"Life Cycle Assessment (LCA) as a Decision Support Tool (DST) for the ecoproduction of olive oil"

TASK 3.2

Implementation of Life Cycle Inventory in Lythrodontas region of Cyprus

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1 Developing a DST for Olive Oil Production

There are approximately 750 million productive olive trees worldwide. These occupy a surface of 7 million hectares from which 98% can be found in the Mediterranean region (Niaounakis and Halvadakis, 2004). In regards to oil production, the countries of the Mediterranean basin, mainly Spain, Portugal, Italy, Greece, Turkey, Tunisia and Morocco concentrate 97% of the world production of olive oil (Lopez-Villalta, 1998).

Both olive tree cultivation and olive oil processing industry produce large amount of by-products, including pruning residues and solid and liquid wastes from the olive mills. Furthermore, both the cultivation of olives and their processing into olive oil consume a significant amount of natural resources and energy. In addition, many sub-processes of olive cultivation, such as soil management, fertilisation and pest control are potential generators of significant emissions with their associated environmental impacts, not to mention any hidden processes associated with olive oil production, such as transportation of agricultural inputs, to which environmental impacts may be attributed. For all these reasons, the need for a comprehensive analysis of the environmental profile of the production of olive oil, mainly in the Mediterranean countries, in view of its optimisation has become a priority.

Life Cycle Analysis is a technique developed to assess the environmental aspects and potential impacts associated with a product over its life cycle. This project aims at utilising this technique as a decision support tool (DST) for the adoption of the appropriate processes throughout the life cycle of olive oil, in order to promote its eco-efficient production in three major olive oil producing areas: Voukolies (Greece), Lythrodontas (Cyprus) and Navarra (Spain).

During the preceding second task of this project the general Life Cycle Assessment methodology as defined by relevant standards and guideline documents was examined, described, explained and reported. Furthermore, the specific framework that will be applied for the specific analysis of the olive oil production system was developed and an appropriate model in SimaPro 6 was created. This report covers the activities of the third task of this project, i.e. the implementation of the Life Cycle Assessment in the region of Lythrodontas in Cyprus.

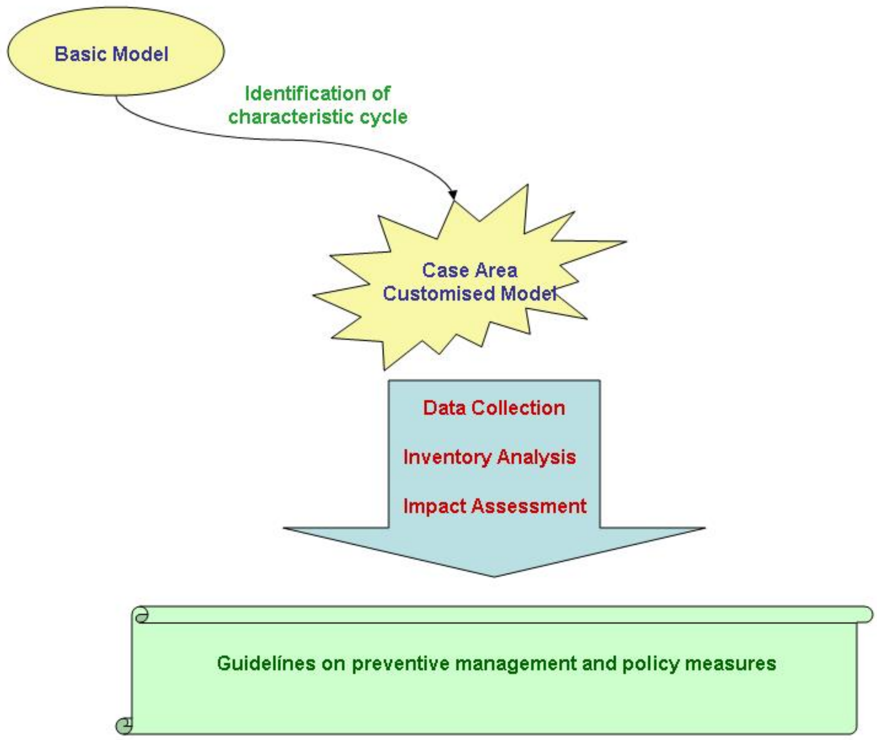

Figure 1 – The implementation plan foreseen during the development of the LCA framework (Avraamides et al., 2005)

Having created the basic model to be used in the analysis, the next step in the project implementation plan as defined in the previous report is the identification of the characteristic olive oil production life cycle in the Lythrodontas case study area. This step involves the qualitative specification of the exact techniques, equipment and materials used for each stage of the production. Since in many of the stages, a variety of techniques are applied by groups of olive oil producers in the region, a simple statistical analysis is carried out in order to identify the most popular (in terms of olive tree populations) technique. Thus, the characteristic life cycle of olive oil production in Lythrodontas will represent the chain of most popular processes.

The identification of the characteristic cycle of olive oil production in Lythrodontas is reported in Chapter 3 of this report.

Subsequently the basic model built in SimaPro 6 will be customised to accommodate the specific idiosyncrasies of the Lythrodontas life cycle. As a result, unit processes which are not applied in the region will be omitted, new processes identified will be added to the model, and the process names will change to more descriptive.

The customisation of the basic model for the Lythrodontas region is reported in Chapter 4.

In the next step, quantitative data of the material and energy flows into and out of each unit process are collected through various techniques in accordance with the data collection plan established in Task 2. The collection techniques, the sources of data, the assumptions on which data is based and the material and energy flows for each process within the customised system are reported in Chapter 5 of this report.

Finally, Chapter 6 reports the inventory of the system, as obtained from the analysis and summarises the main flows from and to the environment from the system as well as the main contributing processes.

2 Olive oil production in the region of Lythrodontas

The cultivation of the olive-tree (Olea europea L.) in Cyprus was known from ancient times and has been one of the traditional cultivations of the island. It is grown in compact groves or, more often, is found mixed with other crops. Olive trees are also found scattered in uncultivated land. They are grown on about 6050 hectares all over the island and represent 4.4% of the cropped area (Gregoriou, 1996). The majority of olive trees are found in the region of Lythrodontas. According to data of the olive growing section of the department of agriculture (MANRE, 2005) there are 57,465 recorded olive trees in the region of Lythrodontas which makes it the largest olive oil producing region of Cyprus. These belong to approximately 190 families.

Lythrodontas is a community situated at the central part of Cyprus about 30km south of the capital Nicosia at an altitude of 420m above the sea level. According to the 2001 census, the population of the community was 2,628 people in 1,087 dwellings. The climate in the area is mountainous, which for Cyprus means 8-15˚C in winter and 15-30˚C in the summer. The region surrounding the community, referred as Lythrodontas region, does not have any extensive surface waters apart from two small dams, the lower Lythrodontas and the upper Lythrodontas dams on the Koutsos (Gialias) stream, both of 32,000m^3 capacity. It should be noted that Koutsos stream flows only in the winter.

The region, apart from the large areas cultivated with olive trees, is also rich in cultivation of citrus and other types of fruits, vines, vegetables, pulses, walnuts and grain.

Figure 2 – Aerial photograph of the Lythrodontas case study region (NASA, 2006)

At the moment (2006) there is one privately owned olive oil processing unit in Lythrodontas, which is used by the majority of the local olive producers, while a similar facility exists in the nearby village of Analiontas.

Lythrodontas was chosen as the case study region in Cyprus, primarily because it is the region with the highest production of olive oil and secondarily because it gives a representative picture of the whole production of olive oil in the island.

3 Identification of the characteristic cycle in Lythrodontas

The Lythrodontas region hosts a variety of different techniques for olive oil production. The main differences are observed in the agricultural stage with differences in the variety of olive trees cultivated, the use or not of artificial irrigation, as well as in the many alternative techniques, equipment and materials used at every stage of the olive tree cultivation. Some of these differences were acknowledged during the first task of this project when the existing situation regarding the production cycle of olive oil, olive cultivation, olive oil milling processes and olive oil mill waste generation and management in the areas under examination was assessed.

As discussed in Task 2 report, LCA is a modelling technique where simplifications and assumptions are necessary. Thus the olive oil production in Lythrodontas will be simplified into a single production chain, which will then be modelled and analysed. This will be referred as "the characteristic life cycle of olive oil production in Lythrodontas region".

In order to do that, accurate data on olive agriculture and oil production is required on which a simple statistical analysis will be carried out in order to identify the most popular processes in terms of olive tree populations. Contact details of the olive tree farmers were obtained from the Ministry of Agriculture, Natural Resources and Environment (MANRE, 2005), with the kind permission of the Community council, which was actively involved in the project.

Figure 3 – Olive varieties cultivated in the region of Lythrodontas: "Cyprus olive" (upper left), "koroneiki" (upper right), "mantzalino" (lower left) and "kalamon (lower right)"

The critical parameter that dictates many of the other variables in the olive oil production chain is the variety of olive trees cultivated. A preliminary inspection of olive orchards in the region showed that the main varieties cultivated in the region are “Cyprus olive”, “koroneiki” and “mantzalino”. However, in their vast majority, olive trees of different varieties are not mixed within the same orchard.

The analysis of the data provided by MANRE (2005), as illustrated in Figure 4, showed that the 57.465 olive trees in the region comprise of 32,243 “Cyprus Olive” trees, which constitute 56% of the total tree production, 27% “koroneiki” and 17% other varieties such as “mantzalino” and “pikoual” etc. On the basis of these results, it was decided that the “Cyprus Olive” should be the characteristic olive tree variety used in the analysis.

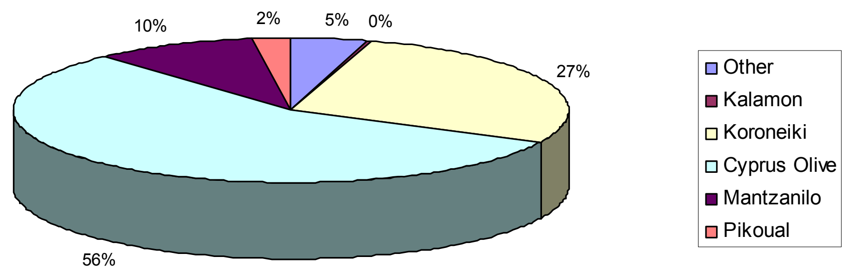

Figure 4 – Number of olive trees per variety in Lythrodontas

The farmers of the “Cyprus Olive” variety were then sorted according to the ascending numbers of tree ownership in order to identify the major growers from which data on the production cycle should be obtained. The conclusion was that a few growers own very large orchards of more than 300 trees and a large number of growers own a few olive trees (less than 50), as illustrated in Figure 5.

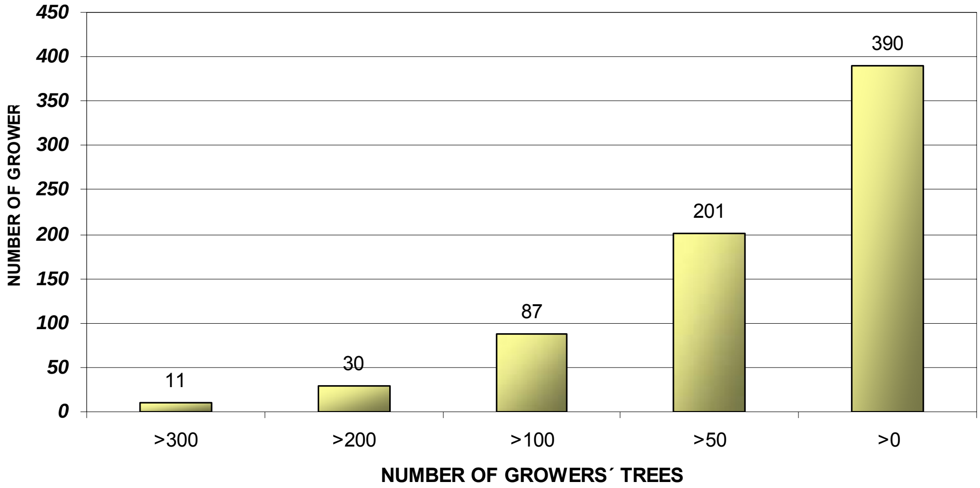

Figure 5 – Tree ownership (number of farmers)

The 11 largest farmers, as shown in Figure 7, own 6.886 trees, i.e. an average of 626 trees per person, whereas the 390 smallest farmers own only 4.884 trees, i.e. 25,8 trees per person.

Figure 6 – A typical olive grove in Lythrodontas

This means that a representative sample could be obtained by contacting the few largest farmers. Such a sample would be both statistically satisfying, i.e. large enough to provide credibility to the conclusions, as well as practically feasible to obtain.

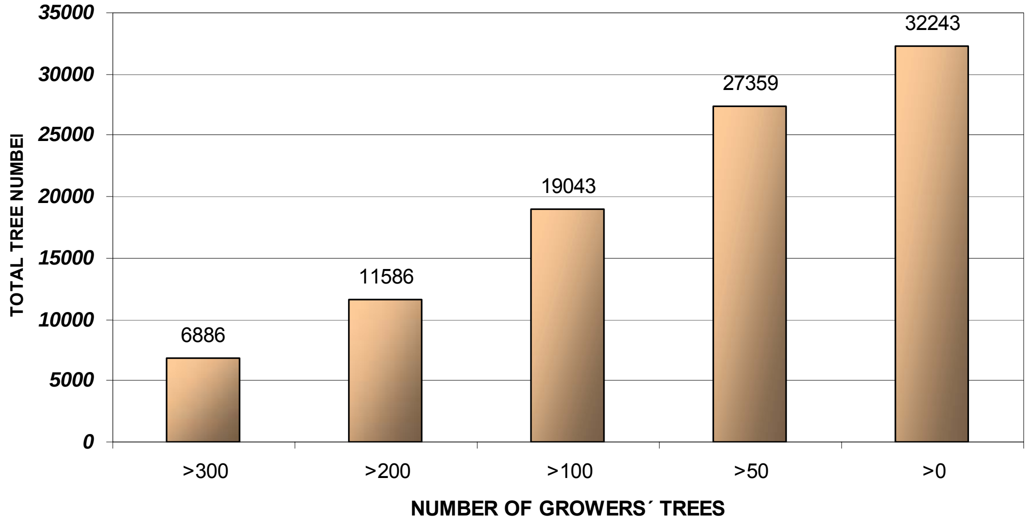

Figure 7 – Tree ownership in number of trees

Based on the findings of this analysis, it was decided to contact the 87 largest farmers, which own 19,043 "Cyprus Olive" trees, (59.05% of the number of trees in the region) as shown in Figure 8, with a target to obtain a sample covering at least 25%.

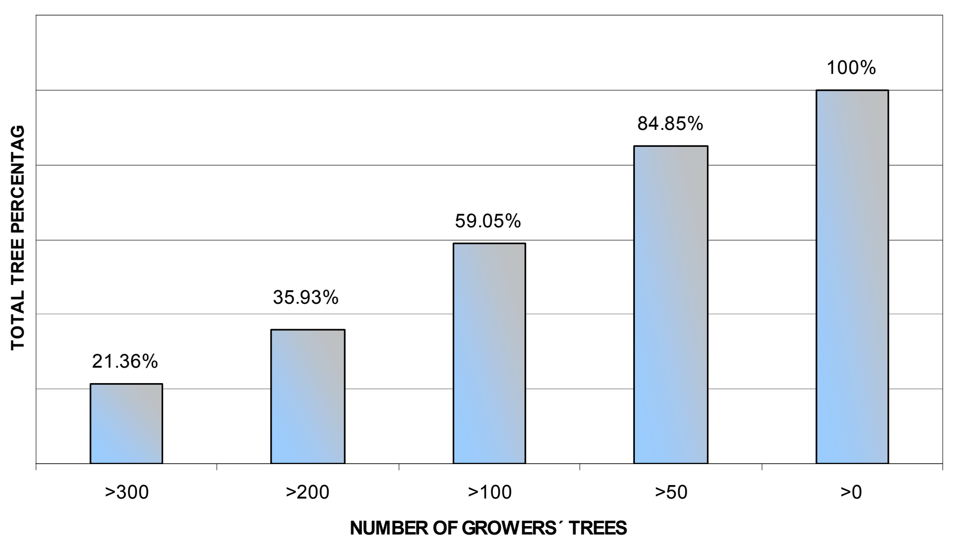

Figure 8 – Tree ownership in percentage

To acquire Lythrodontas-specific data on the agricultural stage of the production chain, a questionnaire was prepared (Appendix A) which covers every process identified during the previous tasks. The questionnaire aimed at acquiring statistical data on the use (or not) of various processes (i.e. whether olive trees are irrigated, whether herbicides, pesticides and fertilisers are used etc.), on the use of alternative techniques for each process (i.e. irrigation method, pesticide, herbicide and fertiliser type and method of application etc.) as well as quantitative data on the main material flows.

Olive farmers in Lythrodontas were then contacted (some in person and some by telephone). By the end of the interviews, 29 farmers had been contacted, representing 8,150 trees, which is approximately 25.3% of the total Cyprus Olive cultivation. For the analysis of the responds to the survey a concept of “weighting” the responds based on the number of trees, each grower is cultivating was used. Thus each questionnaire (and subsequently each answer in it) was given “weight” proportional to the number of olive trees it represents.

3.1 Characteristic olive agriculture processes

3.1.1 Planting the olive trees

Olive trees intended for oil production cannot be planted directly from seeds as seed propagated trees revert to the original small-fruited wild variety. However these wild variety young trees can later be grafted or chip budded with material from desired varieties. Alternatively new olive trees can be planted by transplanting suckers that grow at the base of mature trees. However, these would have to be grafted if the suckers grew from the seedling rootstock.

The most commonly practiced planting method is propagation from cuttings. Cuttings, 30 to 35 centimetres long, 2 to 8 centimetres wide, from the two year old wood of a mature tree are treated with a rooting hormone, planted in a light rooting medium and kept moist in buckets in tree nurseries. The interviews in Lythrodontas have shown that new trees are being planted through this method. New trees are transported to the orchards from the public tree nursery in Athalassa, at a distance of 35km, via private pickup vans.

Planting usually takes place in November and December by digging holes of dimensions 60cmx40cm with a mattock and a spade. The depth of the holes is such that the root of the new tree is at the same depth as was in the nursery bucket. During planting of the young olive trees special care is taken so that the walls of the hole are not compacted. After the hole is filled with soil the tree is irrigated. The water quantity used when planted is, according to the olive growers, approximately two litres of water per tree. The empty buckets are reused.

Figure 9 – Young olive trees in plastic buckets in a tree nursery

3.1.2 Soil Management

Soil management, and more specifically ploughing, is beneficial to olive orchards since it reduces the prevalence of weeds in the fields, and makes the soil more porous. In the past, ploughing was carried out using manual equipment and animals, however, nowadays ploughing is fully mechanised.

The principle of ploughing is to turn and break down the soil. For this purpose a number of ploughing implements have been developed over the last decades, such as rippers, chisel ploughs, disc ploughs, mouldboard ploughs, harrows, etc (State of New South Wales, 2005). All can be attached to an agricultural tractor. Each implement design has its own merits depending upon the cultivation and soil types.

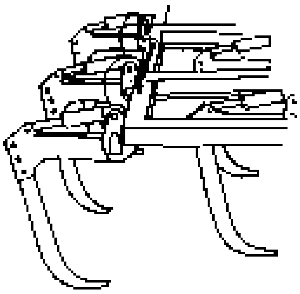

Figure 10 – Chisel plough (State of New South Wales, 2005)

Interviews have indicated that most of the olive tree growers in Lythrodontas use a chisel plough attached to a 45 horsepower tractor. Chisel ploughs, shown in Figure 10, are used to shatter but not turn or move the soil. Olive growers use the chisel plough when soil is reasonably dry as ripping wet soil does not shatter the subsoil and can smear and seal the soil and prevent air, water and roots moving through the soil.

Data also showed that the frequency of the activity varies with the majority (68%) of orchards being ploughed twice a year, whereas a quarter of the trees are ploughed three times annually. In the rest (7%) of the Cyprus olive trees in Lythrodontas, ploughing takes place only once a year, as shown in Figure 11.

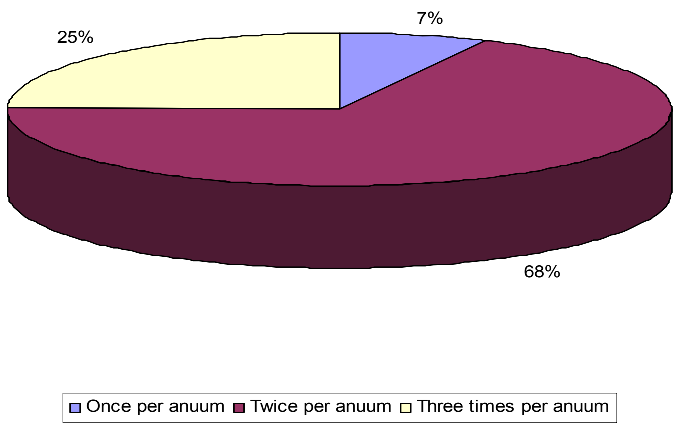

Figure 11 – Soil management frequency

3.1.3 Field water supply and irrigation

Olive trees have small leaves with a protective coating and hairy undersides that slows transpiration, thus, the tree is resistant to hot and dry climates. Subsequently many olive growers in Lythrodontas chose not to irrigate the trees. However as experience and research have shown, this defence system is at the expense of growth and productivity and because of the lower than average precipitation in Cyprus during the last decade, the number of irrigated orchards is increasing. According to the survey (see Appendix B), half (50%) of the Cyprus olive trees in Lythrodontas, are at the moment being irrigated, and the trend is increasing. In those orchards were irrigation is applied, water is extracted from wells inside or very close to the orchards. The equipment used for extraction varies between electric turbine pumps (70%) and diesel turbine pumps (30%). Electric turbine pumps are typically supplied with electricity from on-site generators.

The method used for irrigation in the Lythrodontas olive orchards is spray-type sprinklers (used in 60% of the trees irrigated) and flooding (used in 40% of the trees irrigated), as shown in Figure 12. Spray type sprinklers comprise of small “fixed spray heads” which spray a fan shaped pattern of water. They typically require a water pressure of around 40psi (275.8kN/m^2) to operate properly.

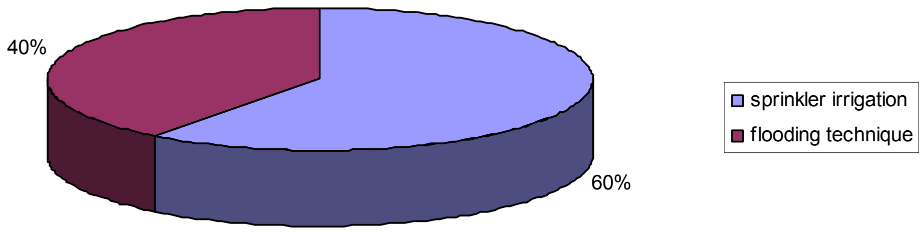

Figure 12 – Irrigation Method

Based on the findings above, irrigation was included in the characteristic cycle of olive oil production in Lythrodontas. Water is pumped by electric turbine pumps from wells inside the orchards and applied to the trees by means of a spray type sprinkler irrigation system. Electricity to turbine pumps is supplied from a field electricity generator.

3.1.4 Fertiliser application

Fertilisers are compounds given to plants for promoting growth. Modern fertiliser practices are based on the chemical concept of plant nutrition (IFA, 2006). Fertilizers typically provide, in varying proportions, the three major plant nutrients (nitrogen, phosphorus, and potassium), the secondary plant nutrients (calcium, sulfur, magnesium), and sometimes trace elements (or micronutrients such as boron, manganese, iron, zinc, copper and molybdenum) with a role in plant nutrition.

Data obtained from the survey analysis (Appendix B) show that 33% of olive trees, as shown in Figure 13, are treated with the use of a compound 20-10-10 fertiliser labelled 20-10-10. This means that the fertiliser contains 20% nitrogen, 10% phosphate and 10% potassium in its ingredients.

Other fertilisers used in the region are: manure (used on 26% of olive trees), nitrogen fertiliser 21-0-0 (13%) and various other types (13%), whereas no fertiliser is used on 15% of olive trees in Lythrodontas.

Fertilisers in general are applied via the soil, for uptake by plant roots, or by foliar spraying, for uptake through leaves. The former technique is used by all Lythrodontas growers contacted. A small quantity of water (a bucket) is applied to the root immediately following fertilisation.

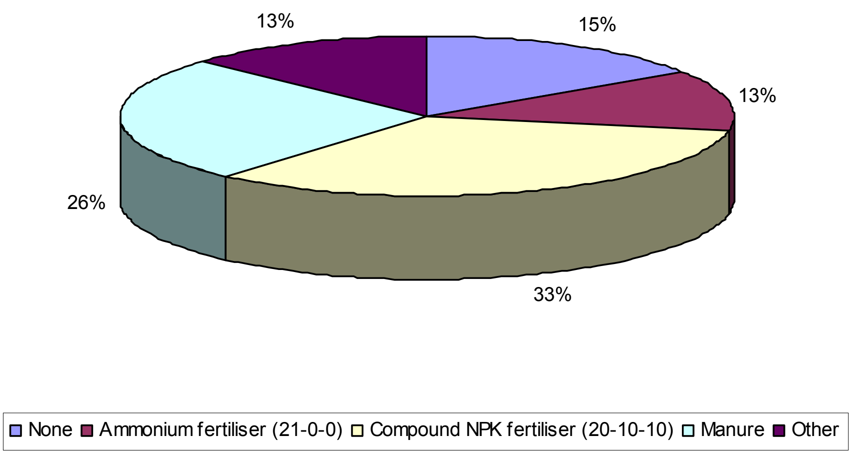

Figure 13 – Application of various types of fertilisers

Considering the data above, it was decided that fertiliser application should be included in the model of the characteristic olive oil production in Lythrodontas and the compound NPK fertiliser 20-10-10 was used as the characteristic fertiliser applied by hand to the root.

