that *the time* is the main factor to establish the moment when wastes are completely degraded.

In spite of the fact that the calendaristic year is the reference year in the msw wastes management, the complete waste degradation, up to DOC, doesn't happen within depositing year.

A certain waste quantity is degraded, annually, in accordance with the -*m*- parameter, the number of months stated at the calculation year -A_T. The -m- value doesn't depend on the msw eliminated quantity when depositing but generate the degraded quantity or taken into consideration [6].

So, the eliminated waste quantities while depositing is an interesting factor and this information should be a mandatory one to be obtained through periodical checking or estimative calculus.

Upon information given in this article it is not a way to make a parallel with the existing practice [5] but the goal is to give the -*m*- parameter establishing methodology at the calculus year -A_T, and setting up the deposit NOMOGRAMA.

With regard the composition establishing of different types of wastes incorporated within main body of deposit such information can be taken from the reference [6].

In accordance with the provision of the European Directive 1999/31/CE [7] the msw wastes incorporated within the deposit (landfill) body, after sorting, are degraded up to DOC (Dissolved Organic Carbon) under the environmental factors action.

The problem of waste disposal (msw), seen from the perspective of agglomeration and the formation of a conglomerate [6], can be treated by mathematical equations [6].

2. Establishing the Equation of a Deposit (msw)

We shall start from the expression to be remembered is "*If* 7 *is added to* 3 *times a natural number the same result is obtained as when this number is reduced from* 13" [8].

This statement lead to the equation $3x+7=13-x$, where x is the variable [8], $x \in N$.

Considering that waste (msw) degrades in time but is stored (quantitatively) in the body of the landfill, daily, monthly, or annually, we can speak of the time equation for a landfill (msw) of

$$3t+7=13-t. \quad (1))$$

Respectively: if 7 accumulate at 3 times the time of stationing a quantity of municipal waste (msw) on a site, the same result is obtained when a time (expressed in months -*m*-) of number 13 is obtained.

In the first year of storage, waste degradation (msw) is incipient so that, $m = 0$, [6].

The equation will make sense if the waste degradation is considered to be made annually depending on the life of each [9] type of waste (msw) and the degradation time (t) will be expressed in months -*m*-.

In the case of an active municipal waste disposal (msw) one we can speak of a calendaristic year -A_C (starts on January the 1st, ending on December 31) and one year of calculation -A_T (shorter by 6 months (between 01.07 and 31.12) remain undegraded).

The equations containing -*m*- parameter are:

Equation (2) $Q_{\text{mswdegrad}.T} = \left[Q_{\text{msw}.T} + Q_{\text{msw}.T-1}\right] * \left[1-\exp(-Kt)\right], [\text{Gg}]$ [6] and

Equation (3) $Q_{\text{mswdegrad}.T} = \left[Q_{\text{msw}.T} + Q_{\text{mswundegrad}.T-1}\right] * \left[1-\exp(-Kt)\right], [\text{Gg}]$

The expression where -*m*-appears is: $\left(1-\text{e}^{-K\left(\frac{25-m}{12}\right)}\right)$ and $\left(1-\text{e}^{-K\left(\frac{13-m}{12}\right)}\right)$

where:

t-(time) expressed in months -*m*- in which degrading up to 45% of the wastes (msw) deposited or taken into account; -*m*- is a natural number, so $m \in N$.

At the time equation we can see:

- *t*-time cannot be measured in years; waste (msw) degrades annually but is stored on a daily basis;
- *t*-time cannot be measured in number of hours or number of days.

The only unit of measure for *t*-time, in the case of municipal deposits (msw) is the number of months, denoted -*m*-.

So every year -A_T-, in a number of months -*m*-, a quantity of waste (msw) stored in the body of the deposit will be degraded.

I have stated (see the above) that x is the variable, so, consequently, -m- is the variable:

$m \in N$. It is established that $7 \le m \le 18$.

The time equation for a municipal waste disposal (msw) after the first year storage can be written, generally as follows:

$$\left(3+\left(8n\right)\right)t+7=\left(\left(12n\right)+13\right)-t, \tag{2}$$

where:

• n = first year of calculation after the 2nd year of waste disposal (msw);

• t (time)-number of months -m-, value set at the calculation year -A_T, when degraded up to 45% of the waste stored or taken into account.

The following **Figure 1**, presents the simulation composition of a non-hazardous municipal wastes disposal (msw)—the mixed wastes deposited within its body.

It is to be noted that the calendar year of depositing starts on January the 1st and ends in the last day of the year, December, 31. It is so called the calendaristic year-A_C.

Calculus regarding the CH_4 emission is processed after the A_C is ended, usually in the first month of the year. This is the so called *the calculus year -A_T and* for this reason appears the value m = 7. So, this has to be considered that $A_C \ne A_T$.

Within an operational (msw) deposit, the collected mixed wastes are degraded at the year A_C, but at the calculus year A_T, it is to be considered that deposited (msw) wastes in the last 6 months, e.g. July, 1st ÷ December 31st, are not degraded.

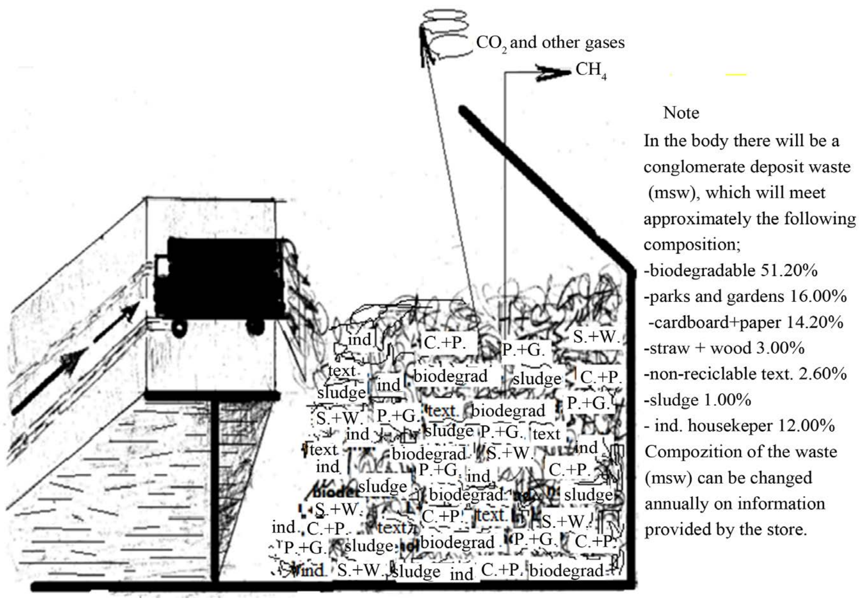

Figure 1. Simulation of a non-hazardous municipal wastes disposal (msw) composition, within its body.

