**SNAP CODE**: **100601**
**100602**
**100603**
**100604**

**SOURCE ACTIVITY TITLE:** **USE OF PESTICIDES AND LIMESTONE (in Agriculture)**

***Use of pesticides and limestone ($CO_2$ only)***
***Agriculture***
***Forestry***
***Market gardening***

**NOSE CODE:** **110.06.01**
**110.06.02**
**110.06.03**

**NFR CODE:** **4 G**
**5 D**

## 1 ACTIVITIES INCLUDED

This chapter considers the emission of carbon species resulting from the application of pesticides and limestone to agricultural soils and plants.

The emission is estimated from the agricultural use of pesticides and limestone and the respective emission factor. For pesticides, other emission sources (e.g. the manufacturing of pesticides or emission of imported products) are considered to be negligible compared to emissions caused by the agricultural use of pesticides. For limestone, emissions from quarrying are being considered in SNAP codes 02 and 03. However, carbon dioxide originating from the production of quicklime is dealt with in SNAP 04 06 18 (Limestone and Dolomite Use). In principle, the amount of carbon dioxide released from the decomposition of $CaCO_3$ during the calcination of limestone which is later used to sweeten soils should be regarded as an agricultural.

This chapter is an extension of chapter ag100600 (EMEP/CORINAIR 2002), which replaced its earlier version (EMEP/CORINAIR 1999).

The chapter is comprised of the following subcodes

| | |
|---|---|
| 10 06 01 | Use of pesticides and limestone ($CO_2$ only) |
| 10 06 02 | Agriculture |
| 10 06 03 | Forestry |
| 10 06 04 | Market gardening |

The pesticides included are Aldrin, Chlordane, DDT, Dieldrin, Endrin, Heptachlor, Hexachlorobenzene, Mirex, Toxaphene, Pentachlorophenol and Lindane. These pesticides have been selected for the base-year 1990. In the future other pesticides may also be included.

For liming, calcium carbonate (lime) may be used as limestone, dolomite or quicklime; it may also be a constituent of mineral fertilizers, in particular of calcium ammonium nitrate.

The methodology applied for liming in agriculture is the same as for forestry and market gardening.

## 2 CONTRIBUTION TO TOTAL EMISSIONS

### 2.1 Use of pesticides

It is estimated that > 99 % of the total pesticide emissions in Europe originate from the agricultural use of pesticides. The remainder is contributed by industrial sources, and emission of imported crops, and is not included in this chapter. A Dutch study estimated that, on average, 25 % of all pesticide used emits to the air.

### 2.2 Limestone

In central Europe, a small fraction of the overall emission of carbon dioxide may originate from soil sweetening in agriculture (Germany 2001: approx. 0.2 %).

## 3 GENERAL

### 3.1 Description

#### 3.1.1 Pesticides

Pesticide emissions from the agricultural use of pesticides are possibly influenced by:

- The way in which a pesticide is applied;
- Whether or not application takes place in closed spaces (greenhouses);
- The vapour pressure of the pesticide involved;
- The additions to the pesticides, that are used to obtain better spray results;
- The meteorological conditions during application;
- The height of the crop.

In order to calculate pesticide emissions precisely, it would be necessary to have quantitative data on all the factors noted above. In practice these data are not available, and even data on the way in which pesticides are applied are scarce and mostly unreliable. Therefore, the emission factors that are given in Table 4.1 can be considered as first estimates, assuming that application takes place under normal field conditions (i.e. no soil injection), with a standard meteorology.

#### 3.1.2 Carbon dioxide

Agricultural land use of soils other than calcareous soils will lead to a depletion of the soil buffer system which help to maintain a favourable range of pH. The most common and cheapest method to restore soil pH is liming.

As agricultural soils are limed regularly, all limestone, dolomite etc. can be considered to react according to

$$\mathrm{CaCO_3 + CO_2 + H_2O \rightarrow Ca^{2+} + 2\ HCO_3^- \rightarrow Ca^{2+} + 2\ OH^- + 2\ CO_2}$$

This long-term process cannot be influenced by other variables.

