THE DATABASE OF LANDFILLS OF MAŁOPOLSKA REGION IN POLAND BUILT ON THE BIOGAS PRODUCTION POTENTIAL CRITERIA.

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ABSTRACT

The paper presents criteria of landfill gas production and extraction and their application in creating a database of landfills. The situation of southern part of Poland is described and presented as a database of landfills in an appendix.

KEY WORDS

Landfill gas extraction, LFG installation, Poland

INTRODUCTION

According to statistics (Yearbook, 1998) in Poland there are about 950 operating municipal landfill sites of the global area of 31 km^2 (12 million tonnes of waste per year). A lot of landfill sites which were not included in the statistics have been recently closed, but due to materialisation processes that have been continuously going on, they still require gas extraction monitoring and leachate control.

Landfill sites are very much different in terms of their size, shape, degree of layers' density, and waste composition. These differences lead to differentiation of technical methods applied to reduce environmental damages caused by a particular landfill. This especially refers to the problem of gas extraction from landfill sites. The authors of the paper have aimed at establishing criteria for classification of landfill sites according to their capacity of biogas generation and ways of its utilisation (Grabowski, Sacharczuk, 1999 and 2000). On the basis of these criteria data from the operating landfill sites in the region of Małopolska have been collected. These data are needed to form an expert system, which would allow for a preliminary assessment of gas extraction purposefulness and to determine an adequate range of investments.

GAS EXTRACTION FROM LANDFILL SITES ACCORDING TO POLISH AND EUROPEAN UNION LEGISLATION

Polish law lacks regulations on gas extraction from landfill sites. In countries belonging to the European Union the directive on landfill sites (EC, 1999) imposes gas extraction from landfill sites. This directive is going to constitute a basis for Polish regulations concerning building, operation and supervision of landfill sites. The directive reads: "landfill gas shall be collected from all landfill sites receiving biodegradable waste and the landfill gas must be treated and used. If the gas collected cannot be used to produce energy it must be flared".

The authors of the paper are of the opinion that an uncritical implementation of the above quoted regulation may lead to investments, which would be unreasonable in both economical and ecological respects

The majority of Polish landfill sites has a small area and geometrical capacity, and the way the sites operate favours aerobic fermentation with carbon dioxide as its main product. In many cases landfill waste comprises small amounts of decomposable organic substances, which results in a little productivity of fermentation processes. Generally, gas extraction from landfill sites should be done when its advantages come from a comparative analysis of cumulated indicators (cumulated energy intensity – energy gains and cumulated emission – neglected emission). Such an analysis is quite complicated and costly.

Simplifying the issue, it can be undisputedly stated that if too small amount of the biogas together with its unfavourable composition do not promote gas flaring, and the neighbourhood area lacks a gas network, then building of any installation for gas utilisation is groundless. The main problem consists in determination of such boundary conditions for which building installations for gas extracting and utilisation can be justified. These conditions can be determined through the analysis of local conditions of some selected landfill sites. While carrying out this task, it was realised that no institution in Poland possesses any database on existing landfill sites. The only accessible information was taken from Central Statistical Office /Główny Urząd Statystyczny/ and it referred to the number of landfill sites and their area. Collecting database on landfill sites may, except for informational meaning, contribute to optimisation of waste management in the whole country.

CRITERIA FOR ASSESSING LANDFILL SITES IN RESPECT TO GAS EXTRACTION POSSIBILITIES

Generally, taking into consideration gas productivity as well as needs for gas extraction, landfill sites can be divided into the following:

- Landfill sites of high gas productivity, with gas of good energetic qualities; for these landfill sites the process of gas extraction is unquestionable, and the only matter to be discussed is the way in which the gas is to be utilised,
- Landfill sites where gas is generated in small amounts, or its composition and energetic qualities make it unsuitable for combustion; these landfill sites do not need gas extraction,

It is quite difficult to set a division boundary required by the above classification because a number of criteria should be taken into consideration. Therefore, the following set of criteria has been selected for the classification purposes:

- Area of a landfill site,
- Amount of waste disposed through a given time unit,
- Amount of organic substance content in waste according to the degree of area urbanisation,
- Method of landfill compaction,
- Landfill layout,
- Geological conditions,
- Landfill site operation method,
- Age of landfill site
- Humidity of waste deposit
- Land reclamation method

Area of a landfill site

The dependence between the gas productivity and the area of a landfill site is obvious – big landfill sites generate more gas, however, the way the process is distributed in time, depends on the other factors mentioned above. This division of landfill sites according to their area is merely conventional.