3. *m*-Values Setting-Up Technique

To set-up the -m- values I used the following temporal equation:

$$3t + 7 = 13 - t \quad (1)$$

This equation can be applied to the non-hazardous mixed deposited wastes.

Some consideration related to the information generated by the Equation (1):

This is an equation which have the solution: $t = 3/2$, where t is expressed by m-number of months, annually stated, in which maximum 45% of the wastes deposited taken into consideration are degraded.

This solution carried-out incorrect information because:

- (msw) mixed wastes deposited are degraded within a year and a half, which is not correctly;
- (msw) mixed wastes deposited are degraded within a period of 18 months, which is not correctly also.

The temporal Equation (2) gives us the equations for the followings depositing years, after the first year of deposit.

After the depositing year 2, but the first year of calculation, the equation has the form:

$$11t + 7 = 25 - t \quad (2\text{-}1)$$

n = 1, year of calculation, $A_T \neq A_C$;

For the 3 rd year of storage, n = 2, year of calculation, $A_T \neq A_C$, the equation is the form:

$$19t + 7 = 37 - t, \quad (2\text{-}2),$$

The same procedure for the following deposited years.

In all cases the equation has, from the mathematical point of view, the same unique solution:

$$t = 3/2$$

4. The Analyze of the Equation Terms

The free term, on the right part, deliver the information, as following:

- In the first year, according to the Equation (1), the waste (msw) depositing took place in 12 months + 1 month necessary for calculus, data collection and information;
- In the second year, according to the Equation (2-1), the waste (msw) depositing took place in 24 months + 1month necessary for calculus, data collection and information;
- In the third year, according to the Equation (2-2), the waste (msw) depositing took place in 36 months + 1 month necessary for calculus, data collection and information;
- In the fourth year, according to the Equation (2-3), the waste (msw) depositing took place in 48 months + 1 month necessary for calculus, data collection and information;

and so on.

t—Coefficient from the left size of the equation:

Generating, the number of months -*m*- (approximately) necessary for the (msw) mixed wastes deposited and its degradation at the calculus year A_T, after dividing by number 7.

Examples:

- $3t + 7 = 13 - t$, (Equation (1)), 3:7 = 0.43; conclusion: in the first year of depositing took place an insignificant degradation, and m = 0,
- $11t + 7 = 25 - t$, (Equation (2-1)), 1st year of calculus, $A_T \neq A_C$, 11:7 = 1.57; conclusion: $m_1 = 7$;
- $19t + 7 = 37 - t$, (Equation (2-2)), 2nd year of calculus, $A_T \neq A_C$, 19:7 = 2.7; conclusion: $m_2 = 11$;
- $27t + 7 = 49 - t$, (Equation (2-3)), 3rd year of calculus, $A_T \neq A_C$, 27:7 = 3.8; conclusion: $m_3 = 14$, and so on.

Finally, the (msw) wastes are deposited, taking into consideration the calendaristic months. At the calculus year A_T you have to subtract 7 months from calendaristic months because in the last 6 months +1, degradation of the wastes didn't take place.

The (msw) wastes deposited within landfill body—a conglomerate of wastes, will be gradually degraded in accordance with the lifetime of every kind of waste.

The following **Table 1** presents the lifetime of some msw wastes as is cited within specific literature [9]:

According to the IPCC expert group, *t* is expressed by m-number of months and belongs to a closed interval $7 \leq m \leq 18$ and is independent by the quantity of mixed (msw) wastes deposited, much smaller one, deposited within -A_C. The degraded process depends by environmental factors.

m-the number of months, is not dependent by the msw waste quantity but give us the quantity of degraded wastes at the calculation year A_T. As a consequence, the msw waste quantity deposited, in every calendaristic year -A_C, have to be known, as valuable information.

The CH_4 emission starting to decrease after depositing of msw wastes ended [5].

Table 1. The degradation time for some types of wastes incorporated within deposit body.

Types of waste (msw)	Degradation periods [years]	Comments
Household bio-degradable wastes	01 ÷ 07	Within arid areas degradation is slower; in wetlands degradation is faster. The newspaper paper is degrading more slowly. Office paper degrades more quickly.
Non-household in wastes (msw)	10 ÷ 13	In arid areas degradation is slower; in wetlands degradation is faster
Industrial waste similar to household waste	20 ÷ 30	In arid areas degradation is slower; in wetlands degradation is faster
Waste paper and cardboard	11 ÷ 23	In arid areas degradation is slower; in wetlands degradation is faster. The newspaper paper is degrading more slowly. Office paper degrades more quickly.
Garden and park waste	02 ÷ 15	In arid areas degradation is slower; in wetlands degradation is faster
Waste wood and straw	01 ÷ 30	In arid areas degradation is slower; in wetlands degradation is faster

The proposed calculus relation and the algorithm one lead to the establishing of the year when CH_4emission quits.

At an active (msw) deposit, the mixed wastes degraded, at the year A_T took place both from the quantity of wastes deposited and, in the same time, from earlier years deposited amount.

For a (msw) landfill where wastes deposit is stopped, -m- will have the value 6, because A_T is identical with A_C, $A_T \equiv A_C$.