### 3.2 Controls

#### 3.2.1 Pesticides

There is very little known about methods that may reduce pesticide emissions. Although it is clear that injection into the soil is very effective, it is only suitable in limited circumstances. In addition, there might be some way of reducing the emissions when effective additives can be found. Mineral oil, for instance, is used as an additive to get a better coverage of the crop, but it (or other compounds) may also have an effect on air emissions. In practise though there are no additives used to reduce air emissions.

#### 3.2.2 Carbon dioxide

There is no method to avoid $CO_2$ emissions from liming.

## 4 SIMPLER METHODOLOGY

### 4.1 Pesticides

The emission of pesticides during application in the field is by far the most important way in which pesticides emit to the air. There are no direct pesticide emission data available for the different countries. Therefore the emission is estimated from the use of the pesticides and an emission factor (see Table 4.1) as:

$$E_{\text{pest}} = \sum_{1}^{i} m_{\text{pest, i}} \cdot EF_{\text{pest, i}}$$

where $E_{\text{pest}}$ total emission of pesticides (in Mg $a^{-1}$)
$m_{\text{pest}}$ mass of individual pesticide applied (Mg $a^{-1}$)
$EF_{\text{pest}}$ emission factor for individual pesticide (kg $kg^{-1}$)

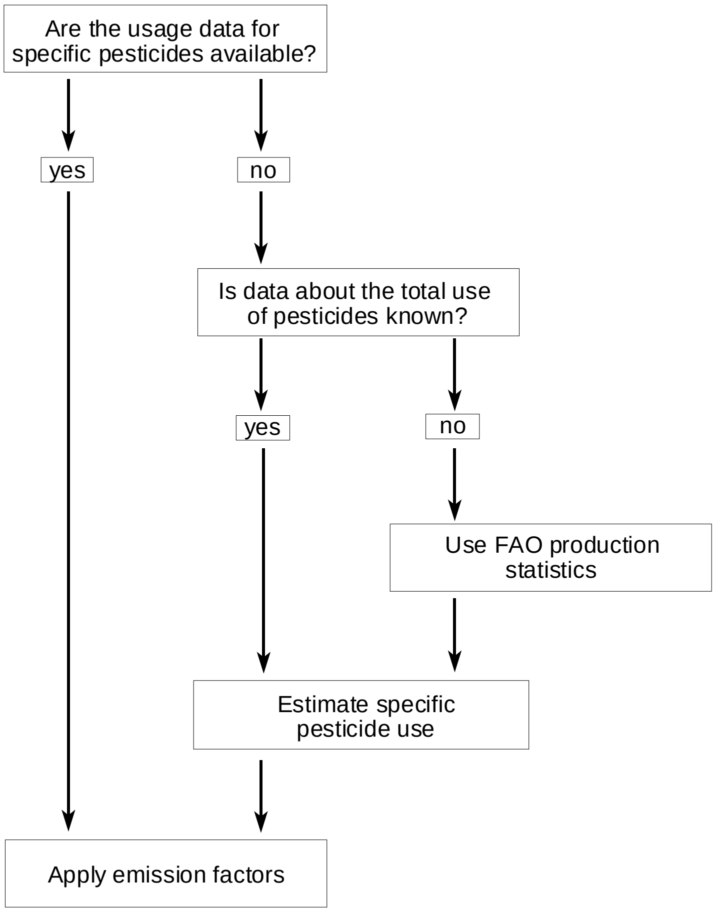
**Table 4.1: Pesticides and estimated emission factors**

| Pesticide | Type | Emission Factor |
|---|---|---|
| Aldrin | Insecticide | 0.50 |
| Chlordane | Insecticide | 0.95 |
| DDT | Insecticide | 0.05 |
| Dieldrin | Insecticide | 0.15 |
| Endrin | Insecticide | 0.05 |
| Heptachlor | Insecticide | 0.95 |
| HCB (Hexachlorobenzene) | Fungicide* | 0.50 |
| Mirex | Insecticide | 0.15 |
| Toxaphene | Insecticide | 0.15 |
| PCP (Pentachlorophenol) | Fungicide* | 0.95 |
| Lindane | Insecticide | 0.50 |

* HCB and PCP are not only used in agriculture. The emission factors only apply to the agricultural use.