The landfill sites have been divided into:

- Small – less than 1 ha
- Medium – 1 to 4 ha
- Large – more than 4 ha

Amount of waste disposed through a given time unit

This criterion refers to waste at a particular fermentation phase.

Biogas productivity is influenced not only by the general mass of waste, but also by the height of waste layer and its increase, because the weight of waste layer affects waste compaction, which in its turn promotes better conditions for aerobic fermentation. In case of a landfill site where the waste is not compacted at all, the waste deposit in form of high layers may intensify the process of gas generation.

The ranges of waste deposit amount have been determined statistically, similarly to the ranges referring to area of landfill sites.

- Less than 5000 m^3/ year
- 5000 m^3/ year to 10000 m^3/ year
- More than 10000 m^3/ year

Amount of organic substance content in waste according to the degree of area urbanisation

Municipal waste consists of both organic and mineral components. Only the organic matter can be biodegradable, and therefore the amount of organic substances induces the size of gas volume and its composition.

Not all organic substances undergo biodegradation in the same extent and rate – there have been distinguished fast and slow biodegradable waste. The first group comprises green waste, and food, the other contains paper, cardboard, wood, and fibres. Plastic and rubber undergo biodegradation in such a slow way, that they can be considered non-biodegradable.

The proportion of organic substance matter in waste can be quite precisely estimated on the basis of urbanisation of the area where the waste has been produced. This is one of the criteria presented in this paper. In village areas the proportion of biodegradable organic substance is small, because such substances are usually composted, used as feeding stuff (food waste and green waste), or burnt at domestic fires. In the municipal areas practically all consumption waste is deposited at landfill sites.

The following division made on the basis of the amount of organic substance content has been accepted:

- Large (>25%) – cities
- Medium (10 - 25%) small towns or villages in the vicinity of big cities,
- Small (8 – 10%) countryside villages

Method of landfill compaction

Loosely deposited waste is characterised by high porosity, which allows for deep aeration, since the atmospheric oxygen can easily penetrate the waste. This prolongs the aerobic phase of fermentation, but later it obstructs the anaerobic decomposition. By means of landfill compaction the further aeration becomes impossible, and after the whole oxygen enclosed in pores is used up, the anaerobic decomposition starts and it results in production of methane, which decides about gas combustibility and is a very atmosphere hazardous component.

The following presents the degree of waste density according to a kind of machine applied.

- Density < 250 kg/m^3 /no compacting machines/
- Density 250 – 500 kg/m^3 /pushing machine/
- Density > 500 kg/m^3 /waste compactor/

Landfill layout

This criterion is also connected with waste aeration.
Layout of a landfill site may improve aeration – as in case of heap waste sites situated on a flat ground, where the waste cannot be aerated only from the bottom side; or it may obstruct aeration – as in case of a ravine or flat-bottom valley, where aeration can be done only from the top. In terms of aeration, slope-like landfill sites filled from the bottom upwards constitute an intermediate case, whereas, when filled from the top downwards (dropping waste down) the aeration is similar to that of heap waste sites.

Taking into account the above, the following types of landfill sites have been determined:

- Heap waste
- Slope-like
- Cavity-like (ravine or flat-bottomed valley)

Geological conditions

Gas generated in waste tends to migrate not only to the atmosphere but it also it permeates the soil, especially at the places of local discontinuity e.g. cavities. Gas can also migrate along gas pipelines, drainage systems, electric pipes, etc. which run in the vicinity of landfill sites. Basal sealing and impermeable soils reduce gas migration.

The classification is thus made on the basis of ground tightness.

- Lack of sealing, highly pervious soil
- Lack of sealing, weakly pervious soil
- Basal sealing by geo-membrane

Landfill site operation method

Besides compaction, gas generation is also influenced by the way a landfill site is formed. Operation on day-sites consisting in covering them with soil layers is optimal in terms of sanitary-hygienic reasons and reduces odour nuisance. The conditions of such formed landfill sections support then methane fermentation. Covering with weakly pervious soil makes it difficult for gas to migrate between landfill sections and may create problem while extracting gas by means of drilled wells without gas drainage.