3.1.5 Fertiliser production and transportation

The production of the characteristic fertiliser used was traced via the Cooperative in Nicosia, from where all Lythrodontas growers are supplied. It is a dense granular compound comprising of ammonium nitrate (max 36% w/w), ammonium sulphate, monoammonium phosphate, diammonium phosphate and 100% water-soluble potassium sulphate.

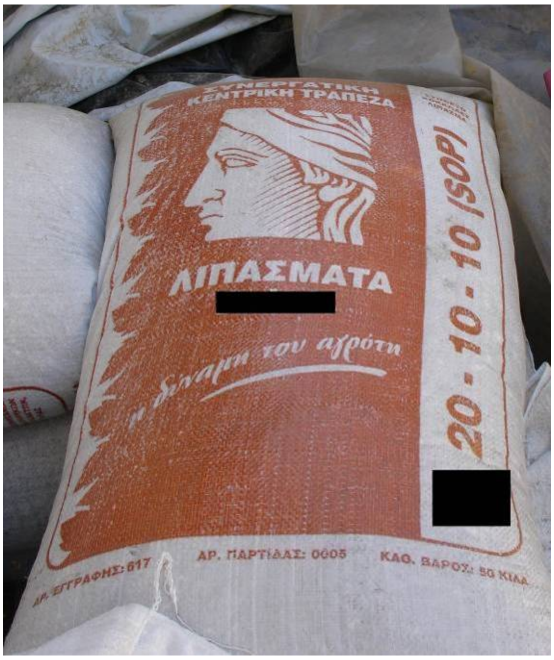

Figure 14 – Characteristic fertiliser used in Lythrodontas

According to Kallis (2006), the NPK 20-10-10 fertiliser used in Lythrodontas olive orchards, shown in Figure 14, is produced in Nea Karvali, Kavala, Greece, packaged in plastic 50kg polypropylene (PP) mesh bags and then imported to Cyprus. The production site is operating their own port, thus this fertiliser is transported by freight-ship from Kavala to Limassol (1138 km). The fertiliser is then transported from the port in Limassol to the Cooperative in Nicosia (the main supplier for olive farmers in Lythrodontas). It is assumed that transportation takes place by 3-axle, 16-tonne lorries, which travel a distance of approximately 100 km. Finally, the fertilisers are purchased by olive farmers and transported to the olive orchards in Lythrodontas at a distance of approximately 40 km using their own private pickup vans, i.e. vehicles of gross weight less than 3.5 tonnes.

3.1.6 Pruning methods and residue management

Pruning is necessary to adjust the trees to the climatic conditions of the area and to increase plantation's productivity. According to TDC-Olive (2005a), the aims of pruning are: (1) to balance vegetation with fruit yield, (2) to minimise the non-productive period, (3) to prolong the productivity of the trees, (4) to delay senescence, and (5) to save soil water, a critical factor especially in non-irrigated orchards.

Pruning can be performed through a variety of techniques and equipment. According to the responses in the olive cultivation questionnaire (Appendix A), olive farmers in Lythrodontas use 3 main methods/equipment for pruning. About 48% of the trees in the region are pruned using a hand-held petrol chainsaw. The rest of the trees are pruned either by equipment operating with compressed air, supplied by an agricultural tractor or a pickup van via a hose (used on 31% of Lythrodontas trees) or by manual methods such as saws and scissors (21%), as shown in Figure 15.

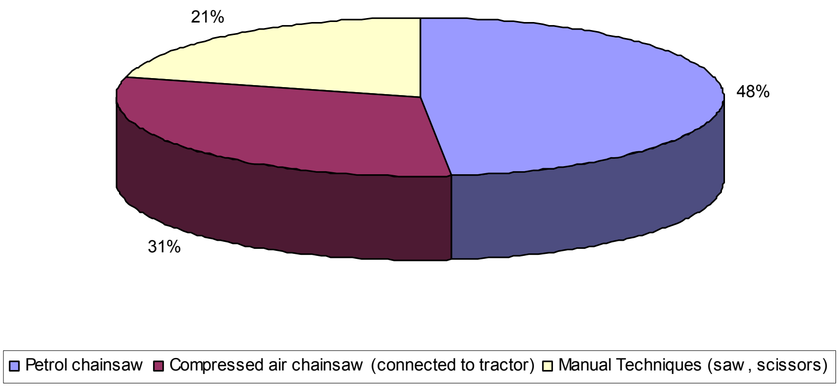

Figure 15 – Pruning Method

In general pruning frequency depends upon a number of parameters such as: the level of rainfall in autumn and winter, the yield of the previous year, the vegetative condition of the tree, the end-product (whether table olives or olive oil), the planting density and the pruning system applied. The average frequency of pruning per olive tree recorded in Lythrodontas was 0.74 times per year, i.e. approximately every 9 months on average.

In regards to the subsequent treatment of the pruning residue, all growers responded that pruned branches are burned in controlled open fires in vegetation-free areas adjacent to the orchards. The residual ash is disposed to the agricultural land by manual methods.

Figure 16 – Pruning by petrol ran chainsaw

Considering the findings above, pruning by petrol chainsaw was included in the LCA model. Furthermore burning of the residue and disposal of the ash to the agricultural land, with all associated emissions, a process not identified during the development of the framework in Task 2 (Avraamides *et al.*, 2005), was added to the model.

3.1.7 Pesticide application

Pesticides are used in various economic sectors, however, agriculture is by far the main user (approx. 80-90% of all pesticides sold) (Brouwer *et al.* 1994). Based on the target-organism group, pesticides of agricultural importance can be broadly categorised as insecticides (insect control), herbicides (weed control) and others such as fungicides, nematicides, bactericides, rodenticides (Nemecek *et al.*, 2004). This section deals with the identification of the characteristic insecticide application, whereas herbicides are dealt with in a different section.

The major insects of olive trees are the olive fruit fly (Bactrocera oleae), the olive-kernel borer or olive moth (Prays oleae) and the black scale (Saissetia oleae). Although all three are widely distributed in the Mediterranean region and are found in olive orchards at population densities causing important economic losses, the olive fruit fly is considered to be the most serious insect. According to Mazomenos *et al.* (2002), “economic losses due to this insect have been estimated to reach up to 15% of the olive crop, in spite of the fact that, pesticide treatments are applied every year to control the fly population”.

Management methods to deal with them include: harvest timing optimisation, fruit sanitation after harvest and biological control. Nevertheless, according to TDC-Olive (2005), the most commonly used olive fruit fly control management method is the use of pesticides (insecticides) in baits or sprays.

Figure 17 – Pesticide application methods in Lythrodontas (spraying and bait techniques)

This was also proved through the interviews of the olive growers, which showed that the most common insect management method used in the Lythrodontas region is the use of pesticides (78% of characteristic olive trees). The main techniques used for their application are, spraying methods (used on 43% of trees), and bait methods (used on 35% of trees), whereas no pesticides are applied in 22% of the Cyprus olive trees, (Figure 18). Based on this analysis, pesticide spraying was included in the LCA model for Lythrodontas.

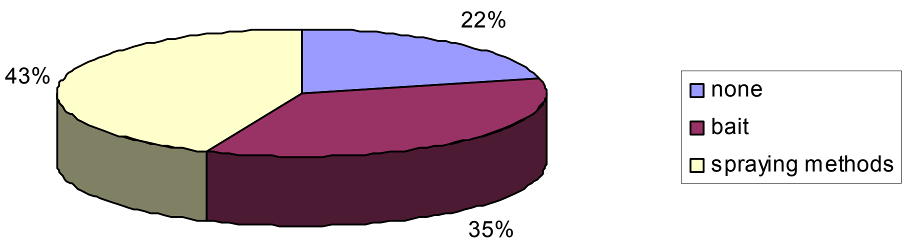

Figure 18 – Pesticide Application Method

Considering spraying techniques, two main types of application equipment have been encountered. In 66% of olive trees, sprayers connected via air hose to agricultural tractors are used whereas in the rest of the trees (usually smaller orchards) manual (hand-held) sprayers are used, as shown in Figure 19.

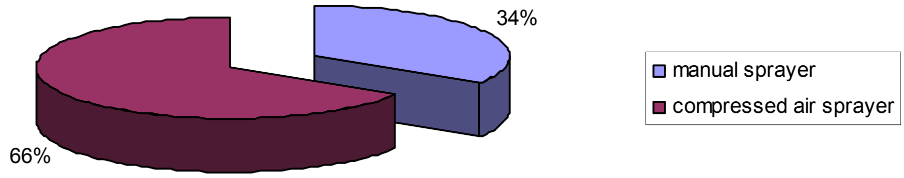

Figure 19 – Equipment used for pesticide spraying in Lythrodontas

In regards to the type of pesticide used, the vast majority of olive producers, indicated that they use a product (the commercial name is not disclosed), of which the active ingredient is dimethoate (molecular formula: $C_5H_{12}NO_3PS_2$, CAS No. 60-51-5), (FAO, 2005) at 40% concentration.

Based on these findings, the application of the particular pesticide by spraying techniques and in particular by sprayers connected to tractors via air hose, was considered.

3.1.8 Pesticide production and transportation

The source of the particular pesticide product used in the region (Figure 20) was traced in order to determine all associated production and transportation processes.

It was found that the active ingredient (dimethoate) is produced in Denmark, where it is mixed at a 40% concentration with inactive ingredients to form the final product. The inactive substances comprise of xylene (CAS number 1330-20-7) at 20% concentration, cyclohexanol (108-94-1) at 25% concentration and emulsifiers at 5% concentration (K&N Efthymiadis, 2004).

Figure 20 – Pesticide used in Lythrodontas

According to Mavridis (2006), the pesticide is then transported in bulk by freight ship from Copenhagen to Thessaloniki port (a distance of 6672 kilometres). From Thessaloniki port, bulk containers of the pesticide are transported to a factory in Sindos at an approximate distance of 17km, typically by 3-axle, 16-tonne lorries. At the factory it is packaged in 1-litre polyethylene (PE) bottles. The product is then transported back to Thessaloniki port (17 km) by 16-tonne lorries from where it is exported to Limassol, Cyprus by freight ship (a distance of 1210km). The pesticide product is then transported from Limassol to the Cooperative in Nicosia by 16-tonne lorry at a distance of approximately 100 km. Finally, when purchased by olive farmers, it is transported to Lythrodontas at a distance of approximately 40 km using their private pickup vans (gross weight <3.5 tonnes).

3.1.9 Herbicide application

Weeds, especially perennial species, have almost the same growth pattern as olive trees and can survive in the same low fertility soils and semi-arid conditions. As a result, they can exercise a strong competition to olive trees for nutrients and moisture, thus their control is essential.

Although, according to TDC Olive (2005), the application of chemicals (herbicides) is in general the most common method of weed control worldwide, weed control in olive orchards can also be achieved by mechanical techniques such as ploughing. In fact, the interviews of the olive producers in the region of Lythrodontas have shown that the use of herbicides in the agriculture of olives is not the most common practice. The statistical analysis of the responses (Appendix B) has shown that only in 14% of the Cyprus olive trees, weed control is achieved by application of herbicides. In this portion, spraying techniques and in particular sprayers connected to agricultural tractors through air hose, dominate. In the majority of the olive orchards in the region (86% of trees), as shown in Figure 21, no chemicals are used and weed control is achieved through the regular ploughing (discussed in section 3.1.2).

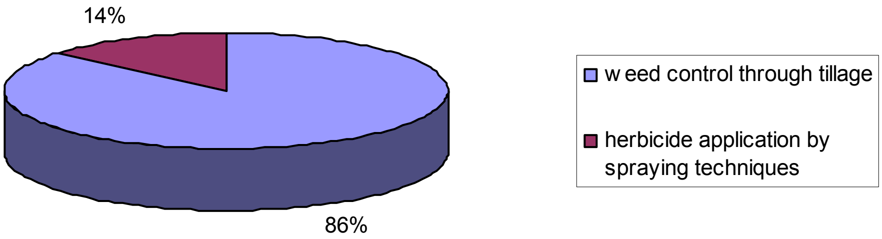

Figure 21 – Weed control techniques in Lythrodontas

On the view of these conclusions, herbicide application was excluded from the characteristic cycle of olive oil production in Lythrodontas.

3.1.10 Collection of olives

Over the years, a variety of methods and equipment for olive fruit harvest have been developed. Although traditional manual methods are gradually being displaced by more sophisticated mechanical equipment, they are still popular in Lythrodontas.

The traditional manual technique is by knocking the branches with long poles made by wood, plastic or aluminium. The olives fall on synthetic nets extended around the trees and then picked directly from the ground. The main disadvantage of this method, apart from the fact that it is extremely labour intensive, is the fact that both olive tree branches (particularly young shoots) and olives are damaged, with a detrimental effect on olive oil quality. Another manual method is the so-called “natural drop”, in which the fruits are harvested gradually, directly from the ground after their natural fall on nets. Although this method is not as labour intensive as the previous, the quality of the oil is still affected by the prolonged harvest period. In order to deal with the quality concerns, a popular alternative to the two manual methods discussed above is the so-called manual “milking” of the branches by hand rakes, in which rake teeth in two sizes facilitate penetration into the crown of the tree and detachment of the fruits.

Nevertheless, despite their higher capital cost, mechanical harvesting systems have considerable economic advantages compared to traditional manual picking procedures, mainly due to the great reduction in labour costs and harvesting time. A common method of mechanical harvesting is by hand-held pneumatic combs. This method requires a motorised air compressor that serves 1-4 pneumatic combs on poles through long plastic tubes. The compressors are typically electric and are supplied by field electricity generators. When the trigger on the handle is depressed it causes two plastic combs to swing back and forth. The comb operators “rake” the moving combs through the foliage to remove the fruit, which is collected in underlying nets, as shown in Figure 22.

Figure 22 – Olive collection by hand-held pneumatic combs (TDC Olive, 2005)

The most popular technique in the region of Lythrodontas, as determined from the survey, is the use of hand-held pneumatic combs, which, as shown in Figure 23, covers 68% of the Cyprus olive trees in the region. Less popular methods of harvest, but still used, are two manual methods, the use of hand rakes (21% of the trees) and the use of poles to knock the branches (11%).

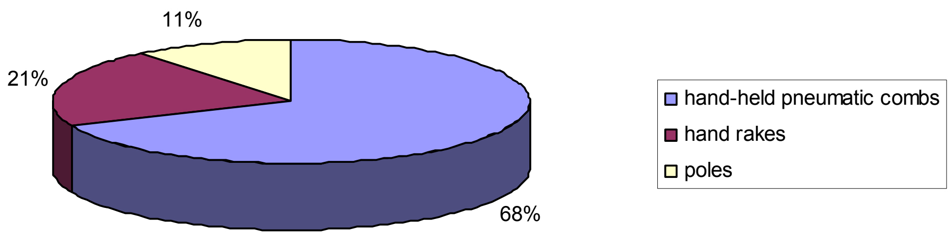

Figure 23 – Collection Method

Olives are collected from the underlying nets by hand and are put in plastic boxes or mesh bags, in which they are later transported to the processing plant.

On the basis of these conclusions, in regards to olive collection, the use of hand-held pneumatic combs and the hand collection from the underlying nets were accounted in the model.

3.1.11 Olive transportation to processing unit

Typically, the processing of olives from the Lythrodontas region into olive oil takes place locally. A modern olive oil processing unit is situated in the outskirts of Lythrodontas village, whereas another facility with identical technology operates in the neighbouring village of Analiontas.

Interviews have shown that olives from the 74.4% of the tress of the Cyprus variety in the region are processed in the Lythrodontas unit exclusively, whereas another 14.7% are processed either in Lythrodontas or the Analiontas units, whereas the rest are processed exclusively in Analiontas.

The Lythrodontas processing unit is located at the outskirts of the Lythrodontas residential area, and the average distance of the olive orchards to the plant has been estimated to approximately 1km. The average distance from the olive orchards to the Analiontas processing plant is about 7 kilometres. Based on the frequency these two plants are used and on the assumption that those who use both units do so equally, the average transportation distance from the grove to the processing plant has been calculated as 2.1 kilometres.

All farmers responded that for transportation of olives for processing, they use their private pickup vans (gross weight < 3.5 tonnes), which was included in the analysis model.

3.2 Characteristic olive oil processing

Based on the findings from the field survey, in regards to the use of olive oil processing plants in the region, the characteristic olive oil processing chain considered was the process chain of the Lythrodontas olive oil plant (Figure 24) which, is being used for the majority of olive oil production. Nevertheless the alternative processing unit located in the village of Analiontas, uses the same technology, therefore processes are characteristic of the whole production.

Figure 24 – The Lythrodontas olive oil processing unit

Olive oil processing has been identified as a significant water and energy consuming activity. The system boundary defined in Task 2 (Avraamides *et al.*, 2005) includes both the treatment of water and the supply of water from the source as well as the production of the grid electricity consumed within the unit.

In regards to the activities taking place in the processing plant, as discussed during the development of the LCA methodology in the previous task, processing of the raw material (olives of the specific variety) into extra virgin olive oil has been separated into three main process blocks: olive purification, olive grinding (including malaxing) and olive oil extraction. Each of these blocks contains various sub-processes and equipment, which are described in the following sections.

3.2.1 Electricity supply

The processing unit is connected to the grid, from where it is supplied with 3-phase electricity. An electricity meter from where consumption is recorded, as shown in Figure 25, is located outside the main building.

Figure 25 – Electricity consumption in Lythrodontas olive oil processing unit

Electricity in Cyprus is, at the moment produced solely by the semi-governmental Electricity Authority of Cyprus, at their three oil fuelled power stations, with an approximate annual output of 4,176 millions kWh (EAC, 2004). Thus grid electricity production from oil was included in the LCA model.

3.2.2 Water supply

The unit is also connected to the main water supply of the community of Lythrodontas, from which it is supplied with potable water for its operational requirements (Mouzouris, 2006). The supply and treatment of the water is under the authority of the Water Development Department.

The source of water used in Lythrodontas is the Dipotamos dam (Pekris, 2006). The dam (Figure 26), was built in 1985 to store water from the Pendaskinos river and is located approximately 15km south of Lythrodontas. Its original capacity was 13.7 million cubic metres; however this was extended to 15.5 million cubic metres in 1998.

Figure 26 – Dipotamos dam: source of potable water for Lythrodontas community

From the dam, water is pumped to Kornos water treatment plant through a 9km long, 500mm diameter asbestos cement pipe. The dam´s pump station consists of three 450kW and three 200kW electric pumps. According to Manoli (2006), under normal operational conditions, two 450kW and one 200kW pumps are in operation simultaneously.

The water treatment plant is located outside the village of Kornos, approximately 10km south-east of Lythrodontas. After treatment, described in section 3.2.3, water is pumped from the water works to a reservoir in the Stavrovouni region through a 3.5km long asbestos cement pipe of 500mm diameter. The pump station in Kornos water works comprises of four 187kW and two 107kW electric pumps. Under normal conditions, either two 187kW and two 107kW or three 187kW pumps are in simultaneous operation (Manoli, 2006).

From the Stavrovouni reservoir the water is pumped to another reservoir in Mallia through a 2.5km long ductile iron pipe of 200mm diameter. The pump station in Stavrovouni consists of two 40kW electric pumps of which one is stand-by.

From the reservoir in Mallia, water is transferred through a 11km long 250mm diameter pipe to a reservoir in a hill about 1km outside the village of Lythrodontas, shown in Figure 27, by gravitational forces. From there, water is transferred to the olive oil processing plant as well as the rest of the community dwellings.

Figure 27 – The reservoir outside Lythrodontas

3.2.3 Water treatment

The plant outside Kornos (Figure 28) has a capacity of 32 thousand cubic metres per day and serves many residential areas in Nicosia, Larnaca and Famagusta districts. The treatment, which takes place in the plant, is typical for potable water originating from surface waters.

Figure 28 – Kornos Water Works

Raw water transferred to the works is temporarily stored in an open reservoir (Figure 29), where suspended matter is removed. Chlorine is then added to the water (pre-chlorination) to oxidise various organic and inorganic materials like iron, hydrogen sulphide and inactivate or destruct pathogen micro-organisms.

Subsequently, water is aerated in order to destruct anaerobic micro-organisms and oxidise organic material present in the water.

The water is then transferred to flocculation tanks where through the addition of aluminium sulphate and an anionic polyelectrolyte (acrylamide and acrylic acid, Filippou, 2006), colloidal particles form heavy flocs. These flocs settle down as sludge in the sedimentation tanks (clarifiers). The sludge which settles at the bottom of the tanks is re-circulated in the flocculation tanks and eventually removed to dry. Dried sludge is, at the moment, stored on-site.

Water flowing out of the sedimentation tanks is transferred to filters where the remaining flocs and other particles are filtered out. Filters are washed at regular time intervals, by flashing water in the opposite direction, in order to keep them clean and in good operation.

Figure 29 – Raw water reservoir at Kornos water works

During the final step in the treatment, chlorine is added to the water for a second time (post-chlorination) to ensure that there is no growth of any pathogenic micro-organisms in the water supplied. The quantity of chlorine is much less than the quantity added during the pre-chlorination stage. It is highlighted that between filtration and post-chlorination, lime may be added to the water, usually during the winter months (WDD, 1999) to adjust its acidity. Treated water is finally transferred to a reservoir.

The water treatment processes, as take place in Kornos water works, were included in the model, in line with the system boundary definition (Avraamides *et al.*, 2005)

3.2.4 Pre-processing storage of olives

Pre-processing storage of olives includes the treatment of olives from the time they are transported to the plant up to the time they are processed. In many olive mills, this may include special climatic conditions, and the process was included in the system during the system definition (Avraamides *et al.*, 2005). However, according to Mouzouris (2006), olives in the Lythrodontas plant are processed immediately or in the worst case (peak season) within a few hours from the time they are transported to the plant. For this reason no olive storage facilities exist at the plant. Based on this conclusion, pre-processing storage of olive was excluded from the characteristic cycle of olive oil production in Lythrodontas.

3.2.5 Olive purification

The purpose of olive purification process is to remove foreign matter such as leaves, dust and stones from olives prior to grinding. Olives transported to the processing unit in reusable plastic boxes are placed in a large crate and are then transferred by means of an inclined conveyor belt (Figure 30) into the washing machine. In this machine, leaves, wood particles, dust, stones and other unwanted solids are removed by suction, and the remaining olives are sprayed with water. According to Mouzouris (2006), approximately 100 litres of water are required to spray 100kg of olives, however, after sedimentation of solids and filtration the water is recycled within the washing machine.

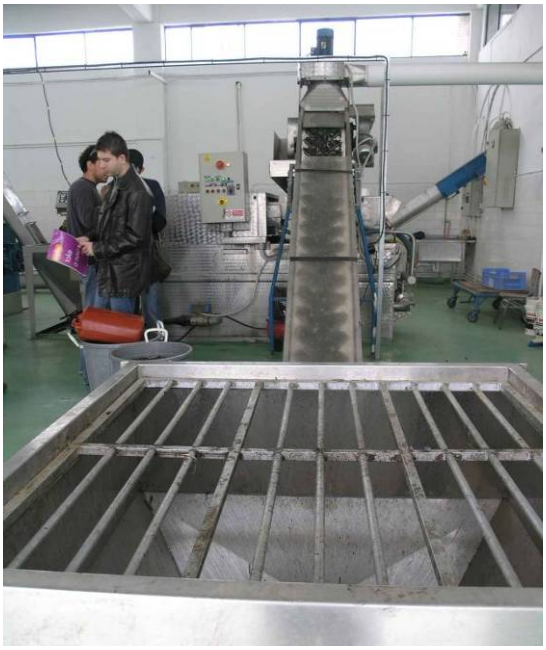

Figure 30 – Olives elevated from crate to suction and washing machine

Waste from this purification process, mainly olive leaves end up in an area just outside the building where they are left to dry out (Figure 31).

Figure 31 – Leaves and other matter removed during olive purification in Lythrodontas

At the final stage of this process block, purified olives are automatically weighed by an electronic scale. The process was included in the model.

3.2.6 Olive grinding and malaxing

In the next process block, olives, through an inclined conveyor belt, enter the olive crusher (Figure 32) where they are ground. Since crushing gives rise to the formation of emulsions between the oil and the water, a mixing vat is used to increase the oil droplet size.

Figure 32 – The olive crusher used in Lythrodontas (Amenduni, 2006)

Mixing allows the smaller droplets of oil that were released by crushing to agglomerate into larger ones which can be more easily separated. Oil yield is directly proportional to the temperature and mixing time, however the use of higher temperatures and longer mixing times increase oxidation of the oil and therefore decreases shelf life. Furthermore, according to Giovacchio (1996), the increase in mixing time results to reduction of phenols contained in the oil. Thus a compromise between oil yield and oil quality shall be struck.