**Figure 4.1: Flow scheme for the calculation/estimation of the emission of pesticides**




Relevant activity statistics and emission factors are given in section 6. A list of common names of pesticides and their properties can be found under ISO (2003). Methods for estimating the use of pesticides are described below. The derivation of the emission factors is explained in Chapter 8.

### Methods for estimating the use of pesticides

The use of pesticides can be estimated using three starting points, depending upon which data are available. It is not necessary to follow the same procedure for different pesticides for one specific country when the required data are not available. Data do seem to be more comparable using the same method to make estimates for the emission; however, the uncertainties of all methods described are quite big (see section 10). Figure 4.1 gives a schematic overview of these three different methods.

The three methods to estimate the emission of pesticides are described below, starting from the most reliable data.

- **Consumption is known for individual pesticides**
  The most reliable data are obtained when pesticide consumption is known.

- **Totals of pesticide consumption are known**
  When there are no direct figures on pesticide consumption for an individual pesticide, the consumption figures are derived from the total pesticide consumption figures. This is done in three steps:

  a Take the OECD data on total pesticide consumption figures. These data are available for most countries in Europe, split into insecticides and herbicides (see Table 6.1).

  b Take the relative use of the specific pesticide from Table 6.2.

  c Calculate the use of a specific pesticide, assuming that the relative use of the pesticide mentioned is applicable for your country.

  *Example: What is the use of Lindane in Austria?*
  This can be estimated in the following way:
  Lindane is an insecticide and the total use of insecticides in Austria equals 500 t $a^{-1}$ (Table 6.1). The use of Lindane equals 5 % of total insecticide use in Austria (Table 6.2); so the Lindane use in Austria equals: 500 t $a^{-1}$ 0.05 = 25 t $a^{-1}$

  Note: It is important to realise that this method is only a tool with limitations to calculate the use and emission of the pesticides, because of lack of data. The limitation of this methodology can easily be illustrated by the fact that there is a significant shift in the relative contribution of lindane to the total use of insecticides from year to year.

- **No consumption data are available.**

  When no pesticide consumption data are available, it is possible to make estimates based on production statistics and comparison with other countries:

  a Identify the main crops where the pesticides of interest (i.e. those listed in table 4.1) are being used (e.g. cereals, maize).

  b Take the total production of the selected crop(s) from FAO data.

  c Take the total crop production for a neighbouring or economically comparable country, where pesticide use is known or calculated, from the FAO data.

  d Calculate the pesticide use, assuming it is proportional to the amount of crop produced.

  *Example: What is the use of Lindane in country A?*
  Lindane is used mainly in cereals. FAO production statistics for cereals in country A equals 12.626.000 Tg. In neighbouring country B 5.290.000 Tg of cereals was produced, and the use of Lindane equalled 25 t $a^{-1}$. So the Lindane use in country A is calculated to be (12.626.000 Tg/5.290.000 Tg) * 25 t $a^{-1}$ = 60 t $a^{-1}$.

- **Total emission**

  The total emission of a specific pesticide can now be calculated by multiplying the total use (calculated as above) and the emission factor.

## 4.2 Carbon dioxide

Carbon dioxide emissions from liming are calculated from the amount of lime, dolomite, quick lime and calcium ammonium nitrate using the relation

$$E_{\mathrm{lime}} = \sum_{1}^{\mathrm{i}} m_{\mathrm{lime,\,i}} \cdot EF_{\mathrm{lime,\,i}}$$

where $E_{\mathrm{lime}}$ total emission of C or $CO_2$ from liming (in Mg $a^{-1}$)
$m_{\mathrm{lime}}$ mass of individual liming agent applied (Mg $a^{-1}$)
$EF_{\mathrm{lime}}$ emission factor (carbon conversion factor) for individual liming agent (kg $kg^{-1}$)

The individual emission factors (carbon conversion factors) are listed in Table 4.2.