The following landfill site operation factors influence biogas generation:

- Random operation method
- Waste deposition in covered landfill sections

Age of landfill site

Due to a relatively long time of methane fermentation (20 –25 years) and changeability of gas generation in time, the age of a landfill site and its particular sections, is essential for the global amount of gas generated. Landfill sites can be divided on the basis of an average age of the whole site or its sections into the following:

- Waste average age < 5 years
- Waste average age 5 – 10 years
- Waste average age > 10 years

Humidity of waste deposit

The content of humidity in waste has its impact on the conditions of gas generation. Water plays an important role in fermentation process as it supports bacteria to reach new sections of a landfill site. Keeping humidity at the optimal level of 50 – 60% is estimated to increase gas generation of 25 – 50 %, whereas, dry operation of a landfill site reduces gas generation at a prolonged time of deposit mineralisation.

Waste humidity may come from three sources: waste itself (waste may be humid), precipitation (snow, rain), and ground water infiltrating a deposit. Moreover, water (or sewage) may be delivered by effluent discharge points or by a special watering system, which would provide evenly distributed wetting.

Oleszkiewicz (1999) claims that there is no upper limit of waste humidity that would no longer help fermentation process, whereas, Banasiak (2000) says that an excessive humidity lowers temperature of waste deposit and then makes fermentation process slower.

Therefore the division is the following:

- Dry deposit
- Optimally humid deposit 50 – 60%
- Humid deposit

Land reclamation method

The way the sealing is carried out is very important for closing landfill sites. The sealing of the total landfill area allows for complete closing of possible ducts of biogas migration. However, due to lack of humidity income the fermentation of waste becomes slower. The capacity of the site is thus clearly reduced and generation of gas lasts a longer period of time.

The following criteria have been accepted for reclaimed landfill sites:

- Lack of planned reclamation
- Tight sealing of landfill site (foil or clay)
- Tight sealing of landfill site with controlled water leakage

OPTIMAL METHOD OF GAS INTAKE AND MANAGEMENT

Gas extraction system

Gas extraction system should meet not only the conditions at the site where gas is generated but also the conditions of expected reception of gas. The simplest method of gas extraction is a passive extraction, which consists in making a set of drilled wells to collect gas from a landfill site and to direct it to the atmosphere. This system, however, does not allow for controlling gas quantity and composition. The system is used for landfill sites of small capacity of gas generation (due to area of the site or e.g. the final stage of fermentation), sites that are closed and under reclamation.

System of drilled wells with active gas extraction. This system is used at landfill sites, which no longer operate; gas is extracted by under-pressure and then utilised. The characteristic feature of this system is the constant stream of gas; however, its composition is changeable.

System of horizontal drainage with pull-up wells is often used at operating landfill sites. This system usually has an active gas intake. The gas stream is more or less constant and gas composition is also unchangeable (characteristic to a particular stage of fermentation), due to elimination of atmospheric air suction. Because of an extant drainage this system provides maximum recovery of the gas generated.

Categories of gas extracting systems:

- Lack of gas extraction system – small, uncompacted, dry landfill sites
- Passive system with drilled wells – closed landfill sites
- Active system with drilled wells – closed landfill sites
- Active system with horizontal drainage (pipes) and pull-up wells - big operating landfill sites with a lot of biogas,

Use of biogas

The basic reason for extracting gas from landfill sites is to reduce the emission of greenhouse gases, and to prevent damage to environment. Since methane increases the greenhouse effect 21 times more than carbon dioxide, all attempts should be made to ensure flaring of the gas and utilisation of the energy produced. Biogas composition is changeable and it depends on circumstances at the moment when gas is being generated (stage of fermentation, process conditions - temperature, humidity, pH, etc.) This phenomenon sometimes makes combustion of gas difficult.

Methods of gas utilisation

The methods of gas utilisation can be systematised according to their energy effects with regards to exergy of the carrier produced.