The environmental condition from the year of calculus, -A_T. It is absolute necessary that:

$$\sum 0 + m_1 + m_2 + \cdots + m_{n+1} \leq \left[(12n) + 13\right] - 7,$$

where:

- 0 correspond to the first depositing year: the degradation isn't significant;
- $m_1, m_2, m_3, m_4, \cdots, m_{n+1}$ are m values established at the year A_T;
- n represent the number of the deposited year -A_C-, in fact the lifetime of the landfill;
- 12—the number of months, calendaristic one;
- 13 = 12 + 1, 12—First year of storage (12 months) and 1—the necessary month for calculus and information collection;
- 7 Months, which has the following structure, 6 months + 1, period which belong to the interval 01.07 ÷ 31.12, when the wastes are considered not degraded at the year A_T.

A (msw) deposit (landfill) with mixed wastes, conforming or non-conforming, will have a starting year of depositing and a ended year of wastes depositing, both years starting and ending, being established by project, according to the national environmental authority decision or due to the external natural conditions (earthquakes, land sliding, floods, tornados, etc.) [10].

As it shown earlier, the (msw) deposit NOMOGRAMA depend by the stated project condition.

As a consequence the project has to be accompanied by its NOMOGRAMA and, eventually by an equivalent graphic regarding the evolution of CO_2 according to the project data.

With referring to the amount of (msw) mixed wastes deposited at the year A_C, an important remark is necessary: at the year A_T the -m- values have to be established in accordance with the environmental conditions (draught, rainfall, freezing times, snow, etc.).

If the lifetime of a (msw) wastes deposit is 100 years, a NOMOGRAMA should be drawing up.

5. Checking Example

For the depositing year 4 (2003) we shall have:

$\sum 0 + m_1 + m_2 + m_3 = 30 \leq 42$ lead to the -m- value; m = 14 for the year 2003.

This is a correct -m- value because the sum:

Table 2. Presents an example for the -m- values setting up in accordance with the depositing year -A_C and the equation of the calculus year -A_T.

Years of depositing/Years of calculation	Number of months necessary for degradation -m-	Number of deposited months in accordance with calendaristic years depositing($12n$)	The equation of every calculus year -A_T after the first depositing year: $(3+(8n))t+7=((12n)+13)-t$, Equation(2)
1(2000)	0	$(12+1)$	$3t+7=13-t$ (Equation (1))
2(2001)1	9	$((1\times12)+13)$	$11t+7=25-t$ (Equation (2-1))
3(2002)2	7	$((2\times12)+13)$	$19t+7=37-t$ (Equation (2-2))
4(2003)3	14	$((3\times12)+13)$	$27t+7=49-t$ (Equation (2-3))
5(2004)4	13	$((4\times12)+13)$	$35t+7=61-t$ (Equation (2-4))
6(2005)5	12	$((5\times12)+13)$	$43t+7=73-t$ (Equation (2-5))
7(2006)6	11	$((6\times12)+13)$	$51t+7=85-t$ (Equation (2-6))
8(2007)7	9	$((7\times12)+13)$	$59t+7=97-t$ (Equation (2-7))
9(2008)8	13	$((8\times12)+13)$	$67t+7=109-t$ (Equation (2-8))
10 (2009)9	11	$((9\times12)+13)$	$75t+7=121-t$ (Equation (2-9))
11(2010)10	10	$((10\times12)+13)$	$83t+7=133-t$ (Equation (2-10))
12(2011)11	7	$((11\times12)+13)$	$91t+7=145-t$ (Equation (2-11))
13(2012)12	9	$((12\times12)+13)$	$99t+7=157-t$ (Equation (2-12))

Legend:• first column:1, 2, 3, 4, 5, 6··· 10··· 13··· years of storage for calendar years, calendar year-A_C, calculation years, -A_T; 0, 1, 2, 3, 4, 5, 6··· 9··· 11··· 13··· after each calendar year -A_C ended;• The 2nd column—the -m- value at the calculation year;• The 3rd column: n—the number of storage months corresponding to the years of calculation, $n \in N$;• The calculation A_T equation year is generated by the Equation (2), where t is the time expressed by -m-number of degradation months having the value established at the calculation year -A_T.

$0+9+7+14 \le 42$; 42 = 49 − 7, is according to the equation corresponding to the year 4 of depositing.

For the depositing year 7 (2006) we shall have:

$\sum 0+m_1+m_2+m_3+m_4+m_5+m_6=66 \le 78$ lead to the -m- value; m = 11 for the year 2006.

This is a correct -m- value because the sum:

$0+9+7+14+13+12+11 \le 78$; 78 = 85−7, is in accordance with the equation corresponding to the year 7 of depositing.

In the Table 3 a NOMOGRAMA of Environmental Region 8 Bucharerst-Ilfov, years 2000 ÷ 2012, is presented Table 3 msw depositing years-deposited quantities. The NOMOGRAME of the landfill:

For the period 2013 ÷ 2016, the manager of the Chitila-Iridex landfill, the 8th environmental region Bucuresti-Ilfov, sent the following information:

- At the year 2015, after 16 years of depositing 6.968 [Gg] of CH_4, [9 721 000 m^3] respectively, there were collected;
- At the year 2016, after 17 years of depositing 5.790 [Gg] of CH_4, [8 077 600 m^3] respectively, there were collected.

As a consequence, the calculated TDOC, by means of Equation (5) [6], have to be increased by an aging coefficient, called msw Deposit Age Coefficient DAC_{10}, where 10 means that msw deposited has more than 10 years age.

Table 3. msw depositing years-deposited quantities. The NOMOGRAME of the landfill.

Landfill (MSW) Chitila-Iridex, environmental Region 8 Bucharest-Ilfov												
years of storage												
2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
quantities of waste (MSW) stored [Gg]												
43,536	361,157	361,656	309,421	349,464	384,451	367,985	245,497	448,694	434,852	425,521	361,000	371,568
m [number of months], values, according Nomogram deposit												
0.0	9.0	7.0	14.0	13.0	12.0	11.0	9.0	8.0	7.0	10.0	7.0	9.0
CH_4 [Gg], collected												
0,000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.640	5.355

Legend:• 2000, 2001, 2002, 2003... etc., years of storage (depositing);• quantities of msw waste stored, [Gg], within storage years;•*m*-number of months, values, in accordance with deposit NOMOGRAMA• CH_4 [Gg], collected.