In Lythrodontas, the mixing vat unit consists of six semi-cylindrical vats; each of 850kg capacity, fitted with an outer chamber through which, water heated at about 38ºC circulates. Inside the vat, and after the addition of warm (around 38ºC) water, the olive paste is maintained in movement for about 45 minutes by means of a spades device that turns around a shaft.

The process, as takes place in the Lythrodontas plant, was included in the model.

3.2.7 Olive oil extraction

The olive paste produced is then transferred to a decanter through a 0.5kW electric pump. The decanter (Figure 33) is a large horizontal centrifuge rotating at 6800 rpm. The high centrifugal force created allows the phases to be readily separated according to their different densities (pomace > vegetation water > oil).

Figure 33 – Decanter used in Lythrodontas

Inside the decanter's rotating conical drum, a coil rotates a few rpm slower, pushing the solid materials (pomace) out of the system. Pomace extracted from the system is pumped through an electric 1kW pump out to a storage space adjacent to the main building (Figure 34), where it is temporarily stored in order to dry. Subsequently, part of it is utilised as fuel in a water boiler, from which warm water supplies the mixing vat. The ash produced is sprayed into agricultural land, whereas the residual pomace quantities remain unused at the processing plant.

Figure 34 – Pomace drying at Lythrodontas processing unit

To facilitate separation process, water is added. The amount of water added to the paste can affect extraction yields and depends on the type of plant and on the rheological characteristics of the olives: too much water cuts extraction yields, as does too little. The optimal paste-water ratio is determined empirically by observing the characteristics of the oil and the water as they flow out of the decanter.

The liquid waste (vegetable water and water added to the system) separated during the centrifuge process is pumped through a 1kW electric pump outside through plastic pipes and is ultimately disposed into an evaporation pond about 500m from the plant. However, the transfer pipes are not buried in the ground, thus they are vulnerable to accidental damage or intrusion. In fact leakage incidents were observed during the site visits, as shown in Figure 35.

Figure 35 – Liquid waste leakage during its transfer to the evaporation pond

The evaporation pond (Figure 36) has an average depth of 1.2m and is covered with an impervious clay layer at the bottom and sides (MANRE, 2002), however there is no evidence of its efficiency in preventing groundwater contamination as no investigation was carried out so far.

Nevertheless, the pond is fenced all around by a wire mesh fence. During the summer months, when the oil processing unit is idle, the liquid waste evaporates. However, no sludge collection is undertaken at present.

Figure 36 – Liquid waste evaporation pond in Lythrodontas

The stream of oil separated in the decanter is transferred into the oil separator, where the last processing stage takes place. The purpose of the separator is to separate pure oil from impurities (such as vegetable water) left after the decanter stage. For this purpose, water is added to the oil and the mixture is passed through further centrifugation in two centrifuges on plates. In this manner, the oil fraction that accompanies the aqueous phase is recovered and collected as shown in Figure 37. Liquid waste from the separator is also pumped to the drying pond through a 1kW electric pump.

Figure 37 – Oil separation in Lythrodontas

The olive oil extraction processes, as described above, as well as the treatment of the associated waste streams, were included in the LCA model.

3.2.8 Olive oil storage

Oil collected is stored in bulk plastic containers (Figure 38) at room temperature. Storage time depends purely on supply and demand and varies from 1 week to 3 months (Mouzouris, 2006).

Figure 38 – Bulk olive oil storage in Lythrodontas processing plant

Prior to its sale an acidity test is carried out on–site. For this purpose a standard laboratory titration method of quantitative/chemical analysis is used.

4 Customisation of the basic model for Lythrodontas region

Following the identification and definition of the characteristic cycle of olive oil production in Lythrodontas, the basic LCA model developed during Task 2 (Avraamides *et al.*, 2005), was modified in order to represent the specific situation in the Lythrodontas region under study. The modifications carried out can be distinguished into four types: [1] exclusion of unit processes included in the basic model (for example herbicide application and associated production and transportation) [2] inclusion of unit processes not included in the basic model (for example inclusion of three different transportation modes for each transportation process), [3] establishment of new links between processes (for example, it was identified that in the orchards, water is required not only for irrigation but also for planting the trees and fertilisation), [4] changes in the names of some unit processes in order to self-explain the specific technique used in the region (for example "field water supply by electricity running pumps" instead of "irrigation water supply", and [5] modifications in the structure of the model as shown in Figure 39 and described below.

Furthermore, following the release of version 7 of the software SimaPro (PRé Consultants, 2006), the customised model for Lythrodontas region was developed in the new version of the software.

The changes performed in the basic model unit processes during customisation are shown in Table 1.

Table 1 – Unit process customisation

Basic model processes (Avraamides *et al.*, 2005)	**Customised model processes**
Electricity production	Grid electricity produced
	Field electricity produced
Irrigation water supply	Field water supply by electricity running pumps
Irrigation	Irrigation (sprinklers)
Fertiliser production	Fertiliser (20-10-10) production
Transportation of fertilisers to farm	Transportation of fertilisers to farm
	Transportation by pickup van
	Transportation by 16t lorry
	Transportation by freight ship
Fertiliser application	Fertiliser (20-10-10 NPK) application
Pesticide production	Pesticide (40% EC dimethoate) production
Transportation of pesticides to farm	Transportation of pesticides to farm
Pesticide application	Pesticide (40% EC dimethoate) application
Herbicide production	*Excluded*
Transportation of herbicides to farm	*Excluded*
Herbicide application	*Excluded*
Soil management	Soil management (tractor - chisel plough)
Olive tree planting	Olive tree planting (manual)
Olive tree cultivation	Olive agriculture (envelope process)
Pruning	Pruning (petrol ran chainsaw)
Not included	Burning of pruning residues
Olive collection	Olive collection (pneumatic hand-held combs)
Transportation of olives from farm to processing unit	Transportation of olives from farm to processing unit
Water treatment	Water treatment

Water supply	Water supply
Pre-processing olive storage	*Excluded*
Olive purification	Olive purification
Olive grinding	Olive grinding
Oil extraction	Oil extraction
On-site liquid waste treatment	Disposal of liquid waste
Wastewater supply through network	*Excluded*
Wastewater treatment (public)	*Excluded*
Pomace processing	*Excluded*
Solid waste treatment	Heat production from solid waste combustion
Not included	Disposal of pomace ash
Bulk storage of olive oil	Bulk storage of olive oil (plastic containers)
Not included	Olive oil processing (envelope process)

The structure of the model has been modified from a network modelling the natural sequence of unit processes into a network, which will allow environmental comparison between the two main phases of olive oil production, i.e. olive agriculture and olive oil processing. This was achieved by introducing two envelope processes, olive agriculture (instead of olive cultivation at a lower level) and olive oil processing, each of which included all associated sub-processes. These two envelope processes are the final inputs to the product assembly.

The network diagram of the Lythrodontas customised model is shown in Figure 39.

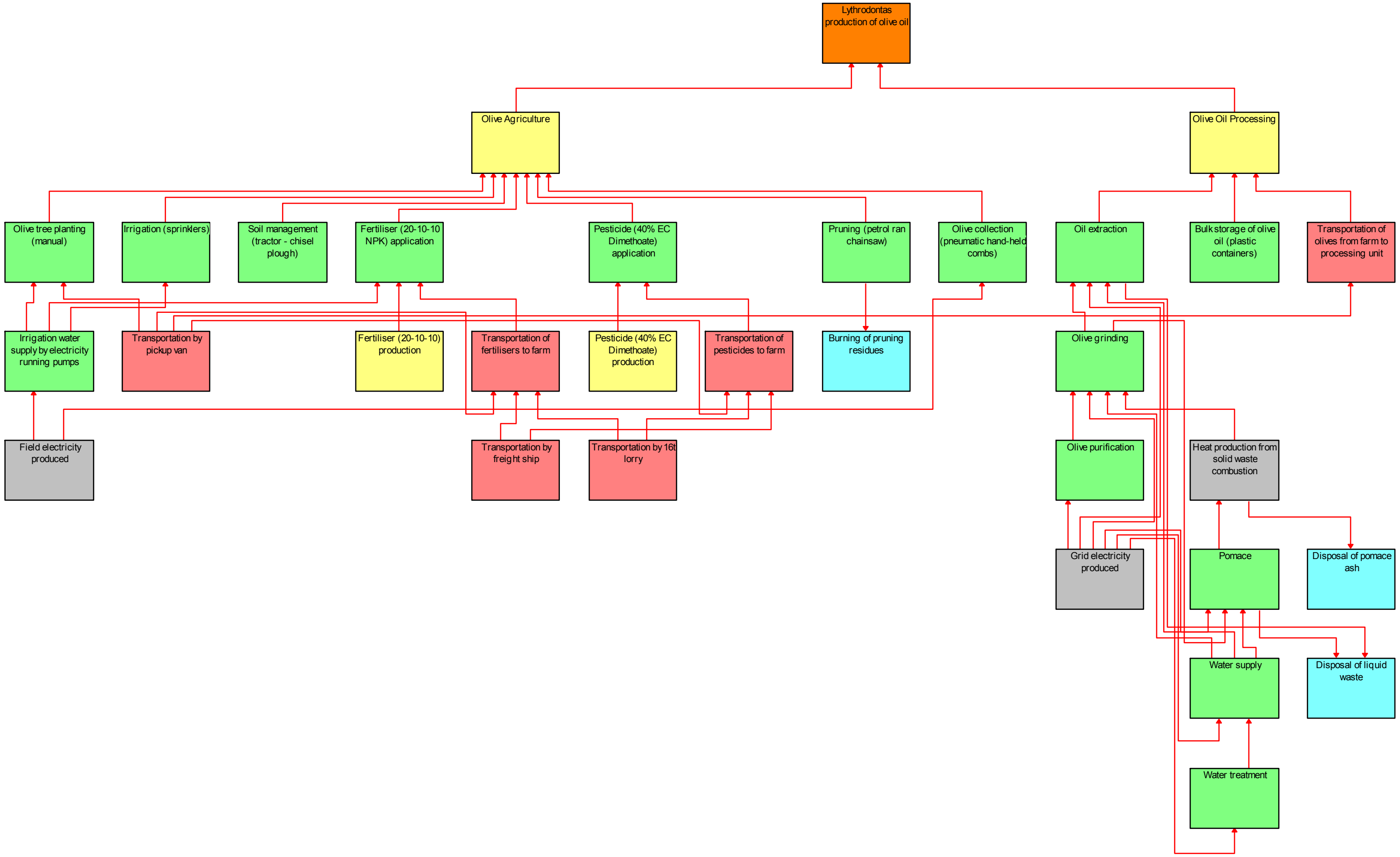

Figure 39 – Customised LCA model for Lythrodontas (SimaPro version 7)

5 Data Collection

The most effort-consuming step of the implementation of LCA studies is the collection and collation of data in order to build the life cycle inventory. For each unit process, within the system boundary defined, qualitative and quantified data on inputs and outputs were collected based on the data collection plan established during Task 2 of this project (Avraamides *et al.*, 2005).

The flow types for which data was required for each unit process within the system boundaries are: output to technosphere (product), inputs from technosphere (manufactured or processed materials, fuel, energy etc.), inputs from the environment (raw materials) and outputs to the environment (emissions). The latter two are also described as elementary flows. In SimaPro 7, these are recorded by the flow name (e.g. carbon dioxide fossil), the category, the subcategory and the unit. Categories describe the different environmental compartments air, water, soil and resource uses. The categories “air”, “water” and “soil” describe the receiving compartment and are used for (direct) pollutant emissions whereas the category "resource" is used for all kinds of resource consumption. Subcategories further distinguish sub-compartments within these compartments which may be relevant for the subsequent impact assessment step. For instance, water consumption is recorded as an input in the category/subcategory "resource/in water". Land transformation and occupation is recorded as an input as well, namely in the category/subcategory “resource/land”.

During the development of the LCA framework for this study, a number of data sources were identified and a data collection plan was established. As prescribed in this framework for the majority of data for background processes, secondary data sources would be used to collect, obtain and calculate the datasets from published sources such as industry data reports, validated life cycle inventory databases, laboratory test results, government documents and reports, reference books, previous life cycle inventory studies, equipment and process specifications.

SimaPro 7 contains several validated databases, from which suitable background data could be selected. Such databases are: ETH-ESU 96, BUWAL 250, IDEMAT 2001, Franklin USA 98, LCA food and Ecoinvent 1.2.

ETH-ESU 96 database is focused on electricity generation and related processes like transport, processing and waste treatment. It includes 1200 unit processes and 1200 system processes. BUWAL 250 focuses on packaging materials (plastic, carton, paper, glass, tin plated steel, aluminium), energy, transport and waste treatments. IDEMAT 2001 mainly covers engineering materials (metals, alloys, plastics, wood), energy and transport. Franklin USA 98 database includes north American inventory data for energy, transport, steel, plastics, processing, whereas LCA food database, which was recently added to SimaPro software provides datasets on basic food products (does not include olive oil) produced and consumed in Denmark and covers processes from primary sectors such as agriculture and fishery through industrial food processing to retail and cooking.

A major source of background data was the Ecoinvent database version 1.2 (Swiss Centre for Life Cycle Inventories, 2005). The Ecoinvent 2000 project was undertaken by the Swiss Centre for Life Cycle Inventories aiming at providing a set of unified and generic LCI data of high quality. The database developed contains more than 2500 datasets of products and services from the energy, transport, building materials, chemicals, pulp and paper, waste treatment and agricultural sector. Each dataset describes a life cycle inventory on a unit process level and they are classified into categories and subcategories. This classification serves an informative purpose only and can be used to search for certain processes. The datasets are available in two versions: the unit process and the system process. The unit process describes a single operation and is linked to other processes. The equivalent system process aggregates all elementary flows of all other unit processes with which a unit process is linked as if it is one process. The advantage of a unit process is that the origin of elementary flows can be traced and it gives a better insight into what is included. However, using processes leads to extremely large and unmanageable networks. For this purpose, in this study, unit processes were used to review what the process includes (and to exclude capital infrastructure as discussed below), but selected unit processes were converted into system processes in order to keep the model network manageable and for more practical interpretation of the analysis results.

According to Frischknecht *et al*. (2004a), the products and services analysed in the Ecoinvent database mainly cover the market (and consumption) situation in Switzerland in the year 2000. Because Switzerland's economy is closely linked to the surrounding countries, a lot of processes are also described for the situation in Europe. In some cases data from outside Europe have been used, e.g. extraction of mineral and energy resources. For all these the reference year 2000 was applied but due to reduced data availability older data has been used in exceptional cases.

Nevertheless, for some regions, data availability is poor. This is mainly the case for south European countries including Cyprus, Greece and Spain. Therefore, background data obtained from databases are not country-specific. Nevertheless, in most situations production conditions are rather similar.

According to the boundary definition (Avraamides *et al.*, 2005), capital infrastructure is not excluded in the system. However, most Ecoinvent processes do include capital infrastructure. In order to exclude them, the unit process version of each selected dataset was calculated, without the capital infrastructure (this function is only available in version 7 of SimaPro) and its inventory was saved as a new system process, which therefore excluded the capital infrastructure.

In regards to cut-off rules, according to ISO 14041 (1998) several criteria are used to decide which inputs to be studied, including mass, energy, and environmental relevance. However, the Ecoinvent database does not follow a strict quantitative cut-off rule. According to Frischknecht *et al*. (2004a), “environmental knowledge of the people involved in compiling LCI data is used to judge whether or not to include the production of a certain input or whether or not to include the release of a certain pollutant”.

The same cut-off approach was applied for the foreground data collected. The main sources of data were the olive growers in the region, as discussed earlier, processors, agricultural and environmental experts and olive oil farming associations. The data collection methods included the circulation of questionnaires, telephone and personal interviews, on-site measurements and laboratory analyses. For the compilation of data from various sources and their adjustment to a reference flow extensive calculations were undertaken. The underlying principles of the calculations as well as the assumptions considered are clearly documented.

The majority of data on the main flows at the agricultural stage were obtained through the questionnaire in Appendix A. The responds to the questionnaires were treated as values weighted in accordance with the number of trees cultivated. Furthermore the minimum and maximum values were recorded and two values for standard deviation were calculated for the sample. The first standard deviation calculated, sd_1, was calculated considering each tree as an individual sample value (i.e. the answers given by each farmer apply to all of his trees). This takes into account the variance of quantities actually used and applied. In order to take into account the degree of error which each respond to the questionnaire includes, a second measure of standard deviation was calculated, sd_2, which considers that the sample consists of the answers given by each farmer (i.e. the answer given by each farmer was considered once, not taking into account the number of trees each farmer represents). The analysis of the questionnaire responses is included in Appendix A. The main product flows at the olive oil processing stage were recorded by measurements on the site and validated through energy and mass balances. Data in regards to elementary flows for foreground processes were mainly collected from literature or calculated from established models, based on assumptions.

The quality of individual datasets is related to the data quality goals defined during the goal and scope definition of this study (Avraamides *et al.*, 2005), through the pedigree matrix of data quality indicators suggested by Weidema and Wesnaes (1996), provided in Table 2.

Table 2 – Pedigree matrix with 5 data quality indicators (Weidema and Wesnaes, 1996)

Indicator score	1	2	3	4	5
Reliability	Verified[1] data based on measurements[2]	Verified data partly based on assumptions or non-verified data based on measurements	Non-verified data partly based on assumptions	Qualified estimate	Non-qualified estimate
Completeness	Representative data from a sufficient sample of sites over an adequate period to even out normal fluctuations	Representative data from a smaller number of sites but for adequate periods	Representative data from an adequate number of sites but from shorter periods	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Representativeness unknown or incomplete data from a smaller number of sites and/or from shorter periods
Temporal correlation	Less than three years of difference to year of study	Less than six years difference	Less than 10 years difference	Less than 15 years difference	Age of data unknown or more than 15 years of difference
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar production conditions	Data from unknown area or area with very different production conditions
Further technological correlation	Data from enterprises, processes and materials under study	Data from processes and materials under study but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials but same technology	Data on related processes or materials but different technology

[1] Verification may take place in several ways, e.g. by on-site sketching, by recalculation, through mass balances or cross-checks with other sources

[2] Includes calculated data (e.g. assumptions calculated from inputs to a process), when the basis for calculation is measurements (e.g. measured inputs). If the calculation is based partly on assumptions, the score should be two or three

In the following sections, data for each unit process included in the model, the sources used to obtain the data, the collection, calculation and measurement methods, the associated assumptions as well as their data quality indicators are reported.

5.1 Fuel production

As discussed in Chapter 3, various fuels such as diesel, petrol and crude oil are used as material inputs from technosphere to various processes of the system. Although in most processes, for which database sets are used, fuel consumption is incorporated into the process inventory as elementary flows, in other processes, such as soil management and pruning, fuels are included as products. The following sections report the data sources for the production of these fuel products.

5.1.1 Diesel

The process of diesel production starts at the extraction of fossil fuels and ends at the distribution of the fuel for regional storage. The output to technosphere of this process is the production and distribution of 1kg of diesel.

Data in regards to the resources and energy consumed and emissions associated with the production of diesel was obtained from IDEMAT 2001 database. The name of the process selected is “Diesel I” (process identifier IDEMAT0106626600018) and is classified under the Material/Fuels/Oil/Diesel subcategory. The data has been collected by the University of Technology Delft and represents the production of 1 kg diesel with 15% North Sea oil. Geographically the dataset represents the situation in Western Europe and although the data is rather old (1994) it covers average technology and excludes capital infrastructure.

The data quality index for this dataset, with reference to Table 2, is (1, 1, 5, 3, 2).

5.1.2 Petrol

Similarly, the process of petrol production starts at the extraction of fossil fuels and ends at the distribution of petrol for regional storage. The output to technosphere of this process is the production and distribution of 1kg of petrol

Data in regards to the resources and energy consumed and emissions associated with the production of diesel was obtained from IDEMAT 2001 database. The name of the process selected is “Petrol I” (process identifier IDEMAT0106626600033) and is classified under the Material/Fuels/Oil/Petrol subcategory. The data has been collected by the University of Technology Delft. Geographically the dataset represents the situation in Western Europe and although the data is rather old (1994) it is considered as representative as it covers average technology and excludes capital infrastructure.

The data quality index for this dataset, with reference to Table 2, is (1, 1, 5, 2, 2).

5.1.3 Oil

The process of oil production starts at the extraction of fossil fuels and ends at the distribution of the fuel for regional storage. The output to technosphere of this process is the production and distribution of 1kg of crude oil.

Data in regards to the resources and energy consumed and emissions associated with the production of diesel was obtained from IDEMAT 2001 database. The name of the process selected is “Crude Oil I” (process identifier IDEMAT0106626600019) and is classified under the Material/Fuels/Oil/Crude oil subcategory. The data has been collected by the University of Technology Delft and represents the production of 1 kg crude oil from Africa 36%, Eastern Europe 12%, Middle East 44% and the remaining 7% includes production and transportation in Europe. Geographically the dataset represents the situation in Western Europe. Data was collected between 1990 and 1994, represents the average from all suppliers and covers average technology.

The dataset excludes capital infrastructure in line with our system boundaries. The data quality index for this dataset, with reference to Table 2, is (1, 1, 5, 3, 2).

5.2 Electricity production

Electricity is a main input of many processes in the olive oil processing stage, as well as in the agricultural stage. Electricity production is a significant polluting activity, thus it was included within the system boundary (Avraamides *et al.*, 2005). As discussed in Chapter 3, two types of electricity production are encountered in the system: production of grid electricity and production of field electricity. The following sections report on the data collected for these two processes.

5.2.1 Grid electricity production

The process of grid electricity production starts at the extraction of fossil fuels required and ends when electricity is supplied to the grid. The production and maintenance of capital infrastructure, such as the power plant and the distribution network is excluded. The output to technosphere (product) of this process is the production and supply of 1kWh of electricity.

In Cyprus, at the moment, the Electricity Authority operates three power stations, which use oil as a fuel and in 2004 produced 4,176 millions kWh of electric power annually (EAC, 2004).

Data on the environmental exchanges of this unit process was obtained from Ecoinvent database, version 1.2. The name of the process selected is “electricity, oil, at power plant/GR” (process identifier EIN_UNIT06567701461) and is classified under the “energy/electricity by fuel/oil” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The inventory includes all energy use, use of chemicals, emissions to air and water including treatment of flue gasses and effluents. In regards to geographical correlation, the data is specific estimation for Greece, however it is considered as representative of the situation in regards to electricity production from oil in Cyprus. Technology represented from the dataset is average.

The data quality index for this dataset, with reference to Table 2, is (2, 1, 1, 3, 2).

5.2.2 Field electricity production

The process of field electricity production starts at the extraction of fossil fuels with which a typical on-site diesel electricity generator is fed and ends when electricity is produced on site. The production and maintenance of capital infrastructure, such as the generator is excluded. The output to technosphere (product) of this process is the production of 1kWh of electricity in the orchards of Lythrodontas.

Data for this unit process was obtained from Ecoinvent database, version 1.2. The name of the process selected is “diesel, burned in diesel-electric generating set” (process identifier EIN_UNIT06567701389) and is classified under the “energy/electricity by fuel/mechanical” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The inventory includes diesel consumption and emissions for the use of diesel in electric generating sets. For the production of diesel, “diesel production” as documented in section 5.1.1.

Transport to site is not included. Geographically the dataset is representative of the situation in Norway and the United States; however the technology is typical of that used in Cyprus.

The data quality index for this dataset, with reference to Table 2, is (3, 3, 3, 4, 2).

5.3 Production of agricultural chemicals

The production of chemicals used as inputs at the agricultural stage of olive oil production is also a significant activity in environmental terms. The collection of data for the production of the characteristic fertilisers and pesticides is reported below.

5.3.1 Fertiliser production

The process of fertiliser production starts at the extraction of raw materials required for the product and ends when 1kg of the identified 20-10-10 compound fertiliser (NPK) is produced and stored at the manufacturing plant. The transformation that takes place in this process is of chemical nature. The production and maintenance of capital infrastructure, such as manufacturing plant buildings and equipment are excluded. The output to technosphere (product) of this process is the production of 1kg of the characteristic fertiliser.

According to EFMA (2000) NPK fertilizers can be produced by two main methods, via the mixed acid route and by the nitrophsopate route. According to Kentepozidis (2006) the characteristic fertiliser used in Lythrodontas is produced through the mixed acid route. This production method allows the creation of a large variety of multinutrient fertilisers by combining phosphoric, sulphuric and nitric acid as well as ammonium nitrate solution in some cases. The manufacture of these products begins with the production of phosphoric acid, a step which creates a large quantity of gypsum. The mixing of the acids, with ammonium nitrate in some cases, is followed by a neutralization step in which gaseous ammonia is added. Other materials may be added at the end of or during this production step (in this system potassium sulphate) in order to enlarge the variety of the final products. The last step consists in the granulation of the final product.

According to PFI (1998) the characteristic fertiliser comprises of ammonium nitrate, ammonium sulphate, monoammonium phosphate, diammonium phosphate and potassium sulphate. The packaging of the product states that ammonium nitrate is at 36% w/w concentration. The concentration of each of the other ingredients is unknown, however this was estimated through a trial and error calculation procedure, based: [1] on the known weight of ammonium nitrate in 1kg of the fertiliser, [2] on the known weight percentage of each nutrient in each ingredient obtained from Zublena *et al.* (1991) and [3] on the known total weight of each nutrient in 1kg of a 20-10-10 fertiliser product, as shown in Table 3.