- Directed emission to atmosphere; the result – reduction of fire risks at a landfill site,
- Combustion in a torch; the result - GWP is reduced due to oxidation of methane to carbon dioxide,
- Combustion of gas in combustion chamber with heat recovery; the result – GWP is reduced + chemical energy is recovered in form of heat energy. Due to exergy of the heat carrier the method should be used in a landfill site infrastructure or for neighbourhood objects (often industrial use),
- Combustion of gas in an engine of a current generating unit; the result – reduction of GWP + chemical energy recovered in form of electric energy. This energy can be transmitted to any place by means of electric power networks.

- Combustion of gas in an engine of a current generating unit with the use of heat of exhaust fumes and engine cooling (CHP); the result - reduction of GWP + chemical energy recovered in form of electric energy and heat. This energy can be transmitted to any place by means of electric power networks and heat to local recipients.

RESTRICTIONS ON UTILISATION OF CHEMICAL ENERGY OF BIOGAS

Self-combustion

In case of too low furnace value or too low concentration of combustion components, the gas mixture needs to be enriched with high methane gas. It is possible if a gas network is situated in the vicinity of biogas installation. This restriction refers to any combustion method of gas utilisation.

Distance to heat energy recipients

Sending energy in form of hot water is expensive. There are limits of remuneration for heat transport. Because of the fact that landfill sites are situated far from urban areas, the heat reception is usually limited to cover the own needs of a landfill site. (Heating + hot domestic hot water)

Continuity of heat energy reception

Process of biogas generation and utilisation progresses in time, although, more biogas is generated in summer than in winter (fermentation processes are influenced by atmospheric conditions). Therefore, reception of heat for technological objectives and for domestic hot water providing is more economic than utilisation of heat for mere heating purposes (seasonal reception). Surpluses of heat must be dispersed. Transformation of chemical energy of biogas into electric energy allows for its utilisation in energetic system in away, which is continuous and free from local requirements. (Obligation of power networks to receive electric energy).

DATABASE OF LANDFILL SITES

On the basis of the above criteria a database of landfill sites in Małopolska region has been prepared [9]. 69 landfill sites (7,5% of all landfill sites in Poland) have been included in an inquiry. The statistical data collected in the inquiry are presented in the appendix.

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APPENDIX. LANDFILLS OF THE MAŁOPOLSKA REGION

No	Location of a landfill (county, community)	Area [ha]	Amount of deposited waste [thous.Mg/year]	Amount of deposited waste [m^3/year]	Beginning of exploration	Operation	Serviced area (degree of urbanisation)	Waste compaction	Landfill layout
1	Barycz – Kraków,	36,7	252,0	630000,0	1974	Operating	city >100000	compactors, pushing machines	cavity like
2	Zabełcze – Nowy Sącz,	8,6	9,1	22750,0	1998	Operating	city >10000 .	compactors, pushing machines	cavity like
3	Tarnów Krzyż – Tarnów;	13,0	30,6	76500,0	1985	Operating	City >10000 .	compactors, pushing machines	heap waste
	BOCHNIA COUNTY								
4	Borek – Rzezawa,	1,2	no data	no data	1998	Operating	Villages	no data	no data
5	Lipnica Murowana - Lipnica Murowana,	1,3	0,5	1250,0	1987	Operating	Villages	no data	no data
6	Łąkta Górna – Żegocina,	0,3	0,4	1000,0	1950	Operating	Villages	pushing machine ocasionally	sloped cavity
7	Krzyżanowice – Bochnia,	1,3	0,06	150,0	1980	Closed	City >10000 , villages	pushing machinee	sloped cavity
8	Nowy Wiśnicz - Nowy Wiśnicz;	1,0	0,8	2000,0	1968	Closed	City >10000 , villages	no data	no data
	BRZESKO COUNTY								
9	Jadowniki – Brzesko,	4,0	16,5	41250,0	1983	Operating	City>10000 M, villages	pushing machine	cavity-like
10	Maszkienice – Dębno,	0,7	5,4	13500,0	1990	Operating	villages	no data	no data
11	Uszew – Gnojnik,	1,1	1,0	2500,0	1980	Operating	villages	no data	no data
12	Okrajki – Szczurowa,	0,7	0,3	750,0	1970	closed	villages	no data	no data
13	Bielcza – Borzęcin;	1,2	no data	no data	1985	closed	villages	no data	no data
	CHRZANOW COUNTY								
14	Balin Okradziejówka – Chrzanów,	1,0	36,0	90000,0	1985	operating	City >10000 , villages	pushing machine	heap waste
15	Libiąż – Libiąż,	2,0	3,6	9000,0	1977	operating	city >10000 , villages	pushing machine	heap waste
16	Trzebinia – Trzebinia,	4,0	30,6	76500,0	1982	operating	city >10000 , villages	pushing machine	heap waste
17	Wygiełzów – Babice,	1,6	0,4	1000,0	1975	operating	villages	no data	no data
18	Szarwark – Dąbrowa Tarnowska;	1,4	8,7	21750,0	1974	operating	City >10000 , villages	no data	no data
	GORLICE COUNTY								
19	Bobowa – Bobowa,	1,7	0,1	250,0	1993	operating	villages	no equipment	gravel cavity
20	Uście Gorlickie - Uście Gorlickie;	0,5	0,6	1500,0	1997	operating	villages	pushing machine	no data
21	Biecz – Biecz	0,64	no data	no data	no data	operating	City<10000 M, villages	pushing machine	gravel cavity
22	Ropica Polska	4,9	no data	no data	no data	closed	villages	pushing machine	gravel cavity
	CRACOW COUNTY								
23	Skawina – Skawina,	6,0	11,0	27500,0	1986	closed	City >10000 , villages	pushing machine	heap waste