Explanation:

Within deposit body, under environmental factors action, some LFG or DOC bags can appears. If these bags are freed the quantity of CH_4 is considerably increased, starting with the year 10 of depositing -A_O, the TDOC [6], calculated at the year A_T have to be increased, starting with this year 10, with 1.05 ÷ 1.055 or 5% ÷ 5.5%.

According to the NOMOGRAMA, the evolution of the greenhouse effect for the Chitila-Rudeni-Iridex landfill is presented in **Figure 2**.

You can see that CH_4 collecting led to the decreasing of the greenhouse effect.

A case study

For this case study I used information issued by the deposit manager regarding CH_4collected quantities/volumes of the deposited wastes for the years 2011 and 2012, as follows:

- 2011- 7 500 000 m^3, 5.640 [Gg];
- 2012-7 470 000 m^3, 5.355 [Gg];

For the years 2011 and 2012, the CH_4 emission is calculated as the difference between CH_4 generated [Gg], calculated and collected.

To carry out calculus, the Equation (1) [6] was used, as follows:

$$CH_{4\,(\mathrm{Gg/year})} = \left(Q_{\mathrm{mswdegrad}.T}\right) * \left(\%\mathrm{TDOC}_{\mathrm{disolved}\,T}\right) * \left(\mathrm{DOC}_f\right) * (16/12) * (F) * (F_r),$$

Equation (1), [6]

where:

$Q_{\mathrm{mswdegrad}.T}$, [Gg], is the msw waste degraded quantity at the calculation year -A_T based on the -*m*- value, according to the earlier presented methodology.

For the estimation of $Q_{\mathrm{mswdegrad}.T}$, [Gg], la -A_T = 12(2011) 11 (see **Table 2**), the Equation (3) was used [6]:

$$Q_{\mathrm{mswdegrad}.T} = \left[Q_{\mathrm{msw}.T} + Q_{\mathrm{mswundegrad}.T-1}\right] * \left[1 - \exp(-Kt)\right], [\mathrm{Gg}] \quad (3)$$

$$Q_{\mathrm{mswdegrad}.2011} = \left[Q_{\mathrm{msw}.2011} + Q_{\mathrm{mswundegrad}.2010}\right] * \left[1 - \exp(-Kt)\right], [\mathrm{Gg}]$$

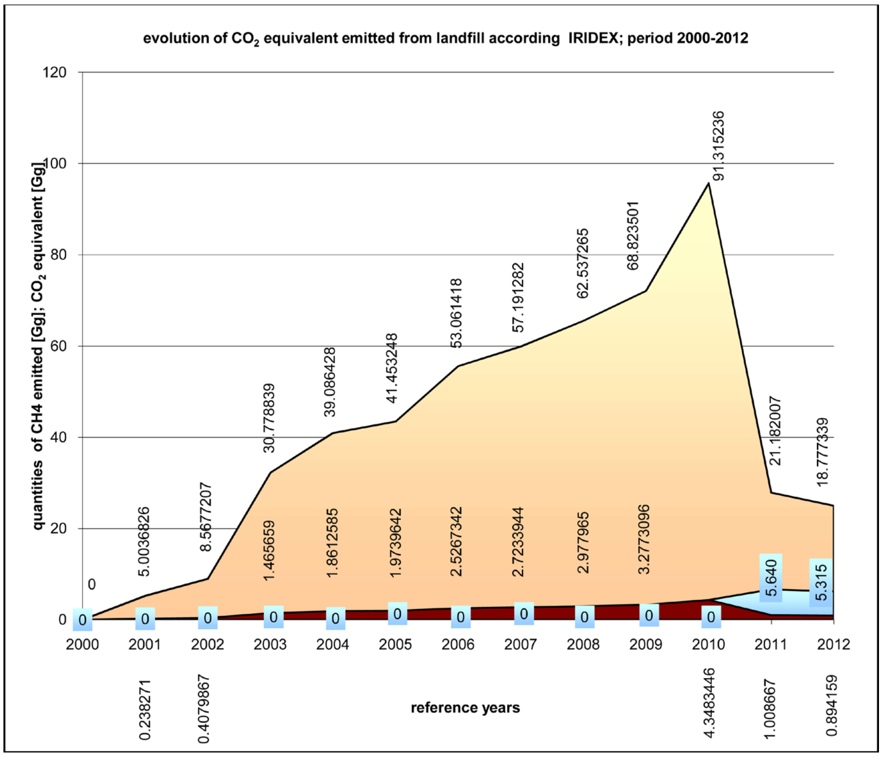

Figure 2. The evolution of greenhouse effect-period 2000 ÷ 2012, for the 8 Environmental Region Bucharest-Ilfov is presented.

where:

$Q_{\text{msw.2011}} = 361.000\,[\text{Gg}]$, msw deposited quantity within deposit body, at the year 2011,

$Q_{\text{mswundegrad.2010}} = 496.989\,[\text{Gg}]$, msw deposited quantity remained undegraded from the year 2010,

$(1-\exp(-Kt))$ means $\left(1-\mathrm{e}^{-K\left(\frac{25-m}{12}\right)}\right)$, m = 7 (-m-establishing value at the calculation year -A_T = 12(2011)11 have to fulfill 2 conditions:

1) $7 \le m \le 18$,
2) $\sum 0 + m_1 + m_2 + m_3 + m_4 + m_5 + m_6 + m_7 + m_8 + m_9 + m_{10} + m_{11} \le (145-7)$.

which means: $\sum 0+9+7+14+13+12+11+9+8+7+10+7 \le 138$, respective $107 \le 138$

As a consequence:

$$Q_{\text{mswdegrad.2011}} = (361.000 + 496.989) * \left(1-\mathrm{e}^{-K\left(\frac{25-m}{12}\right)}\right)[\text{Gg}], \text{ for } K = 0.4, \text{ [11]}$$

and m = 7 the Equation becoming:

$$Q_{\text{mswdegrad.2011}} = (361.000 + 496.989) * \left(1-\mathrm{e}^{-K\left(\frac{25-7}{12}\right)}\right)[\text{Gg}]$$

$$Q_{\text{mswdegrad.2011}} = 387.125\,[\text{Gg}]$$

$$Q_{\text{mswundegrad.2011}} = (361.000 + 496.989) - 387.125\,[\text{Gg}]$$

$$Q_{\text{mswundegrad.2011}} = 470.864\,[\text{Gg}]$$

By using the formula shown below, the percentage% of TDOC has been determined as:

$$\%\text{TDOC}_{\text{dissolved}.T} = (\text{TDOC}_{\text{dissolved}.T}) / (Q_{\text{msw taken in to consid}.T})$$ [6] [%], [12]