Table 3 – Composition of the characteristic Lythrodontas fertiliser

Material	Weight (kg)	N		P_2O_5		K_2O	
		%	Wt (kg)	%	Wt (kg)	%	Wt (kg)
Ammonium nitrate	0.36(1)	30(2)	0.11(5)	-	-	-	-
Ammonium sulphate	0.25(4)	21(2)	0.05(5)	-	-	-	-
Monoammonium phosphate	0.07(4)	11(2)	0.01(5)	48(2)	0.04(5)	-	-
Diammonium phosphate	0.13(4)	18(2)	0.02(5)	46(2)	0.06(5)	-	-
Potassium sulphate	0.2(4)	-	-	-	-	50(2)	0.1(5)
Total	1.0	20%(3)	0.2(3)	10%(3)	0.1(3)	10%(3)	0.1(3)

(1) Manufacturers data (PFI,1998)

(2) Zublena *et al.* (1991)

(3) For a 20-10-10 compound feriliser

(4) Trial and error value

(5) Calculated value

The inventory for the production of the characteristic fertiliser was compiled from the production of each ingredient and more specifically: 0.11kg of ammonium nitrate as N, 0.05kg of ammonium sulphate as N, 0.01kg of monoammonium phosphate as N, 0.04kg of monoammonium phosphate as P_2O_5, 0.02kg of diammonium phosphate as N, 0.06kg of diammonium phosphate as P_2O_5 and 0.1kg of potassium sulphate as K.

Data for the production of ammonium nitrate as N was obtained from Ecoinvent database, version 1.2. The name of the process selected is “Ammonium nitrate, as N, at regional storehouse/RER” (process identifier EIN_UNIT06567700044) and is classified under the “material/chemicals/fertilisers (inorganic)” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process. The unit process inventory takes into account the production of ammonium nitrate from ammonia and nitric acid. Transports of the intermediate products to the fertiliser plant as well as the transport of the fertiliser product from the factory to the regional storehouse are included. Production and waste treatment of catalysts were not included.

Data for the production of ammonium sulphate as N was obtained from Ecoinvent database, version 1.2. The name of the process selected is “Ammonium sulphate, as N, at regional storehouse/RER” (process identifier EIN_UNIT06567700045) and is classified under the “material/chemicals/fertilisers (inorganic)” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process. The unit process inventory takes into account the use of energy resources cited in Kongshaug (1998), needed for the production of ammonium sulphate as by-product during the manufacture of nylon. According to the database documentation, these values must be considered as uncertain, because the system boundaries were not clearly defined by Kongshaug.

Data for the production of monoammonium phosphate as N and as P_2O_5 was obtained from Ecoinvent database, version 1.2. The multioutput-process 'monoammonium phosphate, at regional storehouse' delivers the co-products 'monoammonium phosphate, as N, at regional storehouse' and 'monoammonium phosphate, as P_2O_5, at regional storehouse'. Allocation was based on the energy requirements of the respective nutrients for the production processes: 45% for 'monoammonium phosphate, as N, at regional storehouse' and 55% for 'monoammonium phosphate, as P_2O_5, at regional storehouse''. Therefore, the allocated inventories are both included in the process (0.01kg of MAP as N and 0.04kg of MAP as P_2O_5). The names of the processes selected are “Monoammonium phosphate, as N, at regional storehouse/RER” (process identifier EIN_UNIT06567700052) and “Monoammonium phosphate, as P_2O_5, at regional storehouse/RER” (process identifier EIN_UNIT06567700053) and are classified under the “material/chemicals/fertilisers (inorganic)” subcategory. In order to exclude production and maintenance of capital infrastructure, the processes were analysed as unit process by excluding capital goods and their inventories were saved as a new system process. The inventories take into account the production of monoammonium phosphate from ammonia and phosphoric acid. Transports of raw materials and intermediate products to the fertiliser plant were included. Production and waste treatment of catalysts were not included.

Data for the production of diammonium phosphate as N and as P_2O_5 was obtained from Ecoinvent database, version 1.2. The multioutput-process 'diammonium phosphate, at regional storehouse' delivers the co-products 'diammonium phosphate, as N, at regional storehouse' and 'diammonium phosphate, as P_2O_5, at regional storehouse'. Allocation factors are based on the energy requirements of the respective nutrients for the production processes: 60% for 'diammonium phosphate, as N, at regional storehouse' and 40% for 'diammonium phosphate, as P_2O_5, at regional storehouse''. Therefore the allocated inventories are both included in the process (0.02kg of DAP as N and 0.06kg of DAP as P_2O_5). The name of the processes selected are “Diammonium phosphate, as N, at regional storehouse/RER” (process identifier EIN_UNIT06567700048) and “Diammonium phosphate, as P_2O_5, at regional storehouse/RER” (process identifier EIN_UNIT06567700049) and are classified under the “material/chemicals/fertilisers (inorganic)" subcategory. In order to exclude production and maintenance of capital infrastructure, the processes were analysed as unit process by excluding capital goods and their inventories were saved as a new system process. The inventories take into account the production of diammonium phosphate from ammonia and phosphoric acid. Transports of raw materials and intermediate products to the fertiliser plant were included. Production and waste treatment of catalysts were not included.

Data for the production of potassium sulphate as K_2O was obtained from Ecoinvent database, version 1.2. The name of the process selected is "Potassium sulphate, as K_2O, at regional storehouse/RER" (process identifier EIN_UNIT06567700057) and is classified under the "material/chemicals/fertilisers (inorganic)" subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process. The unit process inventory takes into account the production of potassium sulphate from potassium chloride and sulphuric acid. Transports of raw materials and intermediate products to the fertiliser plant were included. Production and waste treatment of catalysts were not included.

According to the inventory database documentation used for these inventories, the European average is derived from mean values of several fertiliser plants within Europe. The production of raw materials and/or intermediates outside Europe was taken into account by considering the production technology in the respective country and the relative import shares, whereas production inventory was derived from detailed literature studies and specifications from the manufacturer, relevant for the European production.

The data quality index for this dataset, with reference to Table 2, is (2, 1, 1, 2, 2).

5.3.2 Pesticide production

The process of pesticide production starts at the extraction of raw materials required for the product and ends when 1kg of the identified pesticide is produced and stored at the manufacturing plant. The production and maintenance of capital infrastructure, such as manufacturing plant buildings and equipment are excluded. The output to technosphere (product) of this process is 1kg of the characteristic pesticide produced.

Most modern synthetic pesticides are manufactured entirely from intermediates derived from fossil fuels. Primary pesticide production conventionally entails several process steps involving a variety of unit operations such as heating, stirring, distilling, filtering, drying and similar processes to build up a biologically active chemical entity from raw materials and/or specific chemical intermediates (Bhat *et al.*, 1994). Secondary processing involves the formulation of the pesticide in a marketable form, such as wettable powders, dusts, emulsifiable concentrates, granules etc. This normally involves purely physical operations such as vessel charging, mixing, milling, warming, cooling, product transfer, granulation, drying, sieving and packaging. No chemical reactions take place during secondary processing. Nevertheless, both the production and the formulation processes require direct energy inputs for processing, in addition to the intrinsic energy inputs needed (Nemecek, 2004). The production of the characteristic pesticide for Lythrodontas involves the production of the active substance dimethoate and the product formulation into emulsifiable concentrate with 40% concentration of the active ingredient.

According to Nemecek (2004) it is very difficult to obtain current, accurate and specific data on pesticide production and the reason for this is twofold. Firstly, detailed information on the production processes is not easily available to public since a company often does not share information on its patent-protected pesticides. Secondly, the unavailability of data is attributed to the very large number of chemical compounds used as pesticides – over 6,000 worldwide, whereas the active substances belong to very different chemical categories and are synthesised by various, sometimes highly complex chemical pathways.

Data for the production of dimethoate based pesticide was obtained from Ecoinvent database, version 1.2. Since dimethoate is not one of the substances covered by Green (1987) and inventoried by Ecoinvent, the process selected in accordance with the recommendations by Nemecek (2004) is "Pesticide, unspecified, at regional storehouse/RER" (process identifier EIN_UNIT06567700120) and is classified under the "material/chemicals/pesticides" subcategory. Values represent the average of the inventories of all active ingredients (totally 41) included in Green (1987), who approximated energy inputs required for the manufacture of selected pesticides. Apart from energy inputs other inputs are not included. The World Bank (1998) gives the quantity of solid waste produced as 200kg per tonne of active ingredient and this was included in the inventories. According to the same data source the emissions of active ingredients to the environment during manufacture, amounted to only 0.03-14mg per kg of active substance. These emissions are negligible compared to emissions from pesticide application, thus they were not included in the Ecoinvent datasheets (Nemecek, 2004). In the other hand, waste heat production stemming from the use of electricity was quantified as emission into the air.

In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The values used for this inventory primarily apply to US American conditions. It is assumed that these figures can be applied to the manufacturing process in the European Union. Values given represent approximated values which are based on hypothetical material flow sheets and line diagrams from which the energy input of manufacturing process was derived. The manufacturing process was modelled on information given about the method of manufacture in the patents or, in case of pesticides which are no longer subject to patent protection, on detailed literature on the production process.

The data quality index for this dataset, with reference to Table 2, is (2, 2, 4, 3, 2).

5.4 Transportation

The investigation of the means, with which agricultural inputs and outputs are transported, revealed that three main transportation modes are used: freight ship, 3-axle 16 tonne lorry and pickup van. In the following sections environmental exchanges for transportation of goods through each of these are reported. The transportation processes with these modes are combined in order to simulate the transportation practice for the various inputs and outputs as identified in Chapter 3.

5.4.1 Transportation by freight ship

The process of transportation by freight ship starts when loading the goods in the freight ship at the origin port and ends when the goods are unloaded at the destination port. The nature of the transformation that takes place is physical. The production and maintenance of capital infrastructure, such as the vessel and the port is excluded. The output to technosphere (product) of this process is the transportation of a 1-tonne load over 1km by a typical freight ship.

Data for the unit process of transporting goods by freight ship was obtained from Ecoinvent database, version 1.2. The name of the process selected is "operation, transoceanic freight ship/RER" (process identifier EIN_UNIT06567701792) and is classified under the transport/water/operations subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The inventory includes the supply of fuel, direct airborne emissions of gaseous substances, particulate matters, dioxins, PAHs, halogens and heavy metals. Also, the disposal of bilge oil and emissions of tributyltin compounds are included. The spill of oil due to accidents is not included.

Individual hydrocarbons are estimated based on the share of diesel engines of road vehicles. Heavy metals are estimated from trace elements in fuel. A distinction between distilled (28%) and residual fuel (72%) is applied. Amount of disposed bilge oil is estimated as 0.6% of the consumed fuel.

In regards to geographic scope, the data is global, whereas in regards to technology, average data for steam turbine (5%) and diesel engine (95%) propulsion is used. The fuel used is Heavy Fuel Oil (HFO) and is representative for slow speed engine types (speed: 14 knots per hour). The data represents solid bulk transport (about 40,000 dwt). Literature studies and own estimates have been used during sampling procedure for compilation of this process in the Ecoinvent database.

The data quality index for this dataset, with reference to Table 2, is (4, 5, 1, 2, 2).

5.4.2 Transportation by 16-tonne lorry

The process of transportation by a 3-axle, 16-tonne lorry starts when loading the goods in the lorry at the origin location and ends when unloading the goods at the destination location. Thus the nature of the transformation that takes place is also physical. The production and maintenance of capital infrastructure, such as the vehicle and the roads is excluded. The output to technosphere (product) of this process is the transportation of 1 tonne of goods by a 16-tonne lorry over a distance of 1km.

Data for this unit process was obtained from Ecoinvent database, version 1.2. The name of the process selected is “transport, lorry 16t/RER” (process identifier EIN_UNIT06567701774) and is classified under the transport/road subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The inventory includes diesel and petrol supply as well as direct airborne emissions of gaseous substances, particulate matters and heavy metals. Also heavy metal emissions to soil and water are included. Emissions due to losses of air condition systems are estimated. The original Ecoinvent unit process also included the construction, renewal and disposal of roads but these have been excluded from the process, in accordance with the system boundaries.

In regards, to geographic scope, data refers to average transport conditions in Europe, however Cyprus is not included. Nevertheless, as transport conditions in Cyprus are similar to the rest of Europe, the data is considered as geographically representative. The sampling sources used include: European statistics, literature studies and official publications of the European Environmental Agency.

In regards to the technology represented, the data is based on diesel engine concepts, which is representative of the situation in regards to such vehicles in Greece and Cyprus, where transportation takes places for the life cycle of olive oil modelled.

The data quality index for this dataset, with reference to Table 2, is (3, 1, 1, 3, 2).

5.4.3 Transportation by pickup van

The process of transportation by pickup vans starts when loading the goods in the van at the origin location and ends when unloading the goods at the destination location. The production and maintenance of capital infrastructure is also excluded. The output to technosphere (product) of this process is the transportation of 1 tonne of goods by a van with gross weight less than 3.5 tonnes over a distance of 1km.

Data for this unit process was obtained from Ecoinvent database, version 1.2. The name of the process selected is “transport, van<3.5t/RER” (process identifier EIN_UNIT06567701780) and is classified under the transport/road subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The inventory includes diesel and petrol supply, as well as direct airborne emissions of gaseous substances, particulate matters and heavy metals. Furthermore the inventory includes heavy metal emissions to soil. For petrol vans in particular, platinum emissions are accounted for. The original Ecoinvent unit process also the construction, renewal and disposal of roads but these have been excluded from the process, in accordance with the system boundaries.

The data is for the operation of an average European van and geographically the data refers to average transport conditions in Europe. Although Cyprus is not included, transport conditions in Cyprus are similar to the rest of Europe, therefore the data is considered as geographically representative. The sampling sources used include: European statistics, literature studies and official publications of the European Environmental Agency (EEA).

In regards to the technology represented, the data is based on both diesel and petrol engine concepts, which is representative of the situation in regards to such vehicles in Cyprus, with diesel engines dominating.

The data quality index for this dataset, with reference to Table 2, is (3, 1, 1, 3, 2).

5.4.4 Transportation of fertilisers

The process of fertiliser transportation starts when loading 1kg of the fertiliser at the production site, i.e. in Kavala, and ends when unloading 1kg of the fertiliser at the point of application, i.e. Lythrodontas. The production and maintenance of capital infrastructure, such as vessels, vehicles, roads and ports is excluded. The process combines all intermediate transportation that takes place by the all modes used. The output to technosphere (product) of this process is the transportation of 1kg of the characteristic fertiliser used in Lythrodontas, as determined in Chapter 3, from its production site in Kavala to the Lythrodontas olive orchards.

Data for this process was collected during the characteristic cycle identification through personal and telephone interviews. Transportation routes and distances were identified and measured from geographical maps. The data is therefore specific for this case study and collected within the last year (2006). The technology considered in regards to transportation modes is average technology used for the particular routes.

In the process inventory, for 1kg of the output to technosphere, the inputs from technosphere are: 1kg*1138km, i.e. 1.138 tonnes*km of transportation by freight ship (documented in section 5.4.1), 1kg*100km, i.e. 0.1 tonnes*km of transportation by 16-tonne lorry (documented in section 5.4.2) and 1kg*40km, i.e. 0.04 tonnes*km of transportation by pickup vans (documented in section 5.4.3).

No other direct flows from and to technosphere or from and to the environment have been identified.

The data quality index for this dataset, with reference to Table 2, is (3, 3, 1, 1, 1).

5.4.5 Transportation of pesticides

The process of pesticide transportation starts when loading 1kg of the pesticide at the production site in Denmark and ends when unloading 1kg of the pesticide product at the point of application, i.e. the olive orchards in Lythrodontas. The production and maintenance of capital infrastructure, is excluded. The process includes all intermediate transportation that takes place by the all modes used, including transportation in Greece for packaging as identified in section 3.1.8. The output to technosphere (product) of this process is the transportation of 1kg of the characteristic pesticide used in Lythrodontas, from its production site in Denmark to the Lythrodontas olive orchards.

Data for this process was collected during the characteristic cycle identification through personal and telephone interviews. Transportation paths and distances were identified and measured from maps. The data is therefore specific for this case study and collected within the last year (2006). The technology considered in regards to transportation modes is average technology used for the particular routes.

In the process inventory, for 1kg of the output to technosphere, the inputs from technosphere are: 1kg*7882km (total from Copenhagen-Thessaloniki and Thessaloniki-Limassol), i.e. 7.882 tonnes*km of transportation by freight ship (documented in section 5.4.1), 1kg*134km of total transportation by 16-tonne lorry (documented in section 5.4.2), i.e. 0.134 tonnes*km and 1kg*40km of transportation by pickup vans (documented in section 5.4.3), i.e. 0.04 tonnes*km.

No other direct flows from and to technosphere or from and to the environment have been identified.

The data quality index for this dataset, with reference to Table 2, is (3, 3, 1, 1, 1).

5.4.6 Transportation of olives

The process of transportation of olives starts when 1kg of olives are loaded at the collection point, i.e. the olive orchards of Lythrodontas and ends when they are delivered at the olive oil processing unit. The production and maintenance of capital infrastructure, such as vehicles and roads is excluded. The output to technosphere (product) of this process is the transportation of 1kg of olives, from Lythrodontas orchards to the processing unit.

Data for this process was collected during the characteristic cycle identification through personal and telephone interviews. The data is therefore specific for this case study and collected within the last year (2006). The technology considered in regards to transportation modes is average technology used for the particular route.

In the process inventory, for 1kg of the output to technosphere, the only input from technosphere is 1kg*2.1km, i.e. 2.1×10^{-3} tonnes*km of transportation by pickup vans (documented in section 5.4.3).

No other direct flows from and to technosphere or from and to the environment have been identified.

The data quality index for this dataset, with reference to Table 2, is (3, 3, 1, 1, 1).

5.5 Agricultural processes

Processes, which take place within the olive orchards, including the supply of water needed for irrigation and other uses within the orchard, the planting of new trees, irrigation and the management of the agricultural soil etc, are processes of primary importance to the system. Collection of data on the environmental exchanges of each of these processes was based on information obtained from the actual olive growers where possible and also on the application of the results of research undertaken in the past, as found in the relevant literature.

5.5.1 Field water supply

The process starts when groundwater is extracted from the well inside the field, as identified in Chapter 3 and ends when water is supplied to the sprinkler irrigation system at the appropriate operational pressure. The production and maintenance of capital infrastructure e.g. turbine pumps and pipes are excluded in line with the definition of the system boundary. The output to technosphere (product) of this process is 1 kg of water supplied for irrigation.

Groundwater is a valuable resource and its consumption within a technosphere system shall be considered as an environmental input in an LCA. Thus, for the supply of 1kg of water for irrigation, 1 litre (kg) of water from well in ground is recorded as an input from nature. However, for easier interpretation in the water consumption pattern within the system, water resource from wells (as in this case), from rivers and from lakes are all recorded as water from unspecified natural origin.

The main inputs from technosphere in this process is electrical energy consumed by the electric turbine pumps to extract the water from the well and supply the spray type sprinkler irrigation system at the appropriate operational pressure. Since very few of the olive growers questioned were aware of pump power and energy consumed, this was calculated based on reasonable assumptions, partly based on the responses obtained from the actual growers.

The average flow of water during irrigation is, according to the survey results, 7 tonnes/hour. Information based on data from the Cyprus Geological Survey department indicates that the average depth of groundwater table in the region is approximately 520 feet. Assuming a drawdown of 100 ft for the particular soil type (oversaturated basalt with dykes and sills), that the irrigated field is at the same ground level with the extraction point (horizontal field) and assuming that the spray type sprinkler system requires 40psi water pressure (typical for this system), i.e. 93 feet head, the average total head required is 713 feet (217 metres). Furthermore, assuming that the turbine pump operates at 55% efficiency (typical for this type of pumps) and using standard formulas (Curtis, 1990), the calculated power of pump required for extracting water from on-site wells and supplying the spray type sprinkler irrigation systems is 10.1 horsepower. Therefore it is likely that a 12 HP, i.e. 8.83kW turbine pump is used. The supply of 1kg of water at a flow rate of 7tonnes/hour corresponds to $1.43x10^{-4}$ hours of operation of the turbine pump, thus $1.26x10^{-3}$kWh of field electricity produced (documented in section 5.2.2) is consumed from the process, thus included in the inventory as input from the technosphere.

No other flows to and from the environment and the technosphere have been identified in this process.

The data quality index for this dataset, with reference to Table 2, is (3, 3, 1, 1, 1).

5.5.2 Planting the olive trees

The process of olive tree planting starts when new trees in plastic buckets are transported from the tree nursery to the field. It ends when a new Cyprus olive tree is being planted in the Lythrodontas orchards. The process does not include any exchanges occurring as a result of processes taking place in the tree nursery, such as the treatment of cuttings with rooting media. The production of plastic buckets, which contain the new tree prior to planting, is also excluded. As identified in Chapter 3, the buckets are reusable, thus no disposal of buckets is considered. Furthermore the production and maintenance of capital infrastructure such as the tools used are excluded in line with the system boundary definition. The output to technosphere (product) of the process is one olive tree of the Cyprus variety planted in the Lythrodontas orchards.

No mechanical equipment is involved, since only manual tools are used (mattocks and spades), therefore neither energy or fuel consumption, nor emissions to the environment are recorded. The only material flow identified during the process is the use of water, which is surplus to the regular irrigation of the trees. Thus 2 litres of water, as estimated by the growers, from the "field water supply" process (section 5.5.1), are recorded as an input from technosphere to the tree planting process. Furthermore, as identified in Chapter 3, trees for planting are transported from the public tree nursery in Athalassa (35km) by private pickup vans. Considering that the weight of a young olive tree planted in a plastic bucket weighs an estimated 3kg, 0.11tonnes*km of "transportation by private pickup van", documented in section 5.4.3 is also included in the process as an input from technosphere.

No other flows to and from the environment and the technosphere have been identified in this process.

The data quality index for this dataset, with reference to Table 2, is (2, 1, 1, 1, 1).

5.5.3 Irrigation

The process of irrigation starts when water is supplied at the appropriate pressure to the characteristic spray type irrigation system identified in Chapter 3 and ends when water is applied to the root of the olive trees. The production and maintenance the sprinkler irrigation system (capital infrastructure) is excluded. The output to technosphere (product) of this process is the application of 1 kg of water to the root of the olive trees.

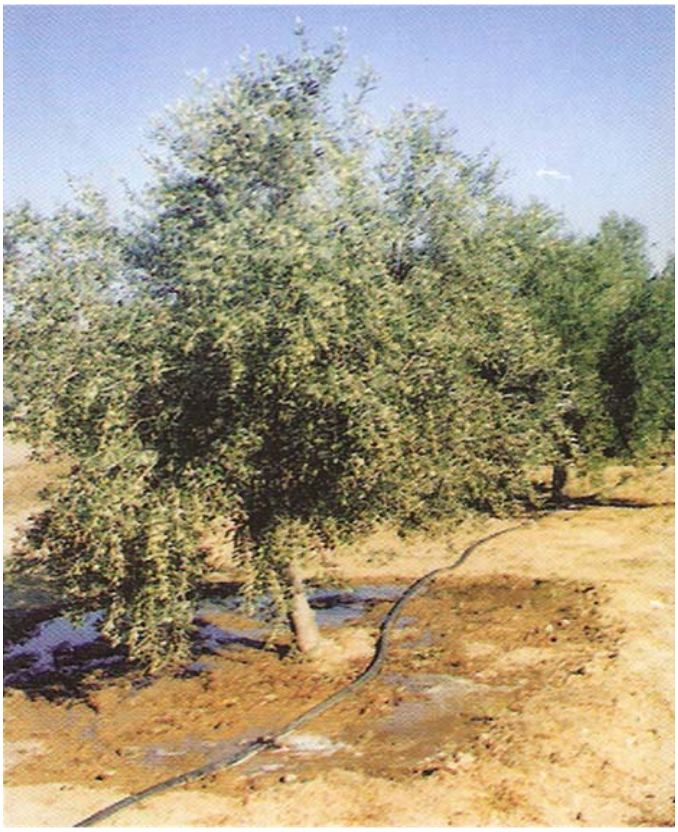

Figure 40 – Irrigation in Lythrodontas

The only input to technosphere in this process is water supplied for irrigation. Provided that water is supplied at the appropriate pressure for the sprinkler system to operate, as assumed in the inventory of irrigation water supplied, no other energy or material inputs are required for irrigation. However loss of water during its application needs to be accounted. Irrigation water losses include air losses, which for this particular system can be large, ground evaporation, runoff and deep percolation. Assuming ground evaporation, runoff and deep percolation are negligible, the efficiency of water application through a solid set sprinkler irrigation system, according to Rogers (1997) varies between 70% and 85%, i.e. an average of 77.5%. Therefore it is assumed that 1.29kg of supplied water (documented in section 5.5.1) is required from the technosphere in order to apply 1kg of water to the olive tree root.

The 0.29kg of water lost are accounted as emissions (vapour) to air. No other flows to and from the environment have been identified in this process.

The data quality index for this dataset, with reference to Table 2, is (3, 1, 1, 1, 1).

