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Documentation of data on landfills

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SMED is short for Swedish Environmental Emissions Data, which is a collaboration between IVL Swedish Environmental Research Institute, SCB Statistics Sweden, SLU Swedish University of Agricultural Sciences, and SMHI Swedish Meteorological and Hydrological Institute. The work co-operation within SMED commenced during 2001 with the long-term aim of acquiring and developing expertise within emission statistics. Through a long-term contract for the Swedish Environmental Protection Agency extending until 2014, SMED is heavily involved in all work related to Sweden's international reporting obligations on emissions to air and water, waste and hazardous substances. A central objective of the SMED collaboration is to develop and operate national emission databases and offer related services to clients such as national, regional and local governmental authorities, air and water quality management districts, as well as industry. For more information visit SMED's website www.smed.se.

Summary

In this report some vital data on landfills, used in Sweden's greenhouse gas inventory to the UNFCCC, are controlled according to current guidelines. Quality aspects of historic surveys on deposited wastes are considered and compared over time. Plant specific data on recovered methane gas from landfills have been scanned into a database, which has been used as a tool for quality control.

Despite of some minor differences, the historic quantities of deposited wastes seem to be consistently estimated. There seem to be no systematic differences between the surveys with data on deposited waste amounts, but the variability in the earliest surveys is probably greater.

Data on recovered methane are accurate in general, since they mainly depend on sold energy; information that is well documented at the plants. Some unexplained deviations are however identified, when comparing the plant specific values over time. In some cases, it may be possible to increase the quality of the data by renewed contacts with the respondents. Much data were however collected some years back in time, which probably will make a systematic revision of the data unrealistic. A revision of a few values would probably only have minor impacts on the total amount of recovered methane. In the future, the quality of data input could be improved, by immediate consistency checks with older data. The collected data could be stored in a waste database, such as DIA (a database created within the project Data om hushållsavfall), to simplify this procedure.

1. Introduction

Activity data used to calculate emissions of CH_4 from landfills are the amounts of deposited wastes and the amount of methane recovered from the waste deposits. Since 1994, the Swedish Association of Waste Management (RVF) has annually collected data from waste disposals and before 1994 the Swedish EPA and Statistics Sweden collected data intermittent. These national data have been used for the Swedish reporting of methane emissions from waste to the UNFCCC. Beyond the need of statistical data, there are requirements on documentation of these data sources in the IPPC Good Practice Guidance and Uncertainty Management in National Greenhouse Inventories (Good Practice Guidance), which have not earlier been completely fulfilled.

1.1 Requirements in the Good Practice Guidance

1.1.1 Amounts of deposited wastes on landfills

The tier 2 methodology demands annual activity data on land filled wastes from some decades back in time, according to the Good Practice Guidance.[1] If such data do not exist, it is possible to use data from available years combined with model trend calculations of deposited amounts for earlier years. This combined method with collected waste statistics and model calculations are used in Sweden, and probably in many other countries using the tier 2 methodology.

According to the IPCC Guidelines,[2] parties shall control and document the method of data recovery and how data have been aggregated if activity data are based on statistical surveys. Data shall also be compared over available years to estimate the accuracy of data. These last two requirements are also mentioned in the Good Practice Guidance chapter 5.1.3.

1.1.2 Methane gas recovery

Data on methane gas recovery is the other activity data needed for estimating emissions from landfills. IPCC Guidelines default value for methane gas recovery is zero. Only parties with well-documented references with information on gas recovery might use an other emission gas recovery factor. According to the Good Practice Guidance, the estimates of gas recovery shall be based on measurements of the gas used for energy production and gas that has been flared.

The requirements on quality control and documentation in the Good Practice Guidance are seemingly more stringent for methane recovery than for deposit waste amounts. According to the Good Practice Guidance chapter 5.1.2, parties ought to accomplish an inventory of waste deposit plants with gas recovery and it is stated that parties shall assure that data has been collected and aggregated correctly. In the Good Practice Guidance chapter 5.1 it is further stated how these data sources should be chosen and documented properly. The size

[1] Good Practice Guidance and Uncertainty Management in National Greenhouse Inventories, Figure 5.1.
[2] Revised 1996 IPPC Guidelines for National Greenhouse Gas Inventories

the collected amounts of gas shall, for instance, be compared on plant level over the whole time series.