$\text{TDOC}_{\text{dissolved}.T}$ -*Total DOC* (*Organic Dissolved Carbon*), [Gg] was determined, such as:

$$\text{TDOC}_{\text{dissolved.2011}} = \sum [A + B + C + D + E + G], [\text{Gg}] \quad [6] \tag{5}$$

The terms *A*, *B*, *C*, *D*, *E*, *G* are calculated at the year 2011, by using adequate equations

$$A = Q_{\text{mswdegrad}.T} * \%\text{MSW}_{\text{biodegrad}.T} * k_0, [\text{Gg}] \quad [6] \tag{6}$$

$$A_{2011} = Q_{\text{mswdegrad.2011}} * \%\text{MSW}_{\text{biodegrad.2011}} * k_0, [\text{Gg}]$$

$k_0 = 0.185$ the bio-degradable wastes DOC generation ratio, is in accordance with [11], Chapter V, wastes;

$$Q_{\text{mswdegrad.2011}} = 387.125\,[\text{Gg}]$$

$\%\text{MSW}_{\text{biodegrad.2011}} = 51.2$ Predetermined for the year 2011;

$$A_{2011} = 387.125 \times 0.512 \times 0.185 = 36.668\,[\text{Gg}]$$

$$B = Q_{\text{mswdegrad}.T} * \%\text{MSW}_{(G+P)\text{degrad}.T} * k_1, [\text{Gg}] \quad [6] \tag{7}$$

$$B_{2011} = Q_{\text{mswdegrad.2011}} * \%\text{MSW}_{(G+P)\text{degrad.2011}} * k_1, [\text{Gg}]$$

$k_1 = 0.1$, the park and garden wastes DOC generation ratio, in accordance with [11], Chapter V wastes;

$\%\text{MSW}_{(G+P)\text{degrad.2011}} = 16$, predetermined for 2011;

$$B_{2011} = 387.125 \times 0.16 \times 0.1 = 6.194\,[\text{Gg}]$$

$$C = Q_{\text{mswdegrad}.T} * \%\text{MSW}_{(P+C+tex.)\text{degrad}.T} * k_2, [\text{Gg}] \quad [6] \tag{8}$$

$$C_{2011} = Q_{\text{mswdegrad.2011}} * \%\text{MSW}_{(P+C+text.)\text{degrad.2011}} * k_2, [\text{Gg}]$$

$k_2 = 0.06$, the papers + cartoon + textiles wastes DOC generation ratio, in accordance with [11], Chapter V, wastes;

$\%\text{MSW}_{(P+C+text).\text{degrad.2011}} = 16.8$, predetermined for 2011;

$$C_{2011} = 387.125 \times 0.168 \times 0.06 = 3.902\,[\text{Gg}]$$

$$D = Q_{\text{mswdegrad}.T} * \%\text{MSW}_{(\text{Wood+straw})\text{degrad}.T} * k_3, [\text{Gg}] \quad [6] \tag{9}$$

$$D_{2011} = Q_{\text{mswdegrad.2011}} * \%\text{MSW}_{(\text{Wood+straw})\text{degrad.2011}} * k_3, [\text{Gg}]$$

$k_3 = 0.03$, the wood + straw wastes DOC generation ratio in accordance with [11], Chapter V, wastes;

$\%\text{MSW}_{(\text{wood+straw})\text{degrad.2011}} = 3$, predetermined for 2011;

$$D_{2011} = 387.125 \times 0.03 \times 0.03 = 0.348\,[\text{Gg}]$$

$$E = Q_{\text{mswdegrad}.T} * \%\text{MSW}_{\text{sludg.degrad}.T} * k_n, [\text{Gg}] \quad [6] \tag{10}$$

$$E_{2011} = Q_{\text{mswdegrad.2011}} * \%\text{MSW}_{\text{sludg.degrad.2011}} * k_n, [\text{Gg}]$$

$k_n = 0.185$, the containing sludge wastes DOC generation ratio in accordance with [11], Chapter V, wastes;

$$\%\text{MSW}_{\text{sludg.degrad.2011}} = 1$$

$$E_{2011} = 387.125 \times 0.01 \times 0.185 = 0.716\,[\text{Gg}]$$

$$G = Q_{\text{mswdegrad}.T} * \%\text{MSW}_{\text{ind.degrad}.T} * k_4, [\text{Gg}] \quad [6] \tag{11}$$

$$G_{2011} = Q_{\text{mswdegrad.2011}} * \%\text{MSW}_{\text{ind.degrad.2011}} * k_4, [\text{Gg}]$$

$k_4 = 0.09$, the industrial wastes (similar to home wastes) DOC generation ratio, in accordance with [11], Chapter V, wastes;

$\%\text{MSW}_{\text{ind.degrad.2012}} = 12$, predetermined for 2011;

$$G_{2011} = 387.125 \times 0.12 \times 0.09 = 4.181\,[\text{Gg}]$$

$$\text{TDOC}_{\text{dissolved.2011}} = 36.668 + 6.194 + 3.902 + 0.348 + 0.716 + 4.181 = 52.01\,[\text{Gg}]$$

$$\%\text{TDOC}_{\text{dissolved}.T} = \left(\text{TDOC}_{\text{dissolved}.T}\right) / \left(Q_{\text{msw taken in to consid}.T}\right), [\%] \quad [6] \tag{12}$$

$$\%\text{TDOC}_{\text{dissolved.2011}} = \left(\text{TDOC}_{\text{dissolved.2011}}\right) / \left(Q_{\text{msw taken in to consid.2011}}\right), [\%]$$

$$Q_{\text{msw taken in to consid}.T} = Q_{\text{msw}\ T} + Q_{\text{msw undegrad}.T-1}, [\text{Gg}] \quad [6] \tag{13}$$

$$Q_{\text{msw taken in to consid.2011}} = Q_{\text{msw 2011}} + Q_{\text{mswundegrad.2010}}, [\text{Gg}]$$

$$Q_{\text{msw taken in to consid.2011}} = 361.000 + 496.989 = 857.989\,[\text{Gg}]$$

$\%\text{TDOC}_{2011} = 52.01/857.989 = 0.06062$; 6.062%, respectively.