5.5.4 Soil management

The process of soil management includes all material and energy flows associated with soil ploughing operations carried out in Lythrodontas olive orchards, as identified in Chapter 3. The production and maintenance of tractors and ploughing implements (capital infrastructure) is excluded. The output to technosphere (product) of this process is 10000m^2 (1 hectare) of ploughed agricultural land. As identified in Chapter 3, according to the grower survey the prevailing ploughing technique is by means of a chisel plough attached to a 45-horsepower tractor.

Figure 41 – Chisel plough attached to a tractor in Lythrodontas

Data in regards to emissions from the operation of tractor during soil management was obtained from the Ecoinvent database, version 1.2. The name of the process selected is “Tillage, ploughing/ CH” (process identifier EIN_UNIT06567700189) and is classified under the “processing/agricultural subcategory". The inventory takes into account the diesel fuel consumption and the amount of agricultural machinery and of the shed, which has to be attributed to the ploughing. Also taken into consideration is the amount of emissions to the air from combustion and the emission to the soil from tyre abrasion during the work process. The following activities where considered part of the work process: preliminary work at the farm, like attaching the adequate machine to the tractor; transfer to field (with an assumed distance of 1 km); field work (for a parcel of land of 1 ha surface); transfer to farm and concluding work, like uncoupling the machine. Not included are dust other than from combustion and noise. The inventories are based on measurements made by the FAT, in Switzerland (Nemecek, 2004). Emissions and fuel consumption are those of the newest models of tractors set into operation during the period from 1999 to 2001 and measurements were made in the period 1999-2001.

However two adjustments were made to this dataset prior to its use in the system. Firstly, the production of capital infrastructure included in the process above (tractor, agricultural machinery and shed) was excluded from the process by analysis the unit process without the capital infrastructure and saving it as a system process.

Secondarily, the consumption of diesel was substituted with technology specific data. According to Nalewaja (2001) based on Nebraska and North Dakota on-farm fuel-use surveys, sited by Garcia-Torres *et al.* (2002), 8.89 litres of diesel are required on average to plough one hectare of land (10000m^2), as shown in Table 4. Thus about 7.5 kg of diesel, the production of which is documented in section 5.1.1, is consumed per 10000m^2 of land ploughed through the particular method and this is included as an input from technosphere to the process.

Table 4 - Average energy consumption of some tillage operations: reproduced from (Nalewaja, 2001)

Operations	Diesel consumption (litres/hectare)	Energy consumption (kcal/ha)
Mouldboard plough	16.81	256,669
Cultivator	5.61	52,285
Disk harrow	6.55	61,046
"Chisel" plough	8.89	82,855
Harrow	3.37	30,476
Pass with no tillage	0.94	8,761

No other flows to and from the environment have been identified in this process. The data quality index for this dataset, with reference to Table 2, is (3, 1, 1, 3, 1).

5.5.5 Pruning

The process of olive tree pruning includes the material and energy flows required in order to undertake regular pruning in Lythrodontas. The production and maintenance of the petrol chainsaw (capital good) is excluded. The output to technosphere (product) of this process is the pruning of one olive tree.

As identified in Chapter 3, the characteristic pruning equipment in Lythrodontas is the petrol chainsaw. Giametta *et al.* (1997) report that pruning duration ranges from 2.4 minutes per tree for pruning with specialised machines to 76.8 minutes per tree for pruning with traditional saws. The interviews of olive growers in Lythrodontas have shown that typically a 45cc chainsaw would be used for 12 minutes in order to prune a tree of average age and size. Therefore the use of the chainsaw for 12 minutes, i.e. 0.2 hours is an input from technosphere to the process of pruning.

The exchanges associated with the actual use of the chainsaw include the consumption of fuel and lubricants and the emissions from combustion. These data were obtained from IDEMAT 2001 database. The name of the process selected is “industrial chain saw” (process identifier IDEMAT0106626600501) and is classified under the “processing/wood subcategory”. The process is a second order process i.e. it includes material and energy flows including operations but excludes the production and maintenance of capital infrastructure, in line with our system boundaries. The source of data is the statistical yearbook (1993) of the Delft University of Technology. The inventory includes the input of petrol and oil (the production of which is documented in sections 5.1.2 and 5.1.3 respectively) and the emission of carbon dioxide, carbon monoxide, sulphur dioxide, nitrogen oxides, hydrocarbons and soot to air. No emissions to soil which may occur from potential oil leakage are accounted. The data represents average technology; however its geographic origin is mixed.

Figure 42 – Pruned trees in Lythrodontas

The process of pruning also results to a significant waste flow, the pruning residue. The quantity of pruning residue for an average tree was calculated from the formulas provided by Civantos and Olid (1985), based on the annual average olive yield per tree, i.e. PR=PB+SB=(0.88Y+4.76)+(0.74Y-6.48), where PR is the quantity of pruning residue per tree in kilograms, PB is the mass of primary branch per tree, SB the mass of secondary branch per tree and Y is the annual average yield per tree. Based on the annual average yield figure obtained from field surveys in Lythrodontas (15.96kg/tree), the mass of pruning residue per tree is calculated as 24.1 kg, which consists of 18.8 kg of primary branch and 5.3 kg of secondary branch. Niaounakis *et al.* (2004) suggests that pruning residue is estimated as 25kg per tree annually, a good correlation with the value calculated from Civantos and Olid (1985). However, since these amounts refer to annual produced residue and since pruning is Lythrodontas is not carried out every year but approximately 3 times in every four years (average pruning frequency from survey was 0.74 times per year), the pruning residue quantity is reduced to 0.74*24.1kg, i.e. 17.8kg per pruned tree. This figure is slightly higher but in a good confidence level from the 15kg, which was roughly estimated by the Lythrodontas growers in the telephone interviews as the mass of branches pruned per tree after every pruning session.

As identified in Chapter 3, pruning residue is subsequently burned. Thus 17.8kg of "burning of pruning residue" was included in the pruning process inventory as "waste to treatment".

The data quality index for this dataset, with reference to Table 2, is (3, 1, 1, 3, 1).

5.5.6 Burning of pruning residues and disposal of ash

The process of pruning residue burning in open fires starts when pruned primary and secondary branches are collected and ends when the leftover ash is sprayed to the agricultural land. The production and maintenance of any capital infrastructure, is excluded. The process is a waste treatment process, thus no outputs to technosphere (products of value) are produced.

The inventory of this unit process is based on the assumption that no significant transportation takes place, since the olive growers' survey indicated that incineration takes place very near to the orchards and also no fuel is used for initial ignition of the residue.

The typical composition of wood is 50.5% carbon, 6% hydrogen, 42.4% oxygen, 0.2% nitrogen, 0.05% sulphur and 1% other non-combustibles (Cheremisinoff, 1992). The emissions to the environment due to its incineration comprise of the emissions to air due to combustion, i.e. smoke and the emissions to soil due to the subsequent spreading of the ash at the land.

Smoke is composed primarily of carbon dioxide, water vapour, carbon monoxide, particulate matter, hydrocarbons and other organic chemicals, nitrogen oxides, trace minerals and several thousand other compounds. The actual composition of smoke depends on the fuel type, the temperature of the fire, and the wind conditions. Different types of wood and vegetation are composed of varying amounts of cellulose, lignin, tannins and other polyphenolics, oils, fats, resins, waxes and starches (Shafizadeh, 1981), which produce different compounds when burned. The inventory of this process included a typical chemical composition of wood smoke, obtained from EPA (1993), as shown in Table 5. It is highlighted that average values were used in the inventory when ranges were given whereas some species, which are not considered by standard environmental impact assessment methods were excluded.

Table 5 – Chemical composition of wood smoke

Substance/ parameter	Probable range (g/kg wood) [1]	Inventory value (g/kg wood)	Substance/ parameter	Probable range (g/kg wood) [1]	Inventory value (g/kg wood)
Water vapour	70	70	Benzofluoranthenes	$6x10^{-4}$-$5x10^{-3}$	2.8x10-3
Carbon dioxide	120	120	Benzo(a)pyrene	$3x10^{-4}$-$5x10^{-3}$	2.65x10-3
Carbon monoxide	80-370	225	Benz(ghi)perylene	$3x10^{-5}$-$1.1x10^{-2}$	5.52x10-3
Methane	14-25	19.5	Dibenzo(a,h) pyrene	$3x10^{-4}$-$1x10^{-3}$	6.5x10-4
VOCs (C_2-C_7)	7-27	17	Dibenz(a,h)anthracene	$2x10^{-5}$-$2x10^{-3}$	1.01x10-3
Aldehydes	0.6-5.4	3	Sodium	$3x10^{-3}$-$1.8x10^{-2}$	0.01
Substituted furans	0.15-1.7	0.93	Magnesium	$2x10^{-4}$-$3x10^{-3}$	1.6x10-3
Benzene	0.6-4.0	2.3	Aluminium	$1x10^{-4}$-$2.4x10^{-2}$	0.01
Toluene	0.15-1.0	0.58	Silicon	$3x10^{-4}$-$3.1x10^{-2}$	0.02
Acetic acid	1.8-2.4	2.1	Chlorine	$7x10^{-4}$-$2.1x10^{-1}$	0.11
Formic acid	0.06-0.08	0.07	Potassium	$3x10^{-3}$-$8.6x10^{-2}$	0.04
Nitrogen oxides	0.2-0.9	0.55	Calcium	$9x10^{-4}$-$1.8x10^{-2}$	$9.45x10^{-3}$
Sulphur dioxide	0.16-0.24	0.2	Titanium	$4x10^{-5}$-$3x10^{-3}$	$1.52x10^{-3}$
Napthalene	0.24-1.6	0.92	Vanadium	$2x10^{-5}$-$4x10^{-3}$	$2.01x10^{-3}$
Phenol (and derivatives)	0.2-0.8	0.5	Chromium	$2x10^{-5}$-$3x10^{-3}$	$1.51x10^{-3}$
Catechol (and derivatives)	0.2-0.8	0.5	Manganese	$7x10^{-5}$-$4x10^{-3}$	$2.04x10^{-3}$
Fluorene	$4x10^{-5}$-$1.7x10^{-2}$	$8.5x10^{-3}$	Iron	$3x10^{-4}$-$5x10^{-3}$	$2.65x10^{-3}$
Phenanthrene	$2x10^{-5}$-$3.4x10^{-2}$	0.02	Nickel	$1x10^{-6}$-$1x10^{-3}$	$5x10^{-4}$
Anthracene	$5x10^{-5}$-$2.1x10^{-2}$	0.01	Copper	$2x10^{-4}$-$8x10^{-3}$	$4.1x10^{-3}$

Fluoranthene	$7x10^{-4}$-$4.2x10^{-2}$	0.02	Zinc	$7x10^{-4}$-$8x10^{-3}$	$4.35x10^{-3}$
Pyrene	$8x10^{-4}$-$3.1x10^{-2}$	0.02	Bromine	$7x10^{-5}$-$9x10^{-4}$	$4.85x10^{-4}$
Benzo(a)anthr acene	$4x10^{-4}$-$2x10^{-3}$	1.2x10-3	Lead	$1x10^{-4}$-$3x10^{-3}$	$1.55x10^{-3}$
Chrysene	$5x10^{-4}$-$1x10^{-2}$	5.25x10-3			

[1] EPA (1993)

Spreading of the residual ash in the land results to emissions of several metals to soil. Data for these emissions was obtained from the Ecoinvent database, version 1.2. The name of the process selected is "Disposal, wood ash mixture, pure, 0% water, to landfarming, CH" (process identifier EIN_UNIT06567701917) and is classified under the "waste treatment/landfarming" subcategory. Since the ash in Lythrodontas, as identified in section 3.1.6, is sprayed by manual methods, the "slurry spreading, by vacuum tanker" process was excluded as an input from the technosphere to the disposal process. Thus, the modified Ecoinvent process includes direct emissions from landfarming applications (100% to agricultural soil) but excludes the burden from the spreading process. The process is modelled as an output to technosphere (waste and emissions to treatment) to the "incineration of pruning residues" process. The mass of the leftover ash is assumed to be 0.45% of the mass of the wood (Shafizadeh, 1981 and Misra, 1993), thus for every 1kg of pruning residue burned 4.5g of ash is disposed to land.

The data quality index for the whole "burning of pruning residues and disposal of ash" dataset, with reference to Table 2, is (3, 3, 4, 4, 3).

5.5.7 Fertiliser application

The process of fertiliser application includes all materials and energy flows associated with the hand application of the 20-10-10 NPK characteristic fertiliser in the Lythrodontas orchards. The treatment of fertiliser packaging is excluded from the process inventory. The output to technosphere (product) of this process is the application of 5.63 kg of the 20-10-10 NPK fertiliser to the Lythrodontas olive orchards. This quantity refers to the average calculated quantity of fertiliser applied per olive tree in Lythrodontas.

The main inputs from technosphere for this process are the production and transportation of 5.63kg of the characteristic fertiliser as previously documented, assuming no material losses during production and transportation.

As reported in Chapter 3, no mechanical equipment is used in Lythrodontas and the fertiliser is simply left to the root of the trees by hand. Therefore neither fuel consumption nor emissions from the operation of mechanical equipment are included in the inventory. The only additional material flow within the process of fertiliser application is the quantity of water used immediately after the fertiliser is left to the root. The quantity used was estimated by the olive tree growers as 35 litres per tree. Thus 35 litres of water (documented in section 5.5.1) is included to the process as input from technosphere.

Furthermore, the inventory for this process covers the emissions to air, water and soil directly attributed to the application of the characteristic fertiliser in Lythrodontas orchards. Since actual measurements of emissions are neither practical nor appropriate for LCA purposes, estimates of emission factors and estimation techniques from literature were obtained. However, it must be highlighted that emissions are strongly influenced by soil type and climatic conditions (Brentrup and Kusters, 2000) and although every effort was taken in order to use emission rates and techniques developed under similar to Lythrodontas conditions, the emissions included in the inventory contain a significant degree of uncertainty.

According to the definition of the system boundary, "fertilizers, pesticides, herbicides and possibly other chemical inputs on agricultural soils should not be counted as emissions into nature as a whole, but only those substances and quantities that leach into deeper soil and water or evaporate in the atmosphere" (Avraamides *et al.*, 2005). Thus the main emission flows covered by the inventory of this process are: ammonia volatisation (air), emissions of dinitrogen monoxide (air), emissions of nitrogen oxides (air), nitrate leaching (groundwater) and emissions of phosphorus (groundwater), identified by several authors (Brentrup and Kusters, 2000, Webb *et al.*, 2000, Canals, 2003, Nemecek *et al.*, 2004). Another potential environmental emission of this process are heavy metals entering the soil, which are only partly taken up by the trees, and thus become part of the technosphere (Canals, 2003). Audsley *et al.* (1997) suggest that the entire fraction not leaving the system with the crop may be considered as an emission to soil. However, in line with the definition of the system boundary in this study and in the absence of evidence that heavy metals enter deeper strata of soil or surface and ground waters, they are not included in the process inventory.

Emission of ammonia to the atmosphere, apart from the application of N fertilisers, can also be generated from the growing crops themselves, especially during senescence (Webb *et al.*, 2000). In practice it is difficult to distinguish between these two sources, if measured in field experiments. Furthermore, emissions of ammonia, are highly dependent on the site of application (Canals, 2003), especially the soil pH (Webb *et al.*, 2000) and the weather conditions (Brentrup and Kusters, 2000). Asman (1992) suggests an emission factor of 4% of N content for NPK multinutrient fertilisers for NH_3-N emissions. Therefore for 5.63kg of NPK fertiliser input, of which N content is, according to its specification, 20%, i.e. 1.13kg, emissions of NH_3-N amount to 0.045kg, i.e. 0.055kg of ammonia. However, the factors suggested by Asman (1992) do not take into account the site of application. ECETOC (1994) proposed an estimation method to evaluate these emissions taking into account the different soil properties throughout Europe. Based on this method, assuming that Cyprus belongs to country group I, where calcareous soil is common and the soil pH is mostly greater than 7, ammonia emissions were calculated as shown in Table 6, as 0.084kg per 5.63kg of the characteristic fertiliser being applied in Lythrodontas.

Table 6 – Estimation of ammonia emissions

Fertiliser type	Mass contained in 5.63kg of 20-10-10 NPK fertiliser [1]	N content	Emission factor [2]	NH_3-N emission	Ammonia emission
Ammonium nitrate	2.03kg	0.62kg	3%	0.0186kg	0.023kg
Ammonium phosphate	1.13kg	0.17kg	5%	8.5×10^{-3}kg	0.010kg
Ammonium suplhate	1.41kg	0.28kg	15%	0.042kg	0.051kg
			Total	0.0691kg	0.084kg

[1] Based on calculated composition of Table 3

[2] Based on ECOTOC, 1994 method

Emissions of dinitrogen monoxide (N_2O), which is one of the greenhouse gases, are the result of mainly two microbial processes, denitrification and nitrification and are influenced by many complex interactions between soil and climate factors (Brentrup and Kusters, 2000). Although the complexity of the interactions between the various parameters is up to now not well enough understood (Enquete-Kommission "Schutz der Erdatmosphare", 1994), Bouwan (1995), based on field experiments, proposed an emission factor for N_2O-N emissions from mineral and organic fertilisers equal to 0.0125 of the N input, corrected for ammonia emissions, as these predominantly occur earlier than N_2O emissions (Kroeze, 1994). Based on this factor the N_2O emissions from the application of 5.63kg of the characteristic fertiliser in Lythrodontas amount to 0.02kg, as shown in Table 7.

Table 7 – Estimation of nitrous oxide emissions

N application per 5.63kg of 20-10-10 NPK fertiliser	N application corrected for NH_3-N emissions [1]	N_2O-N emission [2]	N_2O emission
1.10kg	1.03kg	0.0129kg	0.020kg

[1] Based on Kroeze (1994)

[2] Based on Bouwman (1995)

During denitrification processes in soils, NO_x may also be produced. Grub (1996) cited in Nemecek (2004) suggests that these emissions can be estimated as 21% of the emissions of N_2O. Since this process is not a conversion from N_2O to NO_x but a parallel process, no correction of N_2O emissions is required. The estimated NO_x emissions using the Grub (1996) factor are $4.2x10^{-3}$kg. NOx are usually measures as NO_2. For the same emissions, Audsley *et al.* (1997) proposes a factor of 10% of N_2O-N emissions for NO_x-N emissions. Based on this approach the estimated NO_x-N emissions are $1.29x10^{-3}$kg, thus NO_x emissions, measured as NO_2 are approximately $4.24x10^{-3}$ kg. Therefore, based on the Grub (1996) estimate, validated by Audsley *et al.*, NO_x emissions expressed as NO_2 attributed to the application of 5.63kg of the compound characteristic fertiliser in Lythrodontas are estimated to $4.2x10^{-3}$kg .

Nitrates' leaching to groundwater is a direct result of the imbalance between net nitrogen-uptake by the trees (Canals, 2003), nitrogen produced by microorganisms in the soil via mineralization of organic matter and the total nitrogen that is returned to it in the form of fertilisers. As nitrate is easily dissolved in the water, in periods of heavy rainfall, when precipitation exceeds soil evaporation and transpiration of the plants and following initial saturation of soil with water, nitrates percolate to the groundwater (Nemecek *et al.*, 2004). This balance is affected by the facts that: precipitation and subsequently nitrate leaching is highest in autumn and winter, and also, in late summer, nitrogen-uptake by the trees is low (Stauffer *et al.*, 2001). Therefore, the most important parameters determining the nitrate leaching are: soil related (field capacity of the effective root zone), climate related (drainage water rate) and agriculture related (nitrogen balance) (Brentrup and Kusters, 2000)

Nitrates' leaching to groundwater was calculated using the method suggested by (Brentrup and Kusters, 2000). The field capacity in the effective root zone FC_{RZe} was calculated by multiplying the available field capacity FCa by the effective root zone RZe. Both of these parameters depend on the soil texture. Based on the fact that upper strata in Lythrodontas orchards mainly consist of loamy silt, the average field capacity is $24mm*dm^{-1}$ and the effective rooting zone is 10dm (DBG, 1992), thus the field capacity in the effective root zone FC_{RZe} is 240mm.

The rate of drainage water (W_{drain}) is the difference of the precipitation rate (W_{precip}) and the evapotranspiration rate (W_{et}). Thus, based on the average precipitation rate, which in Lythrodontas is 441.4mm/year (Cyprus Meteorological Service, 2006) and on an average evapotranspiration rate of 86% of rainfall (WDD, 2006), i.e. 379.6mm/year, the rate of drainage water W_{drain} is equal to 61.8mm/year.

A measure for the quantity of water that percolates through the soil profile into the groundwater is the exchange frequency of the drainage water, which can be calculated from the ratio of W_{drain} to FC_{RZe} and is equal to 0.26/year.

As a measure for the amount of nitrate in the soil after the vegetation period a nitrogen balance can be used, as shown in Table 8.

Table 8 – Calculation of the nitrogen balance for an average olive tree in Lythrodontas

N input /year (kg N)		N output /year (kg N)	
From fertiliser	1.10	Removal with harvested crops	0.366 [(1)]
		NH_3 –N emissions	0.0691 [(2)]
		N_2O -N emissions	0.0129 [(3)]
		NO_x –N emissions	$1.29x10^{-3}$ [(4)]
Total input	1.10	Total output	0.45
N-balance /year		0.65kg	

[1] Lasram and Tnani, 2006 (average removal per tree per year)

[2] Previously calculated (Table 6)

[3] Previously calculated (Table 7)

[4] Previously calculated (p.71)

[5] N_2 emissions are not considered as no method to estimate the emissions is available

Therefore, based on the calculated nitrogen balance (available for leaching) and the calculated exchange frequency, the nitrate emission into groundwater via leaching attributed to the application of 5.63kg of the characteristic fertiliser in Lythrodontas is 0.17kg NO_3- N (0.65kg *year*0.26/year), i.e. 0.748kg NO_3.

In regards to phosphorus, Nemecek *et al.* (2004) distinguish three different kinds of phosphorus emissions to water: [1] leaching of soluble phosphate to ground water, [2] run-off of soluble phosphate to surface water and [3] erosion of soil particles containing phosphorus, by surface water. Since there are no significant surface waters around the Lythrodontas orchards (no olive cultivations are adjacent to the two small dams in the region and the Koutsos water stream) only the first mechanism is considered.

The quantity of phosphate leaching to groundwater was calculated based on a factor of 0.06 of the P input applied, suggested by Nemecek *et al.* (2004). Thus for 5.63kg of the 20-10-10 NPK fertiliser applied in Lythrodontas, of which P input is 0.56kg, the quantity of P leaching into groundwater is 0.034kg. It is highlighted that no correction factor is applied since no fertilisation by slurry takes place.

The data quality index for the inventory of this process, with reference to Table 2, is (2, 2, 3, 3, 2).

5.5.8 Pesticide application

The process of pesticide application includes all material and energy flows associated with the spraying of the characteristic pesticide used in the region (40% dimethoate) through compressed air hand-held sprayers connected to agricultural tractors. The production and maintenance of capital infrastructure, such as the tractor and the sprayer is excluded. The treatment of pesticide packaging is also excluded from the process inventory. The output to technosphere (product) of this process is the application of 1kg of the characteristic pesticide product to the Lythrodontas olive orchards.

The main inputs from technosphere for this process are the production and transportation of 1kg of the characteristic pesticide as documented in sections 5.3.2 and 5.4.5 respectively, assuming no material losses during production and transportation.

In regards to material and energy flows occurring from the operation of the tractor for spraying the pesticides, data were obtained from the Ecoinvent database, version 1.2. The name of the process selected is "Application of plant protection products, by field sprayer/CH" (process identifier EIN_UNIT06567700156) and is classified under the "processing/agricultural" subcategory. The production of capital infrastructure included in the process above (tractor, agricultural machinery and shed) were excluded from the process, in line with the requirements of our system and the process was saved as a system process. The inventory takes into account the diesel fuel consumption, which is attributed to the application of the pesticide. Also taken into consideration is the amount of emissions to the air from combustion and the emission to the soil from tyre abrasion during the work process. The emissions and fuel consumption refer to the newest models of tractors set into operation during the period from 1999 to 2001. Since the inputs and outputs in the database process are recorded per m^2 of application area and not per kg of pesticide, based on the survey analysis on land use (see analysis in appendix B) the 1kg is converted to $1232.3m^2$ of the Ecoinvent process and was included in the "pesticide application" process as input from technosphere.

In regards to the emissions to environment from the actual application of the pesticide, Audsley *et al.* (1997) suggests a simplified distribution of the pesticide applied. This distribution is based mainly on Swiss and Dutch conditions, and only uses chemical-dependent parameters for the calculation of pesticide leaching from soil to ground and surface water. The final compartments considered for the pesticide fractions are air (assuming that 2% of the pesticide applied will remain in air after 10 minutes); soil (most of the pesticide); water (1.6% as average Dutch conditions, plus fraction of pesticide coming from soil); and in-food residues (8% as an average). However, Audsley *et al.* (1997) does not account for pesticide volatisation. Furthermore, Canals (2003), argues that the approach suggested by Audsley *et al.* (1997) barely allows for any site-dependency, or even chemical dependency. Besides, no distinction between different practices (e.g.: spraying pesticides at different concentrations, or using different substances) can be done.