1.2 Aim of study

The aim with this study is to assure that the main demands on documentation in the waste sector mentioned above is fulfilled in line with the Good Practice Guidance. The project and the resulting documentation will include three parts:

- **Chapter 2.1: Documentation of data on deposited waste amounts**
  The on-going work in the SMED project "Data om behandlingsanläggningar" will be followed, to study the coverage of treatments plants in the RVF statistic.

  An over-view of relevant quality aspects of the historical waste statistics will be carried out, partly using the quality declarations that have been compiled by SMED, to evaluate the comparability between different waste surveys.

  If possible a list with closed municipal waste deposits was supposed to be compiled in cooperation with the SMED Waste group, based on data from available sources from the database EMIR, and data from RVF and Statistics Sweden. This was however not possible, due to incomplete historical data in the sources that were put together within that project.

- **Chapter 2.2: Comparison of land filled waste amounts and waste incineration**
  To further assure and verify that the amounts of land filled waste used for calculations of methane emissions are reasonable, a comparison will be made with waste incineration.

- **Chapter 2.3: Documentation of data on methane gas recovery**
  A list of landfills with methane gas recovery is compiled, based on available information. This list will be used as a tool for quality assessment of data.

2. Method of analysis

The method used for the three parts described above has mainly been studies of available literature along with data base calculations. The specific methods in each part of the study are described below.

2.1 Documentation of data on deposited waste amounts

Data available on estimated amounts of deposited household waste, park and garden waste and sludge from waste water treatment plants have been collected from different data sources since 1980, summarized in Table 1 below. These are the main data sources used to estimate emissions of CH_4 from landfills.

Table 1. Surveys of waste deposition in Sweden.

Reference year	Statistical producer	Source
1994-2003	RVF	RVF´s annual surveys published in ”Avfallsanläggningar med deponering”
1990	SCB, Swedish EPA	SCB Na 28 SM 9201: ”Avfall och återvinning i kommunalregi” Statistics Sweden 1992.
1988	RVF	RVF 90:1. ”Statistik Svensk avfallshantering” Swedish Association of Waste Management 1990.
1986	RVF	RVF 88:5. ”Statistik, Svensk avfallshantering 1986” Swedish Association of Waste Management 1988.
1985	SCB, Swedish EPA	SCB Na 28 SM 8801. ”Avfall och återvinning i kommunal regi 1985” Statistics Sweden 1988.
1980	Swedish EPA	SNV PM 1652: ”Avfallsanläggningar i Sverige, Statistik och sammanställningar” Swedish EPA 1983.

2.1.1 Quality in used statistics on deposited waste amounts

The surveys regarding data in 1990, 1994, 1996, 1998, 2001 and 2002 have earlier been quality declared by SMED on a commission from the Swedish EPA.[3] The survey in 1985 is quality declared in line with the system for official statistics[4] and the survey report for 1980 includes a relatively extensive description of the methods used. Information about the surveys in 1986 and 1988 are though sparser.

RVF’s annual surveys from 1994 are made in the same way for all years and are completely comparable when it comes to data on amounts of deposited wastes. When comparing specific quality aspects i.e. population, coverage, non-response adjustment and reporting, all the surveys referenced seem very much alike. There are however also some differences between the surveys, as well as variability in the answers. We will investigate the relevant quality aspects one by one.

2.1.1.1 Survey design, data collection and population

All statistical surveys referred in Table 1 are designed as total surveys of landfills, were data on land filled waste quantities, among other data, have been collected by using postal questionnaires.