The CH_4 generated quantity at the year 2011 is calculated by applying the Equation (1), as follows:

$$\text{CH}_{4\ \text{generated/2011}} = 387.125 \times 0.06062 \times 1.3333 \times 0.5 \times 0.8 \times 0.5 = 6.25785\,[\text{Gg}]$$

where:

- 385.125 [Gg] is (msw) degraded quantity at the year 2011 which generated DOC and, later on, CH_4 methane gas [12] [13] [14];
- 0.06062 is the percentage % TDOC within landfill body;
- 0.5 represent DOC_f taking into consideration the existing condition from the analyzed emission;
- 1.3333 (16/12) represent C from CH_4;
- 0.8 Represents the management level of the analyzed msw landfill, at the year 2011;
- 0.5 represents the% content of CH_4 Methane gas within Landfill Gas (LFG).

It is to be observed that the CH_4 gas emission increased gradually, but not suddenly, in accordance with the environmental condition of the landfill location. A certain wastes quantity of msw landfill will remain un-degraded and will be taken into consideration in the next year, so the process of msw degraded will generate, again DOC, and, as a consequence, CH_4 Methane gas.

At the year 2011 the economic operator collected 5.640 [Gg] CH_4, which was used for the green energy production.

In the same time, the operator delivered into atmosphere the difference

$$CH_{4\,\text{generated.2011}} - CH_{4\,\text{collected 2011}} = 6.25785 - 5.640 = 0.61785\,[\text{Gg}]$$

CO_2equivalent is:

$$CO_{2\,\text{equivalent 2011}} = CH_{4\,\text{emitted 2011}} \times 21 = 0.61785 \times 21 = 12.97485\,[\text{Gg}]$$

At the year 2012, for the same msw landfill-Chitila-Rudeni-Iridex, the quantity of CH_4 emission will be [12] [13] [14];

$Q_{\text{msw2012}} = 371.568\,[\text{Gg}]$ msw, deposited.

$Q_{\text{mswundegrad.2011}} = 470.864\,[\text{Gg}]$ the quantity of msw landfill un-degraded, remained from the year 2011;

$$Q_{\text{msw taken in to consid.}T} = Q_{\text{msw }T} + Q_{\text{mswundegrad.}T-1}, [\text{Gg}] \quad [6] \tag{13}$$

$$Q_{\text{msw taken in to consid.2012}} = 371.568 + 470.864 = 842.432\,[\text{Gg}]$$

msw landfill deposited taken into consideration for the calculus of $Q_{\text{mswdegrad.2012}}$, by using the Formula (3):

$$Q_{\text{mswdegrad.}T} = \left[Q_{\text{msw.}T} + Q_{\text{mswundegrad.}T-1}\right] * \left[1 - \exp(-Kt)\right], [\text{Gg}] \quad [6] \tag{3}$$

$K = 0.4$; $m = 9$ in accordance with msw deposit nomograme, (see **Table 3**).

$$Q_{\text{mswdegrad.2012}} = 350.452\,[\text{Gg}]$$

The non-degraded quantity of (msw) remained in the end of the year 2012; the Equation (4) is used:

$$Q_{\text{mswundegrad.}T} = \left(Q_{\text{msw }T} + Q_{\text{mswundegrad.}T-1}\right) - Q_{\text{mswdegrad.}T}, [\text{Gg}] \quad [6] \tag{4}$$

$Q_{\text{mswundegrad.2012}} = 842.432 - 350.452 = 491.980\,[\text{Gg}]$

By using the Equation (12), the percentage $\%\text{TDOC}_{\text{dissolved.}T}$ has been calculated, as follows:

$$\%\text{TDOC}_{\text{dissolved.}T} = \left(\text{TDOC}_{\text{dissolved.}T}\right) / \left(Q_{\text{msw taken in to consid.}T}\right) [\%] \quad [6] \tag{12}$$

$\text{TDOC}_{\text{dissolved 2012}}, [\text{Gg}]$ was calculated by using the Equation (5) :

$$\text{TDOC}_{\text{dissolved.}T} = \sum\left[A + B + C + D + E + G\right], [\text{Gg}] \quad [6] \tag{5}$$

The parameters—A, B, C, D, E, G are determined at the year 2012, by using corresponding equations.

$$A = Q_{\text{mswdegrad.}T} * \%\text{MSW}_{\text{biodegrad.}T} * k_0, [\text{Gg}] \quad [6] \tag{6}$$

$$A_{2012} = Q_{\text{mswdegrad.2012}} * \%\text{MSW}_{\text{biodegrad.2012}} * k_0, [\text{Gg}]$$

$k_0 = 0.185$, the biodegradable DOC generation ratio, in accordance with [11], Chapter V, wastes.

$$Q_{\text{mswdegrad.2012}} = 350.452\,[\text{Gg}]$$

$\%\text{MSW}_{\text{biodegrad.2012}} = 58$, predetermined for 2012;

$$A_{2012} = 350.452 \times 0.58 \times 0.185 = 37.603\,[\text{Gg}]$$

$$B = Q_{\text{msw degrad}.T} * \%\text{MSW}_{(G+P)\text{degrad}.T} * k_1, [\text{Gg}] \quad [6] \tag{7}$$

$$B_{2012} = Q_{\text{msw degrad}.2012} * \%\text{MSW}_{(G+P)\text{degrad}.2012} * k_1, [\text{Gg}]$$

$k_1 = 0.1$, parks and garden wastes DOC generation ratio in accordance with [11], Chapter V, wastes [15] [16]

$\%\text{MSW}_{(G+P)\text{degrad}.2012} = 13.8$, predetermined for the year 2012;

$$B_{2012} = 350.452 \times 0.138 \times 0.1 = 4.836\,[\text{Gg}]$$

$$C = Q_{\text{mswdegrad}.T} * \%\text{MSW}_{(P+C+text.)\text{degrad}.T} * k_2, [\text{Gg}] \quad [6] \tag{8}$$

$$C_{2012} = Q_{\text{mswdegrad}.2012} * \%\text{MSW}_{(P+C+text.)\text{degrad}.2012} * k_2, [\text{Gg}]$$

$k_2 = 0.06$, the papers + cartoon + textiles wastes DOC generation ratio in accordance with [11], Chapter V, wastes.