Hauschild (2000) suggests that the total quantity applied is initially divided into fractions that deposit on the crop plants, on the soil, or drift off the field as particles or vapour to reach the surrounding environment. Depending primarily on the properties of the pesticide ingredients, a fraction of what reaches the plants or the soil of the field may volatise, whereas from the part that deposits on the soil surface, a fraction may reach surrounding surface waters through surface run-off. Another fraction may leach the groundwater or surface waters via drain pipes if the soil is drained.

In our LCA model, in line with the definition of the system boundary (Avraamides *et al.*, 2005), since the agricultural system is considered as part of the technosphere and not as part of the ecosphere, emissions mainly comprise of emissions to air and water and those emissions to soil which fall outside the system boundaries when pesticide application is undertaken very near the border of the olive orchard. An illustration of the pesticide dispersion routes is shown in Figure 43 (Canals, 2003).

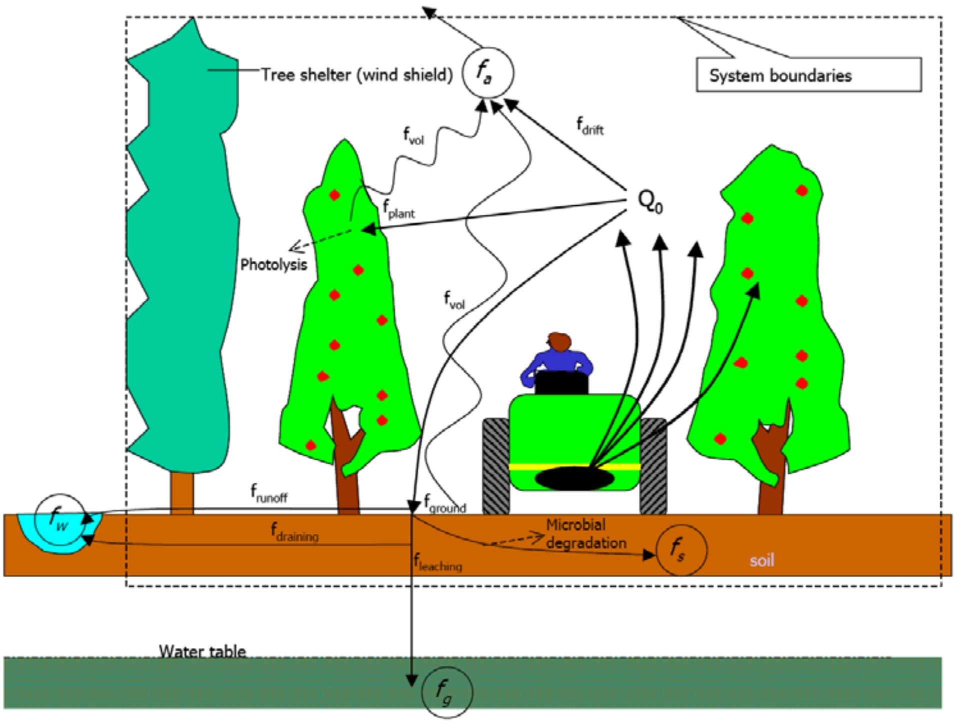

Figure 43 – Dispersion routes following pesticide application (Canals, 2003)

Hauschild (2000) explains that the dispersion of the pesticide through the different routes depends on the application technique, the characteristics of the field-crop system and meteorological conditions. Both Hauschild (2000) and Canals (2003) demonstrate comprehensive models for the estimation of pesticide emissions to each environmental compartment. Although, both models take into account all those factors, which affect the dispersion of the pesticide in the various environmental compartments, their application requires specific data which are not available for the active ingredient dimethoate and the Lythrodontas site characteristics. Nevertheless, since the goal of this LCA study is to identify "hot spots" of the olive oil production, a simpler estimation is acceptable. Thus, an estimate of the fractions of the pesticide which reach each environmental compartment was based on the average fractions calculated by Hauschild (2000) for pesticides of the same chemical group (organo-phosphate) at dilutes of the same order of concentration, applied by the same application technique, as shown in Table 9.

Table 9 – Estimate of fractions of sprayed pesticides in each environment compartment

Active ingredient	Fraction reaching air	Fraction reaching groundwater	Fraction reaching soil outside the system boundary
Azinphosmethyl	65.6%	0.0%	0.5%
Chlorpyrifos[1]	57.0%	0.01%	0.0%
Diazinon[2]	92.7%	0.0%	0.0%
Dimethoate[3]	71.8%	0.0%	0.2%

[1] Average from 7 sites

[2] Average from 4 sites

[3] Calculated values from average fractions of similar pesticides

Thus, the emissions from the application of 1kg of dimethoate to Lythrodontas orchards are: 718g to air (predominant route through volatisation) and 2g to soil outside the system boundary. The remaining 280g of dimethoate either are degraded (by soil micoorganisms or by sunlight) or remains on the olive trees, which are part of the technosphere.

The data quality index for the inventory of this process, with reference to Table 2, is (2, 2, 3, 3, 2).

5.5.9 Collection of olives

The process of olive collection includes all material and energy flows associated with the collection of olives and their temporary storing into plastic boxes or reusable mesh bags, as shown in Figure 44, in the Lythrodontas olive orchards. As identified in Chapter 3, according to the olive agriculture survey, the prevailing collection technique is through the use of hand-held pneumatic combs connected to a motorised air compressor and reusable underlying nets. The production and maintenance of capital infrastructure, such as the air compressor and the combs is excluded. The production of the reusable nets and plastic storage boxes or mesh bags is also excluded. The output to technosphere (product) of this process is the collection of 1kg of olives. It is highlighted that the 1 kilogram of olives is as measured in the orchards and includes a small mass percentage of leaves, dust and other foreign matter, which will be accounted in the inventory of the olive purification process later in this report.

Figure 44 - Temporary storage of olives after collection

This type of combs, typically requires a working air pressure of 6 to 8 bar (84 to 112 psi) and an air capacity of 200 litres per minute (Olives Australia, 2006). For this reason, the typical air compressor required in Lythrodontas would be a 3hp (2.2kW) belt driven electric compressor (max. pressure 145psi).

The average productivity of a hand-held pneumatic comb is estimated around 35kg of olives collected per hour (Vossen, 2006, Tombesi *et al.*, 1996), however typically 4 such combs are connected to the compressor, therefore, based on this assumption, the collection of 1kg of olives corresponds to $7.14x10^{-3}$hours (25.7 seconds) of compressor operation. As a result, 0.016kWh of electricity generated in the field (documented in section 5.2.2) is consumed, thus included in the inventory as input from technosphere.

No other material or energy flows have been identified in this process. The data quality index for the inventory of this process, with reference to Table 2, is (3, 1, 1, 1, 1).

5.5.10 Olive agriculture

The envelope unit process of olive agriculture starts with the plantation of the trees and ends when olives in the Lythrodontas orchards are collected. The process includes all agricultural sub-processes as previously documented. The production and maintenance of capital infrastructure is excluded in line with the boundary definition (Avraamides *et al.*, 2005). The output to technosphere (product) of this process is 3.83kg of unprocessed collected olives of the Cyprus variety, which include some impurities such as leaves, dust etc. This quantity is based on the statistical analysis of the responses obtained from the questionnaire as well as on the measurements undertaken in the processing unit, and it is the average quantity of unprocessed Cyprus variety olives required to produce the system reference flow, i.e. one litre of extra virgin olive oil. Thus all inputs and outputs in the inventory of this process refer to the output quantity.

The first input from technosphere in this process is the planting of the olive trees (documented in section 5.5.2). Based on the statistical analysis of the results obtained from the survey (Appendix B) and based on the average yield production of olive trees during their life, the calculated input of tree planting was 0.0095 trees per 3.83kg of olives.

Another input from technosphere is olive tree irrigation (documented in section 5.5.3). Based on the analysis of the results obtained from the interviews, considering the average annual yield production of olive trees and the annual consumption of water for irrigation purposes through a sprinkler system, the calculated input quantity was 1404kg (or 1.404 cubic metres).

According to the analysis of the data collected, based on the area of the orchards, the ploughing frequency and the annual olive yield in Lythrodontas, an average of 96.376m^2 of agricultural land are ploughed for every 3.83kg of olives produced. Thus, 96.38m^2 of soil management (documented in section 5.5.4) are included as input from technosphere.

In regards to fertiliser application, the analysis has shown that the mean quantity of the 20-10-10 NPK fertiliser applied in Lythrodontas is 1.355kg per 3.83kg olives produced. This quantity is based on the frequency of application, the applied quantity and the annual yield production of the olive orchards in the region. Therefore 1.355kg of fertiliser application (documented in section 5.5.7) is another input from technosphere.

Similarly, for pesticides, the mean quantity of the 40% EC dimethoate pesticide product applied in Lythrodontas is 0.0369kg per 3.83kg olives (pesticide application documented in section 5.5.8).

Another input in the process, is tree pruning. Considering the pruning frequency and the average yield production of olive trees 0.350 trees are pruned for every 3.83kg of olives produced (olive tree pruning documented in section 5.5.5).

Finally, assuming no material losses during collection, 3.83kg of olive collection through the characteristic technique (documented in section 5.5.9) is another input from technosphere to the process.

For methodological purposes, almost all inputs from the environment, as well as the emissions to the environment for the olive agriculture stage have been included in the appropriate sub-processes for ease of interpretation of the results. However, two inputs from the environment apply, which apply agricultural stage as a whole, are inventoried in this process. These are the land occupation and the absorption of carbon dioxide from the trees. It is highlighted that, since according to the definition of the system boundary the agricultural system is considered as part of the production system (technosphere) (Avraamides *et al.*, 2005), both the occupation of the land and the absorption of carbon dioxide are environmental inputs to the system and must be accounted.

In regards to land occupation, based on the survey analysis of Appendix B, for every 3.83kg of olives of the Cyprus variety produced in the region, a mean area of 49.26m^2 of land is being occupied for one year. This resource was categorised as "Occupation, permanent crop, fruit", and will be taken into account later in the impact assessment stage in the Eco-indicator 99 method (Goedkoop and Spriensma, 2000).

Carbon dioxide absorption of olive trees has been studied by Sofo *et al.* (2005). The orchard studied, fixed around 39 tonnes per hectare over the period of 5 years. Considering the tree density in the Lythrodontas orchards under study, CO_2 fixation amounts to 14kg per tree per year. Based on the calculated average yield of 15.96kg olives/tree*year in the region, the calculated carbon dioxide sequestration is 3.36kg per 3.83kg olives.

No other material or energy flows have been identified in this process. The data quality index for the inventory of this process, with reference to Table 2, is (1, 1, 1, 1, 1). It is noted that the index refers to the flows recorded under this inventory and not to the whole inventory of the agricultural system.

5.6 Municipal water treatment and supply

Although water is a renewable resource its treatment and supply are processes entailing environmental exchanges (consumption of resources and energy and emissions) which must be accounted in an LCA study. This requirement for a deeper insight is more important when stages of the product system under study, are theoretically considered as significant consumers of potable water. The three phase centrifuge technology applied in Lythrodontas olive oil processing, is a very good example of this necessity as it is considered a relatively important water consuming activity.

5.6.1 Water treatment

The process of water treatment starts when 1kg of raw water is supplied at the water treatment plant in Kornos and ends when treated potable water exits the treatment works. In this unit process, a combination of physical, chemical and biological transformations take place. The production and maintenance of capital infrastructure, e.g. the civil works and electromechanical installations have been excluded in line with the boundary definition. The output to technosphere (product) of this process is 1kg of treated water at the Kornos water works.

Data on material and energy flows for this process was collected by personal and telephone interviews of officials from the Water Development Department and employees of the Kornos Water Treatment Plant.

The input from nature is 1.01 kg of water from lake (raw water from Kornos dam), assuming 1% loss in the treatment process. As discussed earlier, for easier interpretation in the water consumption pattern within the system, water resource from lakes (as in this case), from rivers (as used for the production of pesticides and fertilisers) and from wells (e.g. in the field water supply) are all recorded as water from unspecified natural origin.

As identified in Chapter 3, for the treatment of water, chlorine (during pre and post-chorination), lime, aluminium sulphate and an anionic polyelectrolyte are used. These are therefore included in the unit process inventory as inputs from technosphere. It is highlighted that the production and disposal of packaging for these material inputs are not included due to their small quantities in relation to the reference flow of the system, which are therefore not expected to contribute any significant environmental load.

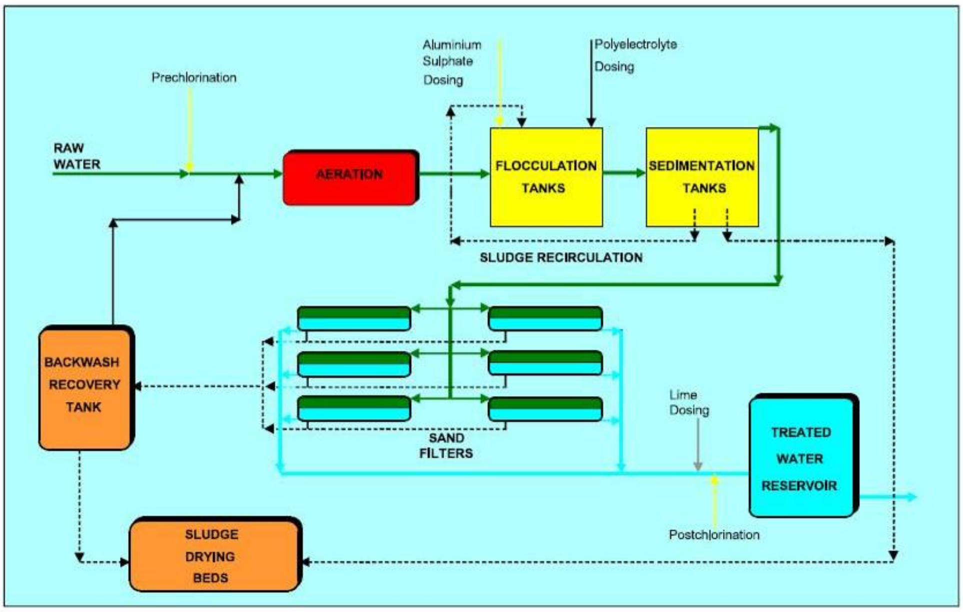

Figure 45 – Kornos Water Works flow diagram (WDD, 1999)

According to Pekris (2006), chlorine liquid is added at a dosage of 1.5-2.5 mg/l, therefore an average of $2x10^{-6}$kg of chlorine is used in the process per 1kg of treated water. Data for the process of chlorine production was obtained from Ecoinvent database, version 1.2. The name of the process selected is "Chlorine, liquid, production mix, at plant/RER" (process identifier EIN_UNIT06567700273) and is classified under the "material/chemicals/gases" subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and the inventory was saved as a new system process. The unit process establishes an average European chlorine production from the three different electrolysis cell technologies (mercury, diaphragm, membrane) and additionally includes the energy consumption for the liquefaction step from gaseous to liquid chlorine.

Aluminium sulphate is added at a 15-30mg/l dosage (Pekris, 2006, Siamarou, 2006), thus, an average of $2.3x10^{-5}$ kg of aluminium sulphate powder is used. Data for the process of aluminium suplahte production was obtained from Ecoinvent database, version 1.2. The name of the process selected is "Aluminium sulphate, powder, at plant/RER" (process identifier EIN_UNIT06567700249) and is classified under the "material/chemicals/inorganic" subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and the resulting inventory was saved as a new system process. The unit process includes raw materials and energy consumption for production, but no air and water emissions, besides waste heat. The source of the data is a single company in Europe in 1995; however, according to the dataset documentation, they are confirmed as still valuable.

Lime is added at a 4 mg/l dosage (Pekris, 2006), thus, 4×10^{-6} kg of hydrated lime is used for every kg of water treated. Data for the process of lime production was obtained from ETH-ESU database. The name of the process selected is "Lime (hydrated) ETH" (process identifier ETHSYSTM07848200189) and is classified under the "material/chemicals/inorganic" subcategory. The system process used is a second order process, i.e. it does not include any capital infrastructure, thus it is included in the system without further modification. Data have been collected in 1990-1994 in Europe and represent average technology. Data have been collected from production of hydrated lime from CaO based on stoichiometric calculations.

The anionic polyelectrolyte (acrylamide and acrylic acid) is added at a 0.05-0.1mg/l dosage (Pekris, 2006, Siamarou, 2006), thus 7.5×10^{-8}kg are used for every kg of water treated. Data for its production process was obtained from Ecoinvent database, version 1.2. The name of the process selected is "Acrylic acid, at plant/RER" (process identifier EIN_UNIT06567700369) and is classified under the "material/chemicals/acids (organic)" subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as a unit process by excluding capital goods and its inventory was saved as a new system process. The inventory includes raw materials and chemicals used for production, transport of materials to manufacturing plant, emissions to air and water from production and estimation of energy demand, whereas solid wastes have been omitted. It is highlighted that large uncertainty of the process data due to weak data on the production process and missing data on process emissions is recorded. In the geographic context, data used has no specific geographical origin and average European processes for raw materials, transport requirements and electricity mix has been used. The technology represented is the production of acrylic acid from propylene by two-step oxidation process with a process yield of 90%.

In regards to the transportation of the material inputs associated with the process, assuming that these are produced in the UK (which is a popular origin of many chemicals for the water industry in Cyprus) and imported to Cyprus, for every 1kg of material input produced, a 5842 km transportation (Liverpool – Limassol) by freight ship, i.e. 5.842 tonnes*km and 150 km transportation by 16-tonne lorry, i.e. 0.15 tonnes*km are considered. Transportation is added into the production process of each material described above as an input from technosphere.

In regards to electricity consumption, according to Stratis (2006), the average electric energy required for the operation of the treatment plant is 0.0721kWh/m^3. Thus 7.21×10^{-5}kWh of electric power is consumed in the plant for the treatment of every kg of water.

No other material or energy flows have been identified or included in this process. The data quality index for the inventory of this process, with reference to Table 2, is (3, 4, 2, 3, 5).

5.6.2 Water supply

The process of water supply starts when 1kg of raw water is extracted from Dipotamos dam and ends when 1kg of potable water is supplied to the olive oil processing unit in Lythrodontas. It includes all water transportation processes but excludes all water treatment processes which have been included in the "water treatment process". The production and maintenance of capital infrastructure, such as pipes, civil works and electromechanical installations of pump stations are excluded. The output to technosphere (product) of this process is 1kg of potable water supplied to the processing unit in Lythrodontas.

Information for this process was collected through personal interviews of Water Development Department officials and inventory data were calculated based on this information.

The main input from technosphere is the treated water (product of the water treatment process). For every 1kg of product 1kg of treated water is required, neglecting any leakages and accidental losses during supply.

As recorded during the identification of the characteristic cycle, water is supplied from Dipotamos dam to Lythrodontas through three pump stations: at the dam, at the Kornos water works and in Stravrovouni.

As discussed, the pump station at the dam consists of three 450kW and three 200kW electric pumps, of which two 450kW and one 200kW pumps are in operation simultaneously, supplying Kornos Water Treatment Plant with raw water. According to Manoli (2006) each 450kW pump operates at a maximum output of 600 tonnes per hour, and each 200kW pump with a maximum output of 250tph, thus, the three pumps which operate simultaneously have a total power of 1100kW and an output of approximately 1450 tonnes per hour. Therefore for 1kg of water the particular pump station requires 6.9×10^{-7} hours of operation thus consumes $1100*6.9 \times 10^{-7}$kWh, i.e. 7.59×10^{-4} kWh of electricity.

Similarly the pump station at the Kornos Water Works consists of four 187kW and two 107kW electric pumps, of which two 187kW and the two 107kW or three 187kW pumps are in simultaneous operation (Manoli, 2006), supplying the Stavrovouni reservoir with treated water. According to Manoli (2006) each 187kW pump operates at a maximum output of 600 tonnes per hour, and each 107kW pump with a maximum output of 250tph. Thus, taking into account both operational scenarios, the pumps which operate simultaneously have a total power of 588kW with an output of 1700 tonnes per hour (scenario 1) or a total power of 561kW and an output of 1800 tonnes per hour (scenario 2). Therefore, considering the least efficient scenario (scenario 1) for 1kg of water the particular pump station requires 5.9×10^{-7} hours of operation thus consumes $588*5.9 \times 10^{-7}$kWh, i.e. 3.45×10^{-4} kWh of electricity.

Figure 46 – Pump station at Kornos Water Works

Finally, the pump station at the Stavrovouni reservoir consists of two 40kW electric pumps, of which one is stand-by (Manoli, 2006), supplying Malia reservoir with potable water. According to Manoli (2006) the 40kW pump operates at a maximum output of 60 tonnes per hour. Therefore, for 1kg of water the particular pump station requires 1.7 $x10^{-5}$ hours of operation thus consumes 40*1.7 $x10^{-5}$kWh, i.e. $6.67x10^{-4}$ kWh of electricity. From Malia, water is supplied to the processing unit by gravity thus no energy is consumed.

Therefore, the total electricity consumed by the process of water supply is therefore $1.77x10^{-3}$kWh per 1kg of water supplied.

No other direct flows from and to technosphere or from and to the environment have been identified. The data quality index for the inventory of this process, with reference to Table 2, is (3, 1, 1, 1, 1).

5.7 Olive mill processes

During the development of the LCA methodology processing of olives to olive oil has been separated into three main process blocks: olive purification, olive grinding (including malaxing) and olive oil extraction. The various sub-processes and equipment involved in each of these process blocks have been described in Chapter 3. In order to collect data on flows to, from and through these processes, material and energy flow measurements and calculations were undertaken on site during regular operation of the plant in February 2006. These were validated through the application of mass and energy balances.

The quantity of unprocessed olives (of the characteristic variety) required to produce 0.92kg of olive oil, i.e. 1 litre (reference flow) was determined as 3.83 kg.

This quantity is used as the base for the determination of all mass and energy flows from, to and within the olive oil processing stage.

5.7.1 Olive purification

The process of olive purification starts when 3.83 kg of raw olives transported to the olive oil processing unit in Lythrodontas are placed in the input crate and ends when purified olives pass through electronic weighing system. The transformation that takes place in this process is of physical nature and involves the transfer of olives by conveyor belts, application of suction for removal of foreign materials, spraying with recycled water and electronic weighing. The production and maintenance of capital infrastructure, such as the electromechanical equipment and the building are excluded. The output to technosphere (product) of this process is 3.82kg of purified olives.

Approximately 3.83 litres of water are required to spray the 3.83kg of raw olives; however, as discussed in Chapter 3, since after sedimentation of solids and filtration the water is recycled within the purification machine, no input of water is included in the process.

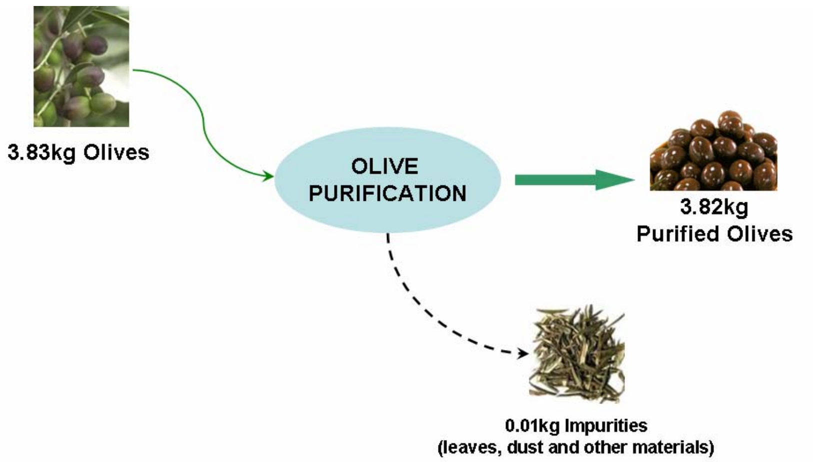

Figure 47 – Material flows during olive purification

To calculate the energy consumption in the process, the operation time of each piece of electrical equipment associated with the processing of 100kg olives input was recorded and this was multiplied with the equipment's power as specified in the manufacturer's brochures. The energy consumption calculation for each piece of electrical equipment in the plant was later validated by comparison with the total electricity consumption of the plant, as recorded by the electricity meter on-site, for the time required to process 100kg of olives (5.89kWh calculated compared to 6.1kWh recorded from meter which also accounts for electricity used for lighting and climate control of the building).

In regards to olive purification, electricity is consumed for the operation of the conveyor belt and of the purification machine. The normalised operational time, associated with the 3.83kg raw olive input was 2.3sec for the 1kW conveyor belt and 4.6sec for the 1.5kW purification machine. Thus a total of $2.56x10^{-3}$kWh of grid electricity is consumed (its production was reported in section 5.2.1) is included as an input from technosphere to the olive purification process.

Furthermore during the process, 0.01kg of impurities (mainly leaves, dust and other materials) are produced. These are stored on site and due to the small quantity involved their biodegradation and associated emissions are not considered, thus the flow is recorded as a final waste flow.

No other direct flows from and to technosphere or from and to the environment have been identified. The data quality index for the inventory of this process, with reference to Table 2, is (1, 2, 1, 1, 1).