The population of interest is from 1990 and later defined to cover landfills, which have received at least 50 ton of waste in the reference year, but in the surveys of data in 1980 and 1985, a cut-off limit of 50 ton of household waste and similar was used. In 1986 and 1988 the cut-off limit was not documented. In order to estimate the possible impact of this somewhat ambiguous definition, the data base with primary data from 1990[5] has been used for checking which waste quantities that are deposed on landfills receiving more than 50 tons of total waste, but less than 50 tons of household waste. The result is given in table 2 and shows that only a negligible fraction on household waste is added when the population is extended, according to the definition used in the survey of 1990. The overestimation of

[3] Internationell rapportering av svenska avfallsdata
[4] MIS 2001:1 Quality definition and recommendations for quality declarations of official statistics. Statistics Sweden 2001.
[5] SCB Na 28 SM 9201: Avfall och återvinning i kommunalregi. Statistics Sweden 1992.

other two waste categories are, not surprisingly, somewhat greater. These waste fractions were however modelled before 1990, proportional to the population size.

Table 2. Land filled waste in 1990, 1000 tons

Reference year	Land filled waste on all landfills receiving more than 50 tons of waste	Land filled waste on landfills receiving more than 50 tons of waste, but less than 50 tons of household waste
Household waste and similar	1 376	0.3
Park and garden waste	*69*	*14*
Sludge from waste water treatment plants	816	72

2.1.1.2 Coverage

In all surveys with available quality declarations, there are only minor coverage problems mentioned. The project "Data om behandlingsanläggningar" has not published any results on coverage of the waste surveys. Preliminary results show however that only very small fractions of deposited household waste have been identified, which were not surveyed by the Swedish Association of Waste Management.[6] This project has however not collected data for earlier years.

2.1.1.3 Non-response adjustment

In the survey for data in 1980, the estimated total of land filled household waste has been based on the amounts that were scaled at the plant, (i. e. about 50 % of the waste amounts). The remaining quantities have been calculated by multiplying the population number with a specific amount of waste per inhabitant. The methodological description of the survey entails no information on non-response, but the method used to estimate the waste amounts should compensate for non-response.

The response was complete in the survey of 1985.

In the surveys for the years 1986 and 1988, the non-response corresponded to 11%-12 % of the population. The adjustment for the non-response was in both cases made proportional to the size of the total population. In 1990, the non-response was very low, corresponding to only 2% of the national population. A non-response adjustment has probably not been made in this year, which may have caused slight under-estimates of the deposited amounts of waste.

In the surveys carried out by RVF (1994-2003) the non-response has been greater, in some cases up to 20 % of the landfills included in the surveys. Non-response adjustment has been made by using the latest available value for the specific facility. It is not stated in the quality declarations whether this might result in under or over estimated values on land filled waste amounts.

[6] Personal commonication, Mikael Szudy, Statistics Sweden, 2004-09-22. phone: +468 506 94000 (swithboard).

2.1.2 Discussion

The similarities in method, population, coverage and detailed reporting of data on land filled amounts of waste in different surveys, indicate that the statistics is comparable over time. Non-response adjustment of amounts of waste deposited has seemingly been carried out in a correct manner, by using the same data as reported for earlier years, or by estimating the amounts based on the national population.

An important aspect is the different scaling practices over time. The earlier surveys may have been affected by the errors in scaling, a problem that does not exist today, since scaling has become increasingly important due to the deposit tax. The quality problem of un-scaled waste fractions was however met in the early survey of 1980 by basing the national estimates on a model calculation based on scaled quantities only. This seems to be a reasonable solution, but it is difficult to decide today if it was the optimal one.

We come to the conclusion that there are no obvious systematic differences between the mentioned historical surveys, when we consider land filled quantities. The variability was however greater in earlier surveys.

2.2 Comparison of deposited waste amounts and waste incineration

Available data from Statistics Sweden, the Swedish EPA and RVF on Swedish waste incineration from 1980 an onwards have earlier been compiled by Profu 2004[7] and can be studied in Appendix 1 and in Figure 1 below. In the figure, data on deposited household waste and similar wastes are combined with the estimated amounts of deposited fraction used in the greenhouse gas inventory. Some of these estimates are based on statistics according to Table 1, the other values are interpolated/extrapolated. The data on waste incineration have however not been imputed, which explains the gaps in the time series.