$\%\text{MSW}_{(P+C+text.)\text{degrad}.2012} = 10.7$, predetermined for the year 2012;

$$C_{2012} = 350.452 \times 0.107 \times 0.06 = 2.249\,[\text{Gg}]$$

$$D = Q_{\text{mswdegrad}.T} * \%\text{MSW}_{(\text{wood+straw})\text{degrad}.T} * k_3, [\text{Gg}] \quad [6] \tag{9}$$

$$D_{2012} = Q_{\text{mswdegrad}.2012} * \%\text{MSW}_{(\text{wood+straw})\text{degrad}.2012} * k_3, [\text{Gg}]$$

$k_3 = 0.03$, the wood + straw wastes DOC generation ratio in accordance with [11], Chapter V, wastes.

$\%\text{MSW}_{(\text{wood+straw})2012} = 3$, predetermined for 2012;

$$D_{2012} = 350.452 \times 0.03 \times 0.03 = 0.315\,[\text{Gg}]$$

$$E = Q_{\text{msw degrad}.T} * \%\text{MSW}_{\text{sludg.degrad}.T} * k_n, [\text{Gg}], \quad [6] \tag{10}$$

$$E_{2012} = Q_{\text{mswdegrad}.2012} * \%\text{MSW}_{\text{sludg.degrad}.2012} * k_n, [\text{Gg}]$$

$k_n = 0.185$, wastes (containing sludge) DOC generation ratio in accordance with [11], Chapter V, wastes;

$\%\text{MSW}_{\text{sludg.degrad}.2012} = 1.5$ Predetermined for the year 2012;

$$E_{2012} = 350.452 \times 0.015 \times 0.185 = 0.973\,[\text{Gg}]$$

$$G = Q_{\text{mswdegrad}.T} * \%\text{MSW}_{\text{ind.degrad}.T} * k_4, [\text{Gg}] \quad [6] \tag{11}$$

$$G_{2012} = Q_{\text{msw degrad}.2012} * \%\text{MSW}_{\text{ind.degrad}.2012} * k_4, [\text{Gg}]$$

$k_4 = 0.09$, (msw) landfill containing industrial wastes (similar to home wastes) DOC generation ratio, in accordance with [11], Chapter V wastes,

$\%\text{MSW}_{\text{ind.degrad}.2012} = 13$, predetermined for the year 2012;

$$G_{2012} = 350.452 \times 0.13 \times 0.09 = 4.100\,[\text{Gg}]$$

$$\text{TDOC}_{\text{dissolved}.2012} = 37.603 + 4.836 + 2.249 + 0.315 + 0.973 + 4.100 = 50.077\,[\text{Gg}]$$

$$\%\text{TDOC}_{\text{dissolved}.T} = \left(\text{TDOC}_{\text{dissolved}.T}\right) / \left(Q_{\text{msw taken in to consid}.T}\right) [\%] \quad [6] \tag{12}$$

$$\%\text{TDOC}_{\text{dissolved}.2012} = \left(\text{TDOC}_{\text{dissolved}.2012}\right) / \left(Q_{\text{msw taken in to consid}.2012}\right) [\%]$$

$$Q_{\text{msw taken in to consid}.T} = Q_{\text{msw}\ T} + Q_{\text{mswundegrad}.T-1}, [\text{Gg}] \quad [6] \tag{13}$$

$$Q_{\text{msw taken in to consid.2012}} = Q_{\text{msw2012}} + Q_{\text{mswundegrad.2011}}, [\text{Gg}]$$

$$Q_{\text{msw taken in to consid.2012}} = 371.568 + 470.864 = 842.432 [\text{Gg}]$$

$\%TDOC_{2012} = 50.077/842.432 = 0.05944$; 5.944%, respectivly.

The quantity of CH_4 in the year 2012 gas generated is calculated by applying the Formula (1) [6] as follows:

$$CH_{4\text{ generated/2012}} = 350.452 \times 0.05944 \times 1.3333 \times 0.5 \times 0.9 \times 0.5 = 6.24945 [\text{Gg}]$$

where:

- 350.452 [Gg] is msw degraded quantity in 2012 which generated DOC and, later on, CH_4;
- 0.05944, is the percentage% TDOC within landfill body;
- 0.5represents DOC_f taking into consideration existing condition from the analyzed emission;
- 1.3333 (16/12) represent C from CH_4;
- 0.9 represents the management level of the analyzed msw landfill, in the year 2012;
- 0.5 the CH_4 methane gas within Landfill Gas (LFG), content [%].

It is to be observed that the CH_4 gas emission increased gradually, but not suddenly, in accordance with the environmental condition of the landfill location [7]. A certain waste (rubbish) quantity of msw landfill will remain un-degraded and will be taken into consideration for the next year, so the process of msw degraded will generate again DOC, and, as a consequence, CH_4 Methane gas.

At the calculation year 2012, the economic operator collected 5.363 [Gg] CH_4, quantity used for the green energy production.

In the same time the operator delivered into atmosphere the difference

$$CH_{4\text{ generated.2012}} - CH_{4\text{ collected 2012}} = 6.24945 - 5.363 = 1.1315 [\text{Gg}]$$

CO_2equivalent is:

$$CO_{2\text{ equivalent 2012}} = CH_{4\text{ emitted 2012}} \times 21 = 1.1315 \times 21 = 23.7615 [\text{Gg}]$$

Table 4 presents NOMOGRAMA of a non-conforming landfill msw located

Table 4. Quantities of msw wastes deposited at Satu Nou-Baia Mare, Maramures District, years of depositing period, 1991 ÷ 2011.