5.7.2 Olive grinding

The process of olive grinding starts when the 3.82 kg of purified olives produced from the olive purification process (input from technosphere) enter the olive crusher and ends when olive paste leaves the mixing vat, as described in Chapter 3. The process block involves the transfer of purified olives by conveyor belts and the operation of the olive crusher and the mixing vat. The production and maintenance of capital infrastructure (electromechanical equipment and the building) are excluded. The output to technosphere (product) of this process is 4.91kg of olive paste.

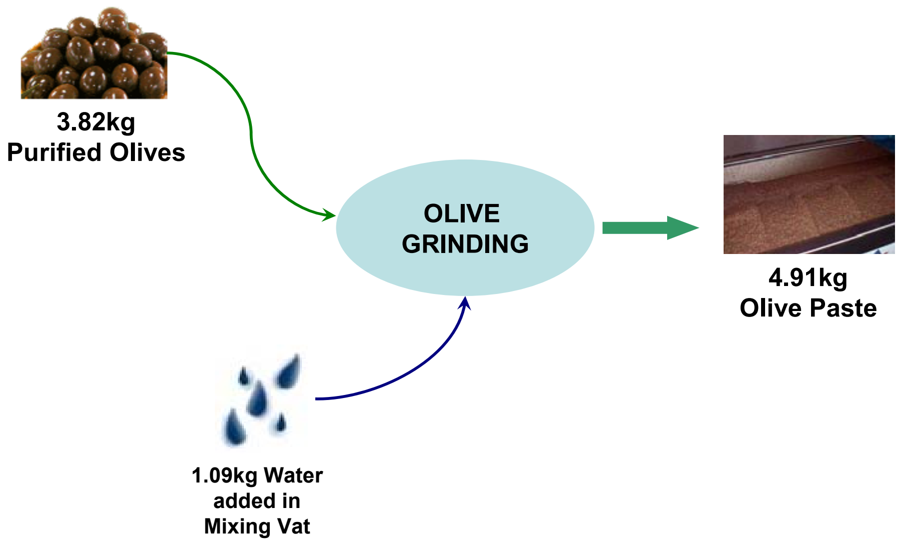

Figure 48 – Material flows during olive grinding

Within the mixing vat outer chamber 0.59kg of water (per 4.91kg of olive paste) heated at about 38ºC circulates, however as this reusable it is not included as input to the process. However additional water at 38ºC is also added to the paste within the mixing vat. Based on the data provided by Mouzouris (2006), the quantity of warm water added is 1.09kg per 4.91kg of olive paste. This is included in the inventory as an input from the technosphere (water supplied, documented in section 5.6.2).

In regards to energy consumption during olive grinding, the consumption of electricity is associated with the operation of the conveyor belt, the crusher and the mixing vat. The normalised operational time, associated with the 3.82kg purified olive input was recorded as approximately 2.3sec for the 1kW conveyor belt, 6.9sec for the 2kW olive crusher and 103.4sec for the 3.5kW mixing vat (45 minutes of mixing for full capacity vat). Thus a total of 0.11kWh of electric energy produced is included as an input from technosphere in the olive grinding process.

The energy consumed for heating the water, as identified in Chapter 3, is produced from the combustion of solid waste (pomace) produced during the olive oil extraction process, thus a closed loop recycling of energy occurs within the system boundary. The energy consumed, considering a rise in the temperature of the 1.68kg of water (0.59kg in the outer chamber and 1.09kg in the paste) from 15°C to 38°C ($Q=m*c*\Delta\theta$), is calculated as 162.2kJ and included as input from technosphere (heat produced from pomace combustion, documented in section 5.7.4).

No other direct flows from and to technosphere or from and to the environment have been identified. The data quality index for the inventory of this process, with reference to Table 2, is (1, 2, 1, 1, 1).

5.7.3 Olive oil extraction

The process of olive grinding starts when 4.91kg of olive paste produced from the olive grinding process (input from technosphere) is pumped to the centrifuge decanted and ends when olive oil is flowing out of the olive oil separator, as described in Chapter 3. The transformation that takes place in this process is of physical nature and involves the transfer of olive paste with the aid of an electric pump to the centrifuge decanter, the operation of the decanter and the olive oil separator as well as the extraction of the waste streams (liquid and solid) from the process. The production and maintenance of capital infrastructure (electromechanical equipment and the building) are excluded. The output to technosphere (product) of this process is 1 litre of olive oil. In the same process a by-product is also produced, pomace. Pomace is normally considered as a solid waste from the virgin olive oil extraction process, however, since as identified in Chapter 3, it is further utilised for heat production, it is considered as a by-product. Nevertheless, in order to allocate environmental load of the process, pomace is allocated a 0% allocation factor, based on its economic value compared to olive oil.

In order to facilitate the transfer of olive paste from the mixing vat to the decanter 1.75kg of water are added to the stream, while a further 0.67kg of water are added after centrifugation, prior to oil separation. It is highlighted that the quantities are normalised for 1 litre of olive oil output, based on data provided by Mouzouris (2006). Thus a total of 2.42kg of supplied water (documented in section 5.6.2) is included in the process inventory as input from technosphere.

In regards to energy consumption during olive oil extraction, the consumption of electricity is associated with the operation of the electric pump used for transferring the olive paste to the decanter, the decanter, the oil separator as well as the two electric pumps which transfer liquid and solid waste out of the unit. The normalised operational time, associated with the 1 litre olive oil output, was recorded as approximately 6.9sec for the 0.5kW electric pump (olive paste), 11.5sec for the 22.5kW decanter, 6.8sec for the 7.5kW oil separator, 11.5sec for the 1kW solid waste pump, and 25.3sec for each of the two 1kW liquid waste pumps (decanter and separator). Thus a total of 0.12kWh of electric energy produced (previously documented) is included as an input from technosphere in the olive oil extraction process.

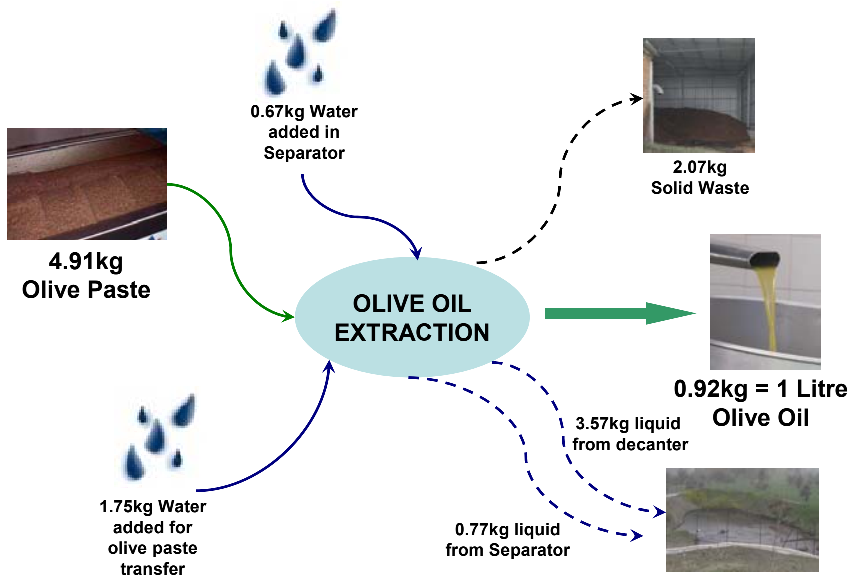

Figure 49 – Material flows during olive oil extraction

In regards to materials flowing out of the process, apart from the main product (olive oil) two streams are encountered: 2.07kg of pomace by-product extracted from the centrifuge decanter (on-site mass measurements normalised to 1 litre olive oil output), whereas liquid waste consists of the main stream (3.57kg) extracted from the decanter and a smaller stream (0.77kg) extracted during oil separation, i.e. a total of 4.34kg. Solid waste, as discussed earlier is considered as a by-product with 0% allocation, whereas the latter is considered as an output waste to treatment.

The data quality index for the inventory of this process, with reference to Table 2, is (1, 2, 1, 1, 1).

5.7.4 Heat from pomace combustion - disposal of residual ash

The process starts when the pomace by-product from the oil extraction process is pumped outside of the olive processing building and ends when the dried solid waste is incinerated in a furnace to produce heat for water in the malaxer. The process includes the drying out process, the incineration and the disposal of the residual ash. The production and maintenance of the furnace is excluded (capital infrastructure). The output to technosphere (product) of this process is 162.2kJ of heat, required for heating the water as described in section 5.7.2.

2.07kg of moist pomace taken out during the extraction of 1 litre of olive oil are an available input to technosphere in this process.

The initial water content of moist pomace extracted from the 3-phase centrifuge oil extraction process is around 55% (Kotronarou and Mendez, 2003; Vlyssides *et al.*, 2004). Therefore during drying out and subsequent combustion of the 2.07kg of pomace per litre olive oil extracted, 1.14kg of water vapour is released to the atmosphere (emissions to air); the remaining solid material amounts 0.93kg. No other emissions to air from drying process are considered in the inventory.

Figure 50 – The boiler furnace in Lythrodontas olive oil processing unit

Dry olive pomace has a calorific value of approximately 12500kJ/kg (Laforgia, 1997; TDC Olive, 2005b; Kotronarou and Mendez, 2003; Vlyssides at al., 2004). Assuming an average boiler furnace efficiency of 56%, 23.2g of dry pomace can be utilised in the closed loop system. Therefore, eventually, the remaining 0.91kg of excess dry pomace remains unused outside the plant as final waste.

Assuming a furnace temperature of 750^{o}C and an oxygen ratio of 0.33 during combustion of the pomace in the furnace, the emissions to air from the furnace chimney are shown in Table 10.

Table 10 – Emissions to air from combustion of dry pomace

Name	Emissions to air at 750^{o}C λ=0.33 (mg/kg of pomace)[1]	Emissions to air (mg per 23.2g dry pomace or 162.2kJ effective heat produced)
Carbon dioxide	$1.45x10^6$	$33.6x10^3$
Carbon monoxide	$3.15x10^4$	730.80
Methane	3946	91.55
Ethane	151	3.50
Ethylene (ethane)	3362	78.00
Propene	71	1.65
Acetylene (ethyne)	1068	24.78
1,3-Butadiene	71	1.65
n-Hexane	73	1.69
Benzene	281	6.52
Napthalene	359	8.33
Anthracene	70	1.62

[1]Jauhiainen *et al.*, 2005

Pomace combustion produces a relatively high amount of ash. According to Jauhiainen *et al.* (2005) every 1kg of dry pomace yields 84.5 g of ash, thus. 23.2g dry pomace yield 1.96g of ash. This ash, the constituents of which are shown in Table 11, is included in the inventory as waste to treatment and it is subsequently disposed to agricultural land, thus modelled as emissions to soil.

Table 11 – Pomace ash composition

Name	mg/kg of pomace dry weight[1]	g per kg of ash
Potassium	18182	215.18
Silicon	5900	69.82
Calcium	5640	66.75
Oxygen	32577	385.54
Aluminium	2036	24.10
Magnesium	2554	30.23
Phosphorus	1441	17.05
Carbon	12550	148.53
Sulphur	834	9.87
Iron	2136	25.28
Sodium	334	3.95
Titanium	55	0.65
Chlorine	258	3.05

[1] Jauhiainen *et al*., 2005

The data quality index for the inventory of this process, with reference to Table 2, is (3, 3, 2, 3, 4).

5.7.5 Disposal of liquid waste

The process starts just after 1 litre of liquid waste from the oil extraction process is pumped outside of the olive processing building to an evaporation pond about 500m away from the processing unit and ends when the liquid waste evaporates completely over the summer months, when the processing unit is idle. The production and maintenance of capital infrastructure e.g. the piping has been excluded. Since this is a waste treatment operation (disposal) there is no product output resulting from the process.

Liquid wastes from olive oil processing units are considered a highly polluting effluent due to their high organic load (Balice and Cera, 1984), the presence of phenolic substances, which resist biological degradation (Abid. and Sayadi, 2005; Sayadi *et al.*, 2000; Ramos-Cormenzana *et al.*, 1995; Saez *et al.*, 1992; Paredes *et* *al.*, 1986; Wang *et al.*, 1967), as well as their acidity and high concentration of potassium, magnesium and phosphate salts (Arienzo and Capasso, 2000). Thus, its uncontrolled disposal may lead to significant environmental pollution problems (Paredes *et al.*, 2002).

The composition of the liquid waste from olive oil processing units is variable, both qualitatively and quantitatively, affected by the cultivation soil, harvesting time, degree of ripening, olive variety, climatic conditions, use of pesticides and fertilisers, duration of aging and employed olive oil extraction process (Niaounakis and Halvadakis, 2004). Thus, it is only possible to obtain an idea of the range of values for each parameter. Table 12 shows typical ranges of the composition parameters, collected from bibliographic references as well as laboratory analysis of samples from Lythrodontas at the GAIA Laboratory of Environmental Engineering at the University of Cyprus.

Table 12 – Liquid waste composition

Parameter	Most probable range (mg/litre)	Data sources	Mean value (mg/litre)
Total solids	48,000-79,100	GAIA Laboratory analysis; Aktas *et al.*, 2001; Hamdi *et al.*, 1992; Vlyssides *et al.*, 2004 ; Potoglou *et al.*, 2004	63,550
Volatile solids	43,800-62,100	GAIA Laboratory analysis; Aktas *et al.*, 2001; Hamdi *et al.*, 1992; Vlyssides *et al.*, 2004 ; Potoglou *et al.*, 2004	52,950
Total suspended solids	7,500-86,840	GAIA Laboratory analysis; Aktas *et al.*, 2001; Hamdi *et al.*, 1992; Vlyssides *et al.*, 2004	47,170
Volatile suspended solids	13,500-24,500	GAIA Laboratory analysis; Aktas *et al.*, 2001; Garcia Garcia *et al.*, 2000	19,000
BOD	35,000-60,000	GAIA Laboratory analysis; Gonzalez-Lopez, 1994; Regional Activity Centre for Cleaner Production, 2000; Caputo *et al.*, 2003; Vlyssides *et al.*, 2004; Skeratt *et al.*, 1999	47,500
COD	55,000-178,000	GAIA Laboratory analysis; Gonzalez-Lopez, 1994; Caputo *et al.*, 2003; Rana *et al.*, 2003; Garcia Garcia *et al.*, 2000; Aktas *et al.*, 2001; Hamdi *et al.*, 1992; Vlyssides *et al.*, 2004; Sobhi *et al.*, 2005; Potoglou *et al.*, 2004	116,500
Phenols	1,200-10,650	Saadi *et al.*, 2006; Rana *et al.*, 2003; Regional Activity Centre for Cleaner Production, 2000; Boubaker *et al.*, 2006; Garcia Garcia *et al.*, 2000; Aktas *et al.*, 2001; Vlyssides *et al.*, 2004; Sobhi *et al.*, 2005	5,925
Volatile phenols	3,100	Aktas *et al.*, 2001	3,100
Total Nitrogen	5,000-15,000	Arienzo and Capasso, 2000	10,000
Phosphorus	300-530	Garcia Garcia *et al.*, 2000; Arienzo and Capasso, 2000; Rana *et al.*, 2003; Vlyssides *et al.*, 2004	415
Potassium	1,200-2,700	Arienzo and Capasso, 2000; Paredes *et al.*, 2005; Hamdi *et al.*, 1992; Vlyssides *et al.*, 2004; Skeratt *et al.*, 1999	1,950
Calcium	47-750	Arienzo and Capasso, 2000; Hamdi *et al.*, 1992; Vlyssides *et al.*, 2004; Skeratt *et al.*, 1999	398.5
Magnesium	50-400	Arienzo and Capasso, 2000; Hamdi *et al.*, 1992; Vlyssides *et al.*, 2004; Skeratt *et al.*, 1999	225
Sodium	40-900	GAIA Laboratory analysis; Arienzo and	470

		Capasso, 2000; Hamdi *et al.*, 1992; Vlyssides *et al.*, 2004	
Silicon	18	Vlyssides *et al.*, 2004	18
Sulphur	63	Vlyssides *et al.*, 2004	63
Chlorine	124	Vlyssides *et al.*, 2004	124
Lead	0.07 - 1	GAIA Laboratory analysis; Paredes *et al.*, 2005; Skeratt *et al.*, 1999	0.54
Iron	12-41	GAIA Laboratory analysis; Paredes *et al.*, 2005; Vlyssides *et al.*, 2004; Skeratt *et al.*, 1999	26.5
Copper	1-7	Paredes *et al.*, 2005; Vlyssides *et al.*, 2004; Skeratt *et al.*, 1999	3.5
Manganese	1-12	Paredes *et al.*, 2005; Vlyssides *et al.*, 2004	6.5
Zinc	1.4-12	Paredes *et al.*, 2005; Vlyssides *et al.*, 2004; Skeratt *et al.*, 1999	6.7
Nickel	0.3 - 12	Paredes *et al.*, 2005; Skeratt *et al.*, 1999	6.2
Chromium	9	Paredes *et al.*, 2005	9
Cadmium	8	Paredes *et al.*, 2005	8

Many different processes have been proposed to treat the effluent (Vitolo *et al.*, 1999); however, the disposal into evaporation ponds has been the most economic option, especially for small rural areas like Lythrodontas.

According to Niaounakis and Halvadakis (2004), in such a lagoon, the sun´s energy is used to speed up the process of evaporation and drying of the olive mill liquid waste. Moreover, the waste is partially degraded by a natural biological route, over very long time periods. In practice treatment period spans for about 9 months, from late February or early March to beginning of November, when the olive mill is idle, as discussed earlier. According to Mouzouris (2006), liquid waste evaporates completely over this period.

The main concerns of this disposal process are: the odours released by volatile substances and the risk of leakage through the soil into groundwater. In regards to odours, methane and other pungent gases (hydrogen sulphide, etc.) emanate due to anaerobic fermentation of the waste water (Stolting and Bolle, 2000; Niaounakis and Halvadakis, 2004). However, research on quantification of emissions from evaporation ponds is extremely limited, especially for three-phase centrifuge effluent.

COD removals of up to 80% in 4 months have been reported by Niaounakis and Halvadakis (2004) and Rozzi and Malpei (1996). Borja *et al.* (2006) in their experiment recorded a production of methane of approximately 22 litres, for an effective volume of 460 litres of liquid waste from two phase centrifuge olive mill extraction process (168g/l COD). In the absence of more specific information, and based on the fact that ambient temperature variation in Andalusia, where the experiment was carried out, is similar to that of Lythrodontas, methane production in Lythrodontas evaporation pond was calculated by assuming that methane production in the evaporation pond is linearly proportional to the initial volume and the chemical oxygen demand. Thus, 1 litre of liquid waste from the three-phase processing in Lythrodontas generates 0.033 litres of methane (22*116.5/168*460), i.e. 0.022g.

Rana *et al.* (2003) in a study on the possible volatisation of substances contained in olive mill wastewater when sprayed on the soil found that when olive mill waste was spread on soil, phenols were released into the atmosphere. Thus, with reference to the mean characterisation of the effluent in Table 12, it is assumed that the 3.1g of volatile phenols will be emitted to the atmosphere.

In regards to groundwater contamination, as discussed in Chapter 3, there is no evidence of the efficiency or the satisfactory condition of the clay layer at the bottom and sides of the pond as no monitoring has ever been undertaken. Additionally leakage from transfer pipes in several locations was observed. In the absence of any information in literature in regards to the magnitude of groundwater contamination from poorly managed evaporation ponds for liquid waste from olive mills, an inventory of the polluting load in groundwater and soil was calculated based on an assumption that 2.5% of the polluting load leaches into groundwater, whereas the residual load after evaporation and leaching is treated as emissions to soil, as shown in Table 13.

Table 13 – Emissions to environmental compartments from disposal of liquid waste into the evaporation pond in Lythrodontas (per kg of liquid waste)

Species	Emissions to air (mg)	Emissions to groundwater (mg)	Emissions to soil (mg)
Water	$25x10^3$	$975x10^3$	-
Methane	22	-	-
BOD	-	1190	-
COD	-	2910	-
Phenols	3100	70	2760
Nitrogen	-	250	9750
Phosphorus	-	10.4	404.6
Potassium	-	48.8	1901.3
Calcium	-	10.0	388.5
Magnesium	-	5.6	219.4
Sodium	-	11.8	458.3
Silicon	-	0.5	17.6
Sulphur	-	1.6	61.4
Chlorine	-	3.1	120.9
Lead	-	0.0	0.5
Iron	-	0.7	25.8
Copper	-	0.1	3.4
Manganese	-	0.2	6.3
Zinc	-	0.2	6.5
Nickel	-	0.2	6.0
Chromium	-	0.2	8.8
Cadmium	-	0.2	7.8

The data quality index for the inventory of this process, with reference to Table 2, is (5, 4, 3, 4, 5).

5.7.6 Olive oil storage

The process of olive oil storage starts when olive oil is placed into the plastic containers and ends when it exits the olive oil processing unit, when sold. The output to technosphere (product) of this process is 1 hour of storage of olive oil.

As described in Chapter 3 olive oil storage takes place at room temperature, thus no energy, material flows and emissions have been recorded. The sample used for the acidity test is small (approximately 50 ml for every 2250 litres), therefore the materials used for titration and wastes are not included in the inventory for the olive oil storage process.

5.7.7 Olive oil processing

The envelope unit process of olive oil processing starts with the transportation of olives from the orchards to the plant location and ends when the system product, i.e. 1 litre of extra virgin olive oil exits the olive oil processing unit (gate). The process includes all processing sub-processes as previously documented. The production and maintenance of capital infrastructure is excluded in line with the boundary definition (Avraamides *et al.*, 2005). The output to technosphere (product) of this process is 1 litre of extra virgin olive oil (reference flow) and all inputs in the inventory of this process refer to the output quantity.

The first input from technosphere in this process is the transportation of 3.83 olives of the characteristic variety from the orchards (documented in section 5.4.6). The second input is 1 litre of olive oil extracted from the oil extraction processes (section 5.7.3). Finally, storage input is another input from technosphere to this process. The average storage period, as recorded in Chapter 3, is 1164 hours (7 weeks).

No other material or energy flows have been identified in this process. The data quality index for the inventory of this process, with reference to Table 2, is (1, 1, 1, 1, 1). It is noted that the index refers to the flows recorded under this inventory and not to the whole inventory of the olive oil processing system.

6 Life Cycle Inventory Analysis

The data reported in Chapter 5 were imported into the customised model of Figure 39. The system process outputs compiling the production of 1 litre of olive oil are listed in Table 14. The final analysis model network including all process inputs from databases, as reported in Chapter 5, is provided in Appendix C. The model was analysed in SimaPro 7.0.

In the following sections, indicative parameters of the inventory are investigated and the contribution of individual processes is discussed. A summary of the results is provided in section 6.5, whereas an extended inventory of the product system with the total amounts of raw materials consumed and of substances emitted to air, water and soil, as well as the contribution of the agricultural and processing stages, is provided in Appendix D.

Table 14 –Outputs for the production of 1 litre of olive oil in Lythrodontas

Product	Quantity
Olive trees planted	0.0095
Water used for irrigation	1.40m^3
Water extracted from wells in orchards	1.82m^3
Field electricity produced and consumed in orchards	2.35kWh
Diesel consumed for soil management and operation of electricity generators in orchards	0.127kg
Land area ploughed	96.4m^2
Compound fertiliser produced and applied	1.35kg
Dimethoate based pesticide produced and applied	0.037kg
Trees pruned	0.35
Time petrol chainsaw operated for pruning	4.2 min
Petrol consumed by chainsaw during pruning	0.05kg
Pruning residue produced and burnt	6.23kg
Ash produced from residue burning disposed	28g
Olives collected	3.83kg
Olives purified during processing	3.82kg
Olive paste produced following grinding	4.91kg
Municipal water treated and supplied for processing	3.51kg
Grid electricity consumed in olive mill	0.23kWh
Liquid waste produced and disposed	4.34kg
Pomace produced	2.07kg
Total transportation by freight ship	1830kg*km
Total transportation by lorry	140kg*km
Total transportation by pickup van	64.8kg*km

6.1 Consumption of environmental resources

6.1.1 Consumption of crude oil

Crude oil is a valuable non-renewable resource, mainly used for producing fuel oil and petrol, both important “primary energy” sources. It is also the raw material for many chemical products, including solvents, fertilizers and pesticides.

The analysis has shown that the system consumes 495g of crude oil for the production of 1 litre of olive oil, of which 434g (87.6%) are consumed in the agriculture related processes of the system and the rest in the olive oil processing stage, as shown in Figure 51.