No	Location of a landfill (county, community)	Area [ha]	Amount of deposited waste [thous.Mg/year]	Amount of deposited waste [m³/year]	Beginning of exploration	Operation	Serviced area (degree of urbanisation)	Waste compaction	Landfill layout
24	Kulerzów – Mogilany;	2,0	5,0	12500,0	1993	operating	villages	pushing machine	flat-bottomed valley
25	Cianowice - Skała	1,2	0,3	750,0	1970	Closed	city <10000 , villages	pushing machine occasionally	clay mine
26	Milonki - Trzyciąż	0,5	no data	no data	1995	Closed	villages	no	cavity
27	Podchybie - Trzyciąż	0,4	no data	no data	no data	closed	villages	no	sand mine
28	Zagacie - Czernichów	2,0	0,5	1250,0	1980	closed	villages	pushing machine occasionally	sand mine
29	Alwernia - Alwernia	0,5	no data	no data	1970	closed	City<10000 M, villages	brak	u podnóża kamieniołomu
	LIMANOWA COUNTY								
30	Kamienica – Kamienica,	0,6	0,1	250,0	1993	closed	villages	no data	no data
31	Słopnice – Limanowa,	2,0	5,3	13250,0	1974	operating	City >10000 , villages	no data	no data
32	Mszana Dolna - Mszana Dolna;	0,7	2,0	5000,0	1966	closed	City >10000 , villages	no data	no data
	MIECHOW COUNTY								
33	Miechów – Miechów,	1,9	4,3	10750,0	1959	operating	City >10000 , villages	no data	no data
34	Mianocice – Książ Wielki;	1,0	0,6	1500,0	1978	operating	City <10000 , villages	no data	no data
	MYSLENICE COUNTY								
35	Borzęta – Myślenice,	4,5	31,7	79250,0	1971	operating	City >10000 , villages	pushing machine	flat bottomed valley
36	Sułkowice – Sułkowice;	1,2	1,7	4250,0	1973	operating	City <10000 , villages	pushing machine	ravine
	NOWY SACZ COUNTY								
37	Grybów – Grybów,	1,8	1,6	4000,0	1990	operating	City <10000 , villages	pushing machine	heap waste (sloped)
38	Uroczysko Głębokie – Krynica,	3,0	4,5	11250,0	1995	operating	City >10000 , villages	pushing machine, compactor	flat bottomed valley
39	Kosarzyska – Piwniczna,	1,0	1,2	3000,0	1976	operating	City <10000 , villages	no data	no data
40	Andrzejówka – Muszyna,	0,7	1,1	2750,0	1960	operating	City <10000 , villages	no data	no data
41	Osowie – Podegrodzie,	1,7	0,2	500,0	1991	operating	villages	no data	no data
42	Piaski – Stary Sącz;	3,2	1,5	3750,0	1970	operating	City <10000 , villages	pushing machine	heap waste
	NOWY TARG COUNTY								
43	Jabłonka – Jabłonka,	3,0	0,1	250,0	1985	operating	villages	no data	no data
44	Nowy Targ - Nowy Targ,	1,0	13,4	33500,0	1957	operating	City >10000 , villages	no data	no data
47	Jaworki – Szczawnica,	1,9	2,0	5000,0	1982	operating	City <10000 , obszary miejskie	no data	no data
45	Zaskale – Szaflary;	1,1	0,9	2250,0	1938	operating	villages	no data	no data