Some other important parameters may be considered as well. Especially the increasing waste amounts in recent years, and the expansion of the capacity for material recovery and biological treatment, [8] would make the picture more complete. The figures need however to be carefully crosschecked to avoid double counting of the incinerated quantities.

[7] Profu i Göteborg AB. 2004. Deponering av olika avfallstyper i Sverige.
[8] Svensk Avfallshantering 2004, Swedish Association of Waste Management

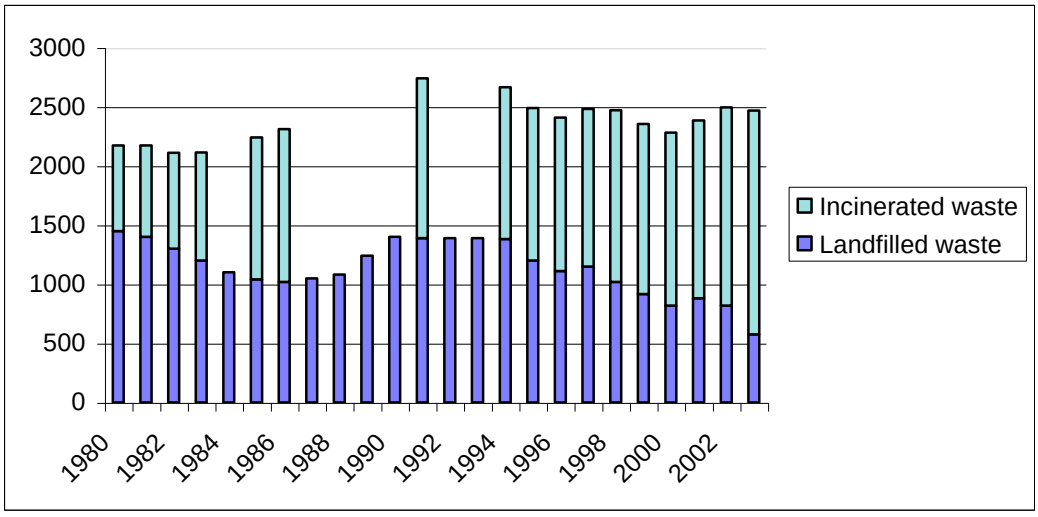

Figure 1. Incineration and land filling of household waste, 1000 ton in 1980-2003.

2.3 Documentation of data on methane gas recovery

2.3.1 Methodology for estimating recovered gas

The reduction in tons of CH_4 emissions through methane recovery is calculated from the amounts of produced energy from landfill gas plus flared amounts. The energy production quantities are measured at the plants,[9] and data are later collected by postal questionnaires by RVF or SCB. The plant specific data are published, together with a summary of the total energy production and divided into heat and electricity production and a small fraction of flared gas. The sum of energy production and flared gas is than used as an input to the greenhouse gas inventory.

2.3.2 Analysis of data

For assessing the quality of the primary data, contacts have been made with RVF. The main analysis is then based on published data on recovered gas amounts on plant level, that are available annually since 1994,[10] and for some earlier years (i. e. 1988 and1990). All published data have been scanned or manually printed in a database in the statistical program SAS and matched with landfill plant specific information from DIA (a database created within the project "Data om avfallsanläggningar"). Information about the first year of methane recovery and other published information have also been reported in the database. Data on recovered amounts of methane (in kWh) have been checked and matched to create time series on a plant level and the consistency of the time series has been compared, in line with the quality control that are described in the GPG. Appendix 2 contains a compilation of sources of the published data used on methane gas recovery.

Data on recovered gas from the company Deponigasteknik have also been used to compare and verify the energy production data. This company has been involved in installing gas-

[9] Personal communication, Thomas Rihm Swedish Association of Waste Management, 2004-09-24, phone: +4640 40 356 600.
[10] Plant level data are published in RVF´s report serie, see Appendix 2.

recovering technique at many plants and they report some plant specific data on their homepage.[11]

The number of active gas plants, reported in the CRF as additional information, is also crosschecked.