**Table 4.2: Simpler methodology emission factors for $CO_2$ emissions resulting from liming**
**Values are kg $CO_2$-C or $CO_2$ per kg liming agent applied.**

| **Liminig agent** | **$CO_2$-C** | **$CO_2$** |
|---|---|---|
| Lime ($CaCO_3$) | 0.120 | 0.440 |
| Dolomite ($CaMg(CO_2)_2$) | 0.130 | 0.477 |
| Calcium ammonium nitrate (CAN) | x · 0.120 | x · 0.440 |
| Quicklime (CaO) | 0.214 | 0.785 |

where x denotes the proportion of calcium carbonate in calcium ammonium nitrate, which is normally 0.4.

# 5 DETAILED METHODOLOGY

Not available for pesticides. For liming, the simpler methodology cannot be improved.

# 6 RELEVANT ACTIVITY STATISTICS

Recent use of pesticides is not documented. For recalculations, Table 6.1 may be useful.

**Table 6.1: OECD data on the use of pesticides in 1990**

| Country | Insecticides Mg $a^{-1}$ | Herbicides Mg $a^{-1}$ | Available base year |
|---|---|---|---|
| Austria | 500 | 3053 | 1986 |
| Belgium | 1313 | 5307 | 1989 |
| Canada | 2262 | 26414 | 1990 |
| Denmark | 146 | 1426 | 1991 |
| Finland | 69 | 1375 | 1991 |
| France | 7096 | 33713 | 1991 |
| Germany | 1525 | 16957 | 1990 |
| Greece | 2844 | 3031 | 1989 |
| Hungary | 2806 | 9622 | 1989 |
| Iceland | 1 | 2 | 1983 |
| Ireland | 162 | 1097 | 1991 |
| Italy | 10744 | 10566 | 1989 |
| Netherlands | 745 | 3330 | 1989 |
| Norway | 19 | 965 | 1990 |
| Poland | 1065 | 11875 | 1989 |
| Portugal | 2700 | 5000 | 1989 |
| Spain | 52754 | 20342 | 1989 |
| Turkey | 10412 | 7191 | 1991 |
| USA | 79450 | 224730 | 1991 |
| USSR | 1298 | 12450 | 1985 |
| Sweden | 19 | 1054 | 1991 |
| Switzerland | 153 | 925 | 1989 |

Data on the relative use of pesticides are given in Table 6.2. No data are available on the use of Toxaphene and Chlordane. Just as for the pesticides Drins, Heptachlor, DDT and Mirex, use of Toxaphene and Chlordane is forbidden in Europe and America.

The percentages mentioned in Table 6.2 originate from The European Emission Inventory of Heavy Metals and Persistent Organic Pollutants. Percentages for USA, Turkey and Canada are estimated, based on neighbouring countries or on countries lying on the same longitude. No data are available for toxaphene and for USSR for pentachlorophenol.

## 7 POINT SOURCE CRITERIA

Not applicable.

## 8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

The emission factors are derived from the vapour pressure of the pesticides. The vapour pressure is until now the most convenient way to begin to estimate the emission. Other estimates may take into account Henry coefficients or other parameters, but there are not enough data available to make a more reliable estimate of the emission factors.

**Table 6.2: Relative use of pesticides (in % of total use of insecticides or fungicides per country)** (Berdowski et al., 1997)