No	Location of a landfill (county, community)	Area [ha]	Amount of deposited waste [thous.Mg/year]	Amount of deposited waste [m³/year]	Beginning of exploration	Operation	Serviced area (degree of urbanisation)	Waste compaction	Landfill layout
	OLKUSZ COUNTY								
46	Ujków Stary – Bolesław;	13,1	31,3	78250,0	1997	operating	City>10000 M, villages	pushing machine	mine cavity
	OŚWIĘCIM COUNTY								
47	Chełmek – Chełmek,	2,5	3,8	9500,0	1976	operating	City <10000 , villages	pushing machine	heap waste
48	Jawiszowice – Brzeszcze,	10,9	9,0	22500,0	1990	operating	City >10000 , villages	no data	no data
49	Kęty – Kęty,	5,0	9,6	24000,0	1998	operating	City >10000 , villages	pushing machine	heap waste
50	Oświęcim – Oświęcim,	8,6	20,0	50000,0	1993	operating	City >10000 , villages	pushing machine, compactor	heap waste
51	Zator – Zator;	1,3	2,0	5000,0	1994	operating	City <10000 , villages	no data	no data
	PROSZOWICE COUNTY								
52	Polanowice –Słomniki,	1,2	4,0	10000,0	1989	operating	gmina<10000 M, villages	pushing machine	cavity
53	Żębocin – Proszowice;	4,0	13,2	33000,0	1982	operating	city <10000 , villages	pushing machine	sloped heap waste
	SUCHA BESKIDZKA COUNTY								
54	Jordanów – Jordanów,	1,5	1,2	3000,0	1984	closed	city <10000 , villages	no data	no data
55	Maków Podhalański - Maków Podhalański,		2,8	7000,0	1968	operating	city <10000 , villages	no data	no data
56	Sucha Beskidzka - Sucha Beskidzka,	1,8	7,0	17500,0	1960	operating	city <10000 , villages	pushing machine	heap waste
57	Zembrzyce – Zembrzyce;	0,3	0,4	1000,0	1978	operating	villages	no data	no data
	TARNOW COUNTY								
58	Charzewice – Zakliczyn,	0,5	0,76	1900,0	1985	operating	villages	no data	no data
59	Gromnik – Gromnik,	0,9	0,1	250,0	1990	operating	villages	no data	no data
60	Tuchów – Tuchów,	1,7	1,0	2500,0	1960	operating	City <10000 , villages	no data	no data
61	Żabno – Żabno;	4,0	3,6	9000,0	1974	operating	City <10000 , villages	no data	no data
	TATRA COUNTY								
62	Zoniówki – Zakopane;	1,0	7,7	19250,0	1986	operating	City <10000 , villages	pushing machine, compactor	sloped
	WADOWICE COUNTY								
63	Andrychów – Andrychów,	5,0	11,3	28250,0	1969	operating	City >10000 , villages	no data	no data
64	Lanckorona – Lanckorona,	0,3	0,6	1500,0	1980	operating	City<10000 M, villages	pushing machine	sloped

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65	Spytkowice – Spytkowice,	2,2	0,3	750,0	1978	closed	City<10000 M, villages	no data	no data
66	Chocznia- Wadowice,	5,5	9,2	23000,0	1966	operating	City >10000 , villages	pushing machine, compactor	cavity
67	Zebrzydowice-Bieńkowice – Kalwaria Zebrzydowska;	1,0	2,0	5000,0	1991	operating	city >10000 , villages	no data	no data
	WIELICZKA COUNTY								
68	Niepolomice – Niepolomice,	4,0	19,8	49500,0	1991	operating	city <10000 , villages	2 pushing machines	heap waste
69	Skrzynka – Dobczyce.	2,0	3,8	9500,0	1980	operating	city <10000 , villages	pushing machine, compactor	ravine