2.3.3 Quality of primary data on recovered methane gas

Since the main part of the energy is sold, for heating and as electricity, data available at plant level are of high quality. There is however a risk for underestimating the total amounts of gas recovered from landfills, due to variations in efficiency between the energy production plants.[12]

An alternative methodology to estimate methane gas recovery would be to use the data on recovered landfill gas volumes. This information is however rare, it is stated only for 1988, 1990 and 1994 (see Appendix 2). Since data on gas volumes are not complete, the calculations should be based on energy production in line with the Good Practice Guidance.

2.3.3.1 Assessing the time series

By matching the available information on year of inauguration with the time series of energy production data from the gas recovery plants, these two sources were found to be consistent. In five cases the data were the same for every reported year, as a result of imputation, and hence these plants were excluded from the analysis. The remaining time series vary and the energy production increases, decreases or fluctuates arbitrarily around the mean value.

It is generally not possible to judge from the data only, if a deviation is normal or whether its indicating measurement errors. Some plants (Filborna, Hult, Hyllstofta, Spillepeng and Häringetorp) have gotten their capacity expanded during the period, which explains a sudden increase of reported energy production.[13] In some cases (i. e. Bockarp, Lessebo, Björnhyttan and Göinge Kattarp) the energy production continuously decreases during the period.

When analysing the time series a simple objective approach was used. All single values deviating about 100% or more from the mean value of all reported years for a single plant were chosen and studied. Eleven such values were found, of which three were obviously estimated 1000 times to low (Tagene in 1995, Blåberget in 1999, Göinge Kattarp in 2001). In two cases, the plants were newly opened, which may have affected the deviating estimates. The remaining outliers are probably not possible to explain, without contacting the plant.

[11] http://www.deponigasteknik.se/
[12] Personal communication, Thomas Rihm Swedish Association of Waste Management, 2004-09-24, phone: +4640 40 356 600.
[13] http://www.deponigasteknik.se/

2.3.3.2 Quality of aggregated data

Published data are extensive, but not complete: data are totally lacking for the years 1991-1992. For 1997 data on gas recovering on three closed down landfills are lacking.

When data for single plants are lacking, values have normally been imputed by using the value from the previous year. This method of compensation for non-response is necessary for making a correct estimate of the total energy production, but of course the overall data quality gets affected when too many values are imputed.

2.3.3.3 Discussion

By using available statistical sources, important information for documentation purposes have been compiled. The consistency and comparability of the historic surveys of landfills, which constitute an important part of the activity data needed for estimating methane emissions from land filled waste, have been checked by using available information on quality and design of the surveys. By comparing important quality aspects we have seen that the estimates of deposited wastes may be comparable over the years. The estimates also seem consistent with historic estimates of energy recovered waste quantities, when the time series are put together in a figure.

The compilation and review that has been made of published data on recovered gas strengthen the assumption that data has a high quality in general. Data on recovered gas are collected in a consistent manner over the years, and the active plants are well known by RVF.

Some problems have also been found. Different scaling practices over time have caused unknown errors when estimating land filled waste quantities.

The data on energy production from landfill gas are extensive, but not complete. Historical plant specific data are not published for some years (1991-1992), and in other years the compensating for non-response influence the uncertainty on the estimated total gas recovered.

The variation between years found when comparing data from single plants, is assumed to be normal. Some variation can be explained as a result of the plants being extended. A few figures are however found to be implausible or wrong.

One way of improving the quality of the time series of energy production and flaring of landfill gas, would be letting it be cross-checked by the local staff. This might in some cases improve the data quality and explain some of the values that can be considered as outliers. In a few obvious cases, the estimates could even be corrected without this procedure. We believe however that this procedure would only have a minor effect on the estimated gas recovery.

Even with high quality activity data, the methane emissions from landfills are estimated with great uncertainty according to the Good Practice Guidance.[14] The great uncertainty is mainly due to unknown content of organic matter in different waste types, especially industrial wastes, and poorly estimated parameters in the equation of methane production.

[14] GPG 5.1.1.5

Some important quality aspects of the official data available have now been assessed, by referencing the information from the work that was carried out with quality declarations within SMED,[15] as well as other data sources. We believe now that the necessary requirements of documentation of the waste statistics on data from landfills are fulfilled.