| Country | Lindane | PCP* | HCB* | Drins* | DDT | Heptachlor | Mirex |
|---|---|---|---|---|---|---|---|
| Austria | 5.0 | 41 | <0.1 | 0 | 0 | 0 | 0 |
| Belgium | 2.7 | 2.2 | <0.1 | 0 | 0 | 0 | 0 |
| Canada | 3 | 0.5 | * | 0 | 0 | 0 | 0 |
| Denmark | 3.4 | 0.5 | <0.1 | 0 | 0 | 0 | 0 |
| Finland | 23 | 10 | <0.1 | 0 | 0 | 0 | 0 |
| France | 7.0 | 0 | <0.1 | 0 | 0 | 0 | 0 |
| Germany | 4.6 | 0 | - | 0 | 0 | 0 | 0 |
| Greece | 0.9 | 12 | <0.1 | 0 | 0 | 0 | 0 |
| Hungary | 3.5 | 11 | 0.1 | 0 | 0 | 0 | 0 |
| Iceland | 5.0 | 0 | <0.1 | 0 | 0 | 0 | 0 |
| Ireland | 3.1 | 11 | <0.1 | 0 | 0 | 0 | 0 |
| Italy | 0.9 | 1.2 | <0.1 | 0 | 0 | 0 | 0 |
| Netherlands | 4.0 | 0.5 | - | 0 | 0 | 0 | 0 |
| Norway | 32 | 31 | <0.1 | 0 | 0 | 0 | 0 |
| Poland | 0.2 | 0 | <0.1 | 0 | 0 | 0 | 0 |
| Portugal | 0.2 | 6.1 | <0.1 | 0 | 0 | 0 | 0 |
| Spain | 0.2 | 0 | <0.1 | 0 | 0 | 0 | 0 |
| Turkey | 1 | 12 | <0.1 | 0 | 0 | 0 | 0 |
| USA | 3 | 0.5 | <0.1 | 0 | 0 | 0 | 0 |
| USSR | 75 | nd | <0.1 | 0 | 0 | 0 | 0 |
| Sweden | 22 | 0 | <0.1 | 0 | 0 | 0 | 0 |
| Switzerland | 0.7 | 8.4 | <0.1 | 0 | 0 | 0 | 0 |

* PCP: pentachlorophenol; HCB: hexachlorobenzene; Drins: aldrin + dieldrin + endrin
nd: no data

The emission factors are derived from the vapour pressure according to Table 8.1.

**Table 8.1: Derivation of emission factors from vapour pressures**

| Vapour pressure class | Vapour pressure *p* mPa | Emission factor |
|---|---|---|
| very high | $p > 10$ | 0.95 |
| high | $1 < p < 10$ | 0.50 |
| AVERAGE | $0.1 < p$ 1 | 0.15 |
| low | $0.01 < p < 0.1$ | 0.05 |
| very low | $p < 0.01$ | 0.01 |

Comparison of these factors with former emission factors made for OSPARCOM-HELCOM-UNECE (TNO-Report TNO-MEP-R 95/247) indicates that the values have changed. Explanation is the more detailed classification. In the former study three different classes were distinguished; this methodology determines five classes.

When more recent data are available, countries may calculate their emissions using both the ‘old data’ and the ‘new data’. Recalculation might be of interest.

## 9 SPECIES PROFILES

Not applicable

## 10, 11 CURRENT UNCERTAINTY ESTIMATES AND PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Uncertainties in pesticide emissions are in the magnitude of a factor of 2 - 5. Uncertainty is introduced by poor emission factors. There are reliable emission factors for only for a few compounds (about 15). The emission factors for the other compounds (about 800 different compounds are allowed in the EU) are derived by extrapolation or from few measurements.

Another difficulty is that data on the use of pesticides are scarce and unreliable for most countries. Though these data are sometimes available, they are not always available for research groups. Making these figures public is an easy way to get a major improvement in the data.

For liming, the accuracy depends on the accuracy of the amounts of liming agents applied.

## 12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Considering the potential for pesticides to have local effects on ecology, emission estimates should be disaggregated on the basis of land use data as much as possible.

For liming, disaggregation is not necessary due to the minor importance of the source and the atmospheric half-life of carbon dioxide.

## 13 TEMPORAL DISSAGGREGATION CRITERIA

The methodology does not give emissions with a temporal dissaggregation, although the use (and emission) of pesticides takes place during the growing season.

## 14 ADDITIONAL COMMENTS

No additional comments.

## 15 SUPPLEMENTARY DOCUMENTS

FAO production statistics (see http://apps.fao.org/page/collections?subset=agriculture)
OECD pesticide data (however, no recent data published)

## 16 VERIFICATION PROCEDURES

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## 17 REFERENCES

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## 18 BIBLIOGRAPHY

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## 19 RELEASE VERSION, DATE AND SOURCE

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