During storage (storage Baia Mare-Satu Nou)																				
1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Quantity of waste (MSW) stored in the body of the deposit [Gg]																				
85,60	86,30	87,50	89,30	88,80	89,70	90,60	93,50	92,90	106,80	105,00	122,20	110,00	135,70	126,30	122,50	100,27	91,23	102,82	98,24	90,01
m—number of months fixed annual waste degradation, according NOMOGRAM																				
0	10	9	8	7	7	18	14	15	14	18	14	14	13	7	14	18	13	7	7	12

Legendă• 1991, 1992, 1993... 2011, msw depositing years: • msw quantities deposited within waste landfill body; •*m*—number of months fixed annually waste degradation, according to NOMOGRAMA.

in Maramures district, Romania, for the 1991 ÷ 2011 period.

And, accordingly to msw landfill Maramures, NOMOGRAMA, the evolution of greenhouse gas effect for the period 1991-2011 is presented in **Figure 3**.

6. Conclusions

Have to be taken into consideration that, at the global level, the mixed msw waste landfills (deposits) are one of the responsible for the global atmosphere warming by 3% ÷ 5% percentage.

So the necessity of a drawing up of a dispersion map of a msw mixed wastes deposits (landfills) is absolutely to be imposed.

An adequate and correct management of the msw deposits (landfills) is a stringent requirement for developed countries and a necessary one for undeveloped countries or those being in transition economies.

Year by year the global population rises and the quantity of msw wastes generated, increases, consequently [17], so it is absolute necessary to approach a new type of waste management—a friendly one. The waste depositing on the landfill has to be carried out according with legal environmental legislation, but in the same time, wastes depositing on other places than those legally approved will continues, unfortunately.

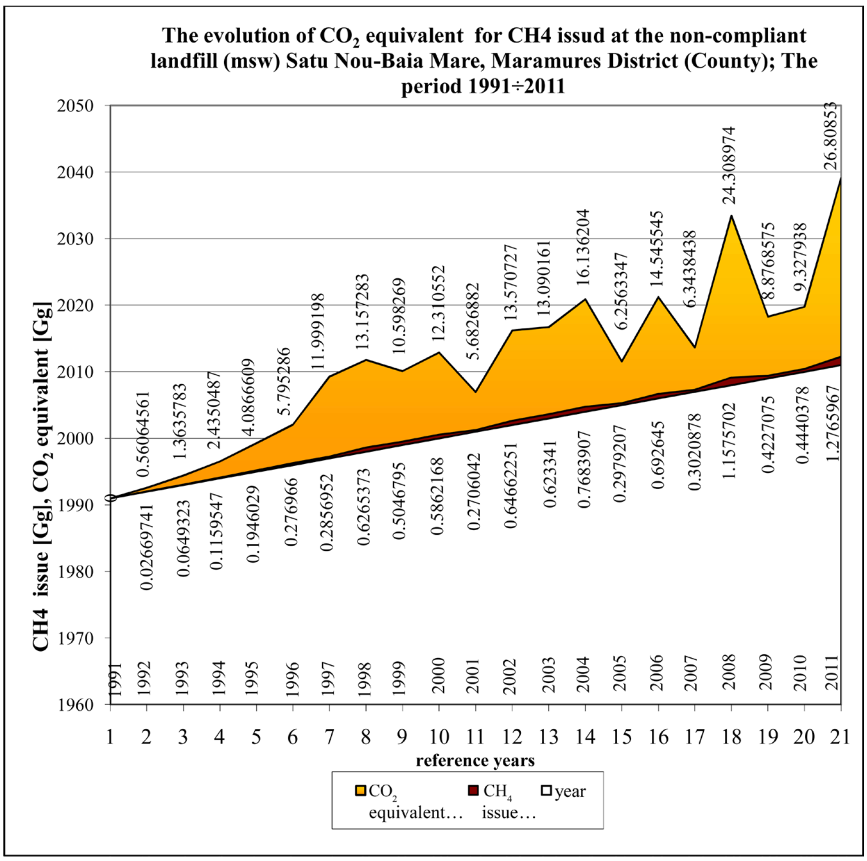

Figure 3. The evolution of greenhouse effect for the period 1991 ÷ 2011-Maramures District.

The best solution for the msw wastes management is their depositing on soil or within subsoil, with the exceptions of those without economical value. Of course, when the msw wastes is depositing on soil or subsoil, the problem of gas emission, particularly CH_4 is extremely important, according to the Kyoto Protocol [2].

Beside other calculation relations related to the estimation of waste gas emission, the formula presented [6] and dealing with the calculation of waste gas emission is based on the msw wastes degradation under the environmental factors action. The waste degradation period cover both active depositing period and post degradation time.

By implementing the idea of establishing -*m*- (number of months) parameter values—the period when maximum 45% of the waste deposited or taken into consideration is degraded, it is possible to estimate the quantity of CH_4emission from deposits with more than 0.1 Gg, annually deposited.

The proposed calculus relation is:

$$\text{CH}_{4(\text{Gg/year})} = \left(Q_{\text{mswdegrad.}T}\right) * \left(\%\text{TDOC}_{\text{disolved }T}\right) * \left(\text{DOC}_f\right) * (16/12) * (F) * (F_r),$$

Together with the *m* parameter establishing methodology and those 12 equations associated, the estimation is possible, by calculus, of the quantitative estimation of CH_4 from *msw* waste deposits.

For the legal environmental authorities but also for potential investors, the drawing up of the CO_2 evolution for every *msw* waste deposit is absolutely necessary for the first 10 years lifetime period [18].

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List of Abbreviation (LFG)—Landfill Gas

CH_4: Methane gas;
CO_2: Carbon dioxide;
UNFCCC (CCONUSC)—United Nations Framework Convention on Climate Change. Paris 2015;
C: Carbon;
A_C: Calendaristic year;
A_T: The year of calculus;
m: Number of months, the time in which max. 45 % of the wastes deposited or takeninto consideration at the year A_T, is a natural number $7 \le m \le 18$, $n \in N$;
(msw)—municipal solid waste;
n: number of years, $n \in N$;
N_2O: nitrogen dioxide;
HFC: hidrofluorocarbons;
PFC: per fluorocarbons;
DOC: Dissolved Organic Carbon;
GWP: Global warming potential.