Data on gas recovery could in future be kept or collected by the database DIA. This would make it possible to cross-check the reported values over years as a yearly quality control.

[15] Internationell rapportering av svenska avfallsdata

Appendix 1. Swedish waste incineration 1980-2002

Year	Household waste and similar waste (kton)	Industrial waste and other waste (kton)	Total (kton)	Reference
1980	722	148	870	SNV PM 1884, Driftdata 83 med aktuell utformning av svenska avfallsverk 1984," Swedish EPA 1984.
1981	773	151	923	"
1982	812	170	982	"
1983	913	300	1 213	"
1984	..	..	..	
1985	1 200	200	1 400	SCB Na 28 SM 8801, "Avfall och återvinning i kommunal regi 1985," Statistics Sweden 1988.
1986	1 290	240	1 530	RVF rapport 92:8, Biobränsle i avfall, Swedish Association of Waste Management 1992
1987	..	..	..	
1988	..	..	..	
1989	..	..	..	
1990	..	..	..	
1991	1 350	350	1 700	RVF rapport 92:8, Biobränsle i avfall, Swedish Association of Waste Management 1992
1992	..	..	..	
1993	..	..	..	
1994	1 285	400	1 685	RVF rapport 95:13, "Svensk avfallshantering år 2000…eller strax därefter", Swedish Association of Waste Management 1995
1995	1 290	523	1 812	RVF rapport 97:1 Svensk avfallsförbränning 1994-1995, Swedish Association of Waste Management 1997
1996	1 298	555	1 853	RVF Energi och miljö, faktapärm, juli, 1998. Swedish Association of Waste Management 1998
1997	1 331	511	1 842	RVF Svensk Avfallshantering 2002. Årsskrift från RVF. Swedish Association of Waste Management 2002
1998	1 464	806	2 271	"
1999	1 440	702	2 141	"
2000	1 456	891	2 347	"
2001	1 504	955	2 459	RVF Svensk Avfallshantering 2004. Årsskrift från RVF. Swedish Association of Waste Management 2004
2002	1 675	1 116	2 791	"
2003	1 893	1 239	3 132	"

The table was put together by Profu. 2004: "Deponering av olika avfallstyper i Sverige." (Disposal of different waste categories in Sweden). The table has later been completed with data from Swedish Association of Waste Management for 2003.

Appendix 2 Data sources on methane gas recovery

Year of reporting	Statistical report
1988	RVF Publikation 90:1 Statistik svensk Avfallshantering. Swedish Association of Waste Management 1990.
1990	Na 28 SM 9201, Avfall och återvinning i kommunal regi 1990. Statistics Sweden 1992.
1991-1992	No published data on plant level
1993-1995	RVF Rapport nr 96:7. Deponigas Teknik och production vid svenska anläggningar idag. Association of Waste Management 1996.
1996	RVF 97:8: Deponering i Sverige, Statistik för 1996. Swedish Association of Waste Management 1997.
1997	RVF 98:9: Avfallsanläggningar med deponering, Statistik 1997. Swedish Association of Waste Management 1998.
1998	RVF 99:5: Avfallsanläggningar med deponering, Statistik 1998. Swedish Association of Waste Management 1999.
1999	RVF Rapport 00:14 Avfallsanläggningar med deponering Statistik 1999. Swedish Association of Waste Management 2000.
2000	RVF Rapport 01:11 Avfallsanläggningar med deponering Statistik 2000. Swedish Association of Waste Management 2001.
2001	RVF 02:14 Avfallsanläggningar med deponering Statistik 2001
2002	RVF rapport 2003:08 Avfallsanläggningar med deponering Statistik 2002. Swedish Association of Waste Management 2003.

Appendix 3 Number of landfills with active gas plants

Reference year	Active gas plants
2002	73
2001	75
2000	75
1999	75
1998	74
1997	66
1996	58
1995	58
1994	52
1993	46
1992	40
1991	33
1990	31

The number of landfills with active gas plants was compiled during the project from the collected plant specific data.