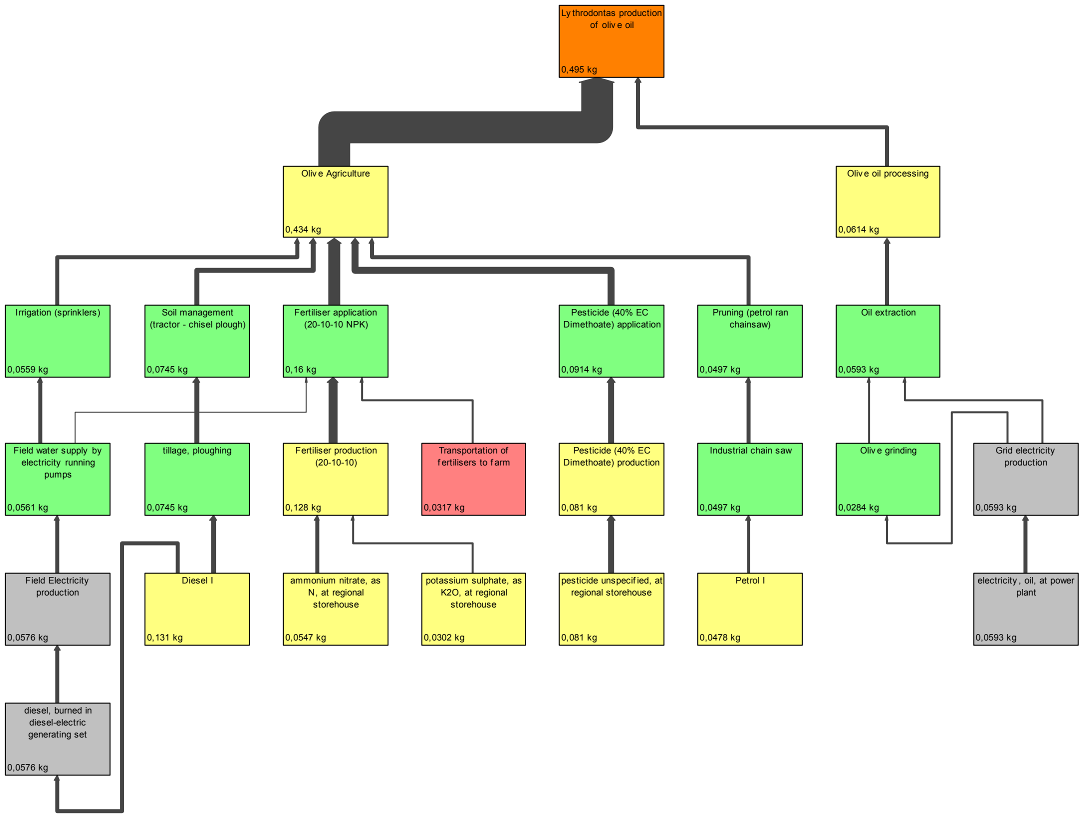

Figure 51 – Flowchart for consumption of crude oil in kg (processes contributing more than 4%)

Within the system, crude oil is consumed in almost all processes, from the production of agricultural inputs to transportation, electricity generation etc. Figure 51 illustrates crude oil consumption flow from processes consuming more than 4% of the overall 495g load.

The activities which most heavily consume crude oil are fertilisation and pest control as they consume 160g (32.3% of the overall consumption) and 91.4g (18.5%) of crude oil per litre olive oil produced respectively. It is highlighted that these envelop all lower level associated sub-processes, i.e. production (including electricity generation consumed within the manufacturing plants), transportation and application. From these, production is the most heavy oil consuming stage.

Other contributors to the consumption of crude oil are soil management (15.1% due to the diesel consumption in agricultural tractors), olive oil processing (12.4% because of the fuel requirements of electricity generation), irrigation (11.3% due to diesel consumption in field electricity generators for water extraction) and pruning (10.0% due to petrol consumption of chainsaws). Other processes such as olive collection and olive tree planting are insignificant in regards to crude oil consumption as collectively they contribute less than 1% of the overall consumption of the system, as shown in Figure 52.

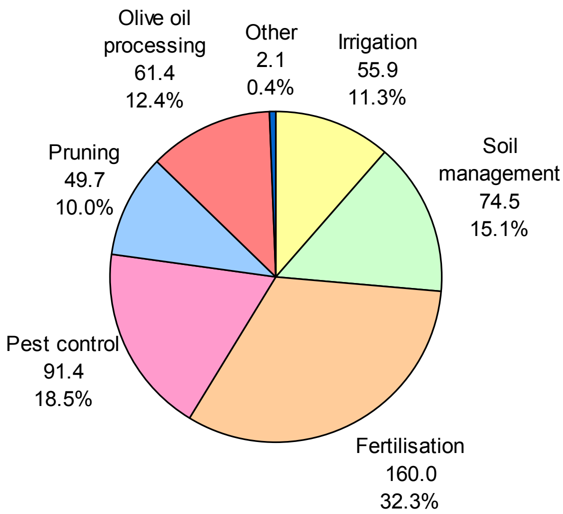

Figure 52 – Crude oil consumption in grams and % process contribution to overall load

6.1.2 Consumption of fresh water

Although renewable, water is a valuable resource, especially in a dry ecosystem like Cyprus. The olive oil system consumes a total of 3914 litres of fresh water for the production of 1 litre of olive oil. Despite the perceived importance of the olive oil processing stage, especially with the three phase centrifuge technology used in Lythrodontas, the analysis has shown that it only consumes 54.1 litres of water (1.4% of overall consumption), from which 48.9 litres are consumed for the generation of the electricity required and only the remaining 5.2 litres are consumed in the actual processing, as shown in Figure 53.

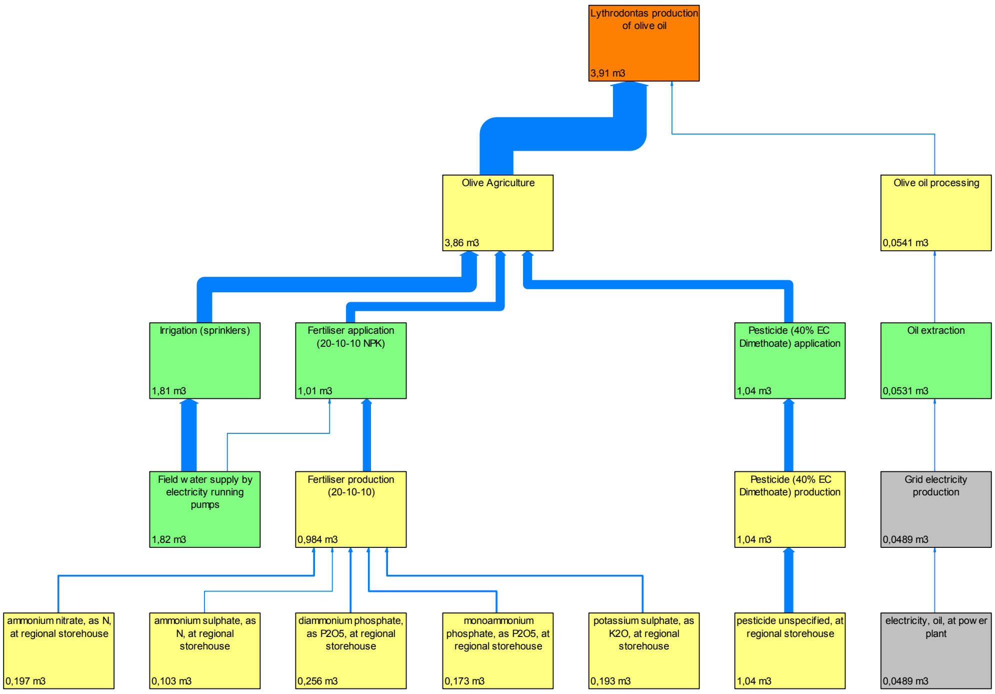

Figure 53 – Flowchart for consumption of fresh water in cubic metres (processes contributing more than 1%)

In the other hand, the agricultural stage is responsible for an enormous consumption of 3860 litres. However, it must be highlighted that much of the water use is consumed in background processes, such as the production of pesticides and fertilisers. This consumption takes place in countries where water scarcity is possibly not of concern.

Irrigation is, naturally, the highest water using process, as it consumes 1810 litres of water (46.2%) per litre of olive oil produced, followed by pest control and fertilisation, which are accountable for the use of 1040 (26.6%) and 1010 litres (25.8%) of fresh water respectively, as shown in Figure 54. Again it is highlighted that each process in Figure 54 envelops all lower level associated sub-processes, e.g. production (with associated power generation), transportation, and application.

For both fertilisation and pest control, production processes are by far the most significant fresh water consumers.

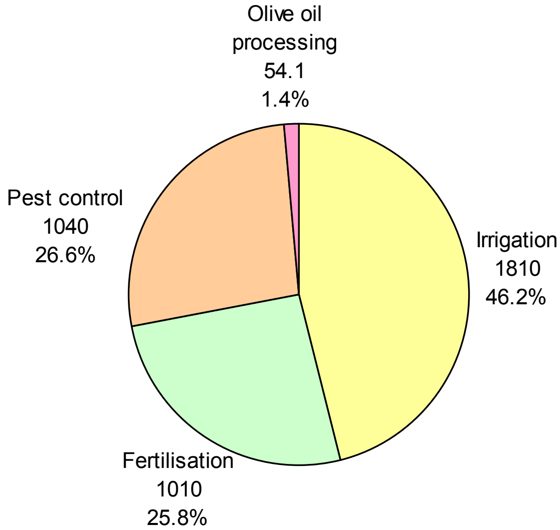

Figure 54 – Fresh water consumption in litres and % process contribution to overall load

6.2 Emissions to air

6.2.1 Emissions of fossil carbon dioxide

Carbon dioxide is an important greenhouse gas, which derives from multiple natural sources such as fermentation and cellular respiration of various microorganisms (biogenic carbon dioxide) and man-made sources like combustion of fossil fuels for power generation and transport and burning of forests (fossil carbon dioxide). In this section the latter sources of carbon dioxide emissions are discussed, whereas carbon dioxide from biogenic sources is separately included in the inventory (Appendix D).

The overall system releases 3.9kg of fossil carbon dioxide per litre of olive oil produced, from which 3.66kg (93.8%), as shown in Figure 55, are released from processes related to the agricultural phase of the product.

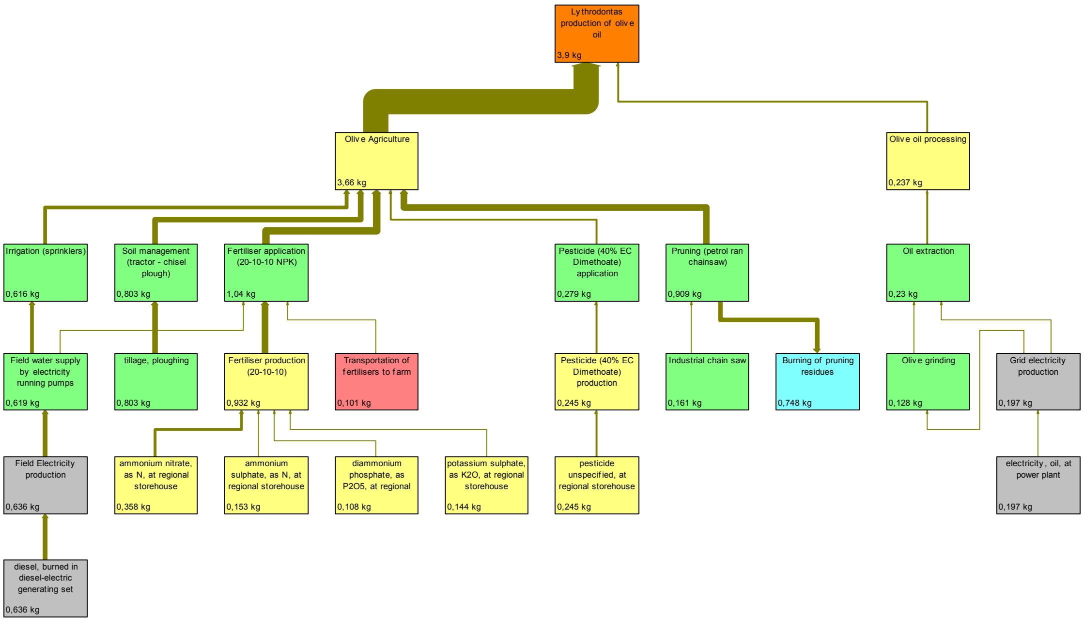

Figure 55 – Flowchart for emissions of fossil carbon dioxide in kilograms (processes contributing more than 2%)

Within the agricultural phase, emissions of fossil carbon dioxide are relatively evenly distributed between fertilisation, pruning and soil management, whereas irrigation and pest control emit significantly less amounts of the gas. The contribution of planting and collection is again negligible relatively to the overall load.

The contribution of envelope processes in the overall carbon dioxide load is shown in Figure 56. Fertilisation is accountable for the release of 1040g (26.7%) of carbon dioxide per litre olive oil produced, the source of which is traced mainly at the industrial production processes of its constituents and to a lesser extend to its transportation to the farm and its application.

Pruning is also a significant activity in regards to CO_2 as it releases 909g (23.3% of overall CO_2 emissions) from which 748g are released when pruning residues are burned.

Agricultural tractors during the soil management of 96.4m^2 attributed to the production of 1 litre of olive oil emit 803kg of CO_2 (20.6%), whereas irrigation due to diesel combustion for field electricity generation with which water pumps are supplied release a further 616g (15.8%).

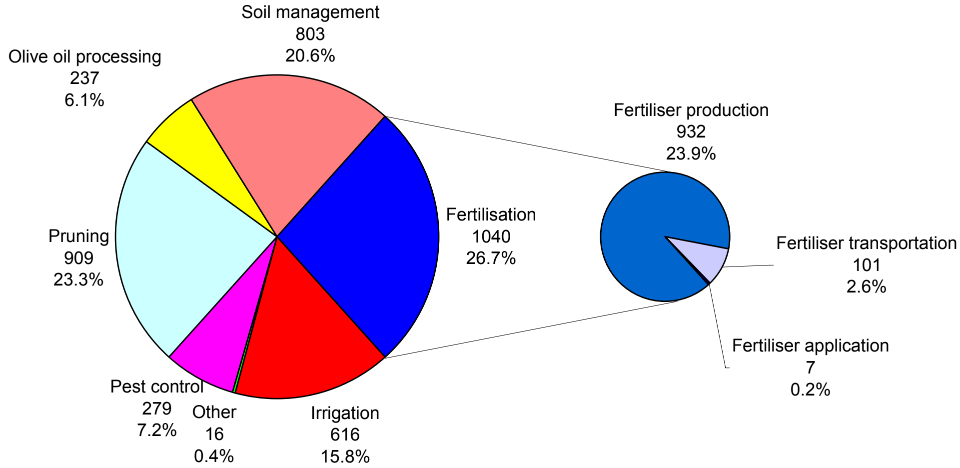

Figure 56 –Emissions of fossil carbon dioxide in grams and % process contribution to overall load

6.2.2 Emission of nitrogen oxides

Nitrogen oxides (NO_x) refer to the total concentration of NO plus NO_2, expressed as NO_2. During daylight NO and NO_2 are in equilibrium with the ratio NO/NO_2 determined by the intensity of sunshine (which converts NO_2 to NO) and ozone (which reacts with NO to give back NO_2).

The system overall produces 32.2g of nitrogen oxides per litre of olive oil produced, from which 99.1% are released from processes related to the agricultural phase of the product. Irrigation, soil management, fertiliser application, pruning and pest control are the main NO_x polluters within the system, as shown in Figure 59.

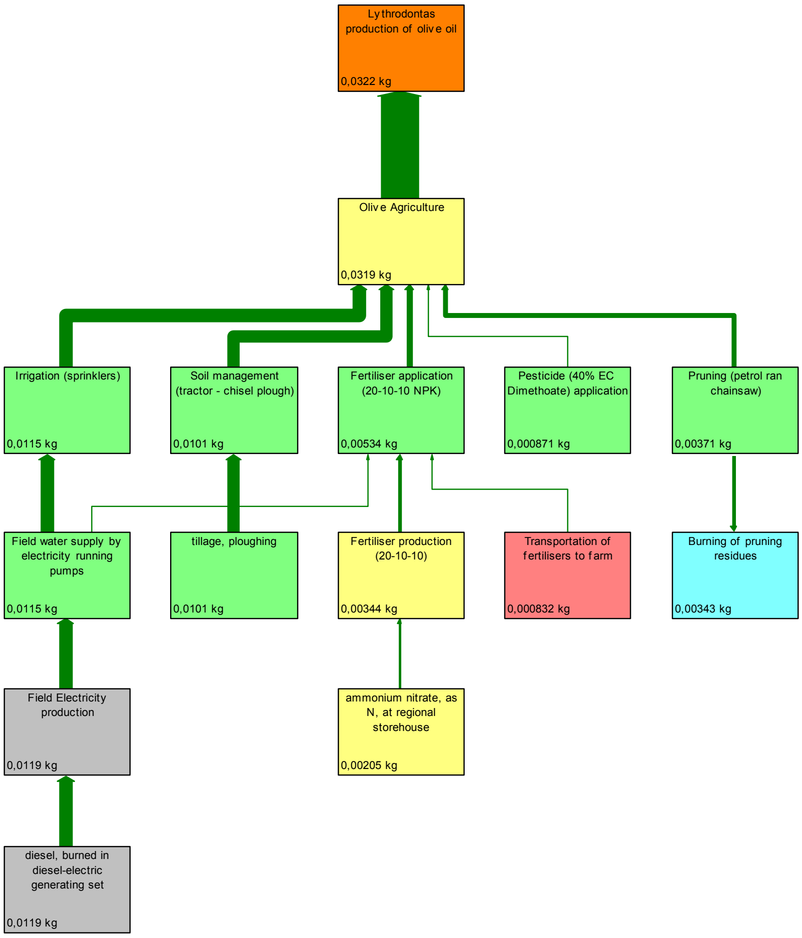

Figure 59 – Flowchart for emissions of nitrogen oxides in kilograms (processes contributing more than 2%)

The emission of nitrogen oxides from on-site electricity generators is the main contributor to the overall load. These generators mainly supply the electric pumps for water extraction during irrigation, thus 11.5g of NO_x emissions per litre of olive oil production are attributed to irrigation. These constitute 35.7% of the overall NO_x load emitted by the system.

Similarly, the emissions of nitrogen oxides from the exhausts of agricultural tractors during soil management are very significant as they contribute another 10.1g (31.4% of the overall load), as shown in Figure 60.

Other “hot spot” processes in regards to NO_x emissions are fertilisation, which contributes 5.3g (16.6%) from which 3.4g are traced to the production of the fertiliser and the rest to its application (1.1g) and transportation (0.8g) as well as pruning which contributes another 3.7g (11.5%) from which only 0.3g relate to the actual pruning process whereas the rest are emitted during the subsequent management of the residue as it is undertaken in Lythrodontas.

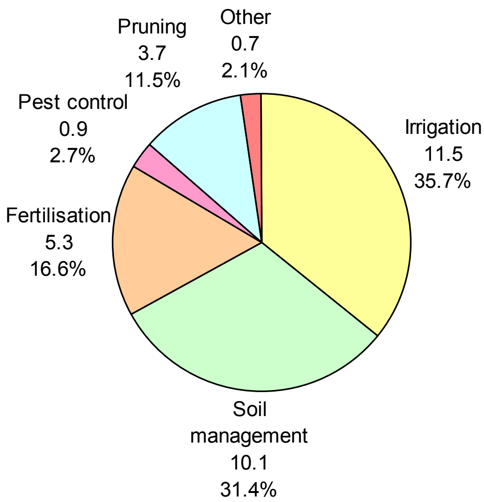

Figure 60 –Emissions of nitrogen oxides in grams and % process contribution to overall load

6.2.3 Emission of sulphur dioxide

Sulphur dioxide (SO_2) in general, is emitted by various industrial processes including electricity generation. Its presence in air can cause adverse health effects, mainly breathing problems. Furthermore, SO_2, along with nitrogen oxides, are the main precursors of acid rain.

The olive oil production system produces 13.7g of SO_2 per litre of olive oil, from which 12.1g (88.3%) are released from processes related to the agricultural phase of the product, as shown in Figure 61 and 1.6g of SO_2 emissions are released during the generation of electricity required to power the processing of 1 litre of olive oil.

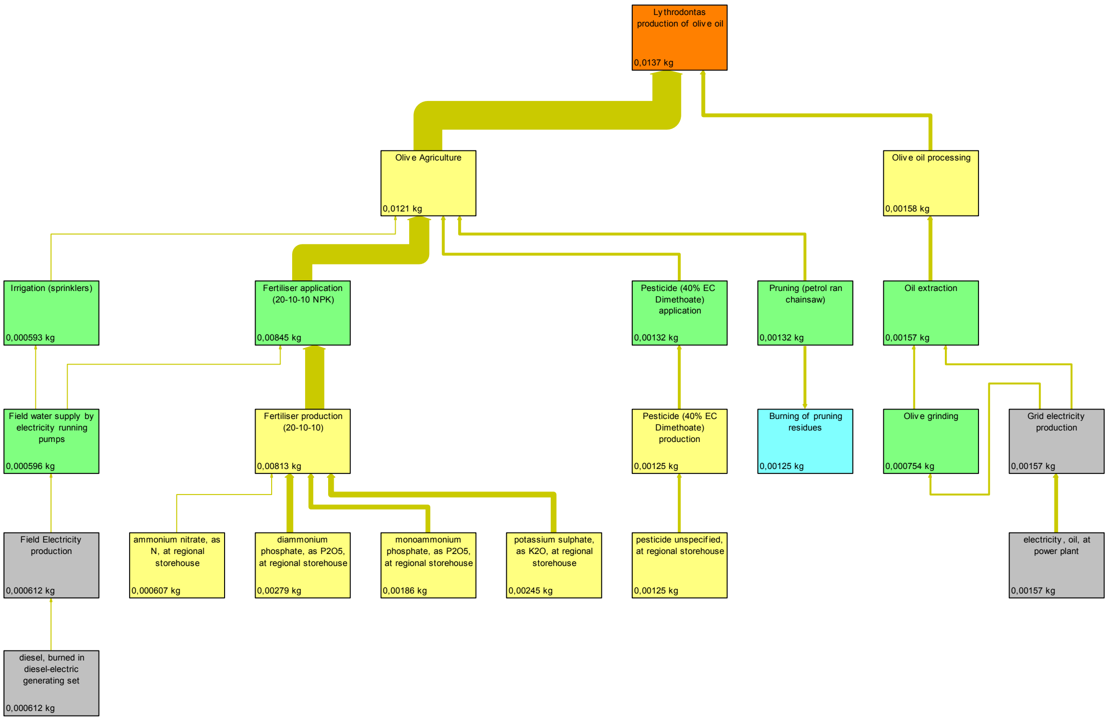

Figure 61 – Flowchart for emissions of sulphur dioxide in kilograms (processes contributing more than 4%)

The use of fertilisers is by far the primary contributor of sulphur dioxide emissions as they contribute a total of 8.5g per litre of olive oil produced which corresponds to 61.7% of the total SO_2 load of the product system. From these, 8.1g are emitted during the production of the 1.35kg (per litre of olive oil) 20-10-10 fertiliser used in Lythrodontas.

Other significant sources of SO_2 emissions from the olive oil system include pest control and pruning. The contribution of each of these processes is 1.3g, which corresponds to 9.6% of the overall load of the system, as shown in Figure 62.

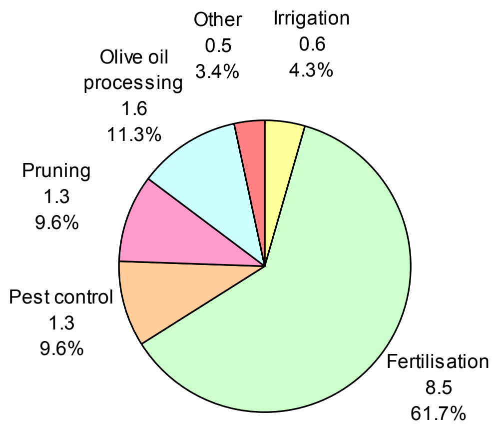

Figure 62 –Emissions of sulphur dioxide in grams and % process contribution to overall load

In regards to pest control, the primary source of SO_2 emissions is the production phase. For the production of 36.9g of pesticide used per litre of olive oil production, 1.25g of SO_2 emissions are released in the atmosphere.

Similarly, in pruning, the primary emission source is the management of the pruning residue as burning the 6.23kg of branches pruned per litre of olive oil release another 1.25g of SO_2 to the air.

Finally, irrigation contributes to a lesser extent to the overall emission load with another 0.6g of sulphur dioxide emissions, released during the operation of on-site power generators for the extraction of water.

6.3 Emissions to water

6.3.1 Chemical Oxygen Demand

Chemical Oxygen Demand (COD) is the test commonly used to indirectly measure the amount of organic compounds in water. Usually COD is expressed in milligrams per litre (mg/l), which indicates the mass of oxygen required to chemically oxidise organic and inorganic compounds present in 1 litre of water.

Nevertheless, dealing with COD (and BOD) emissions in a life cycle system raises two concerns. Firstly, both COD and BOD are not specific substances but indicators of the presence of various substances. As a result the inclusion in a process inventory may result to double counting (Heijungs *et al.*, 2002). For this reason these are not included in most standard life cycle impact assessment methods. Moreover, the nature of the LCA technique dictates that environmental inputs (resources) and outputs (emissions) should be normalised to the product reference flow. For this reason both COD and BOD emissions are expressed as masses per reference flow, i.e. kg COD per litre of olive oil produced, and not as concentrations. As a result the analysis, for these indicators in particular, does not give a very useful representation of the problem occurring. For example, 1kg of total COD emitted in several large rivers would not be an issue of environmental importance whereas 1kg of COD emitted in a small stream could be.

Bearing the above concerns in mind, the olive oil production system produces 17.1g of COD per litre of olive oil produced, from which 13.5g (78.9%) are released in the olive oil processing stage, as shown in Figures 63 and 64, and 3.6g are released from agriculture related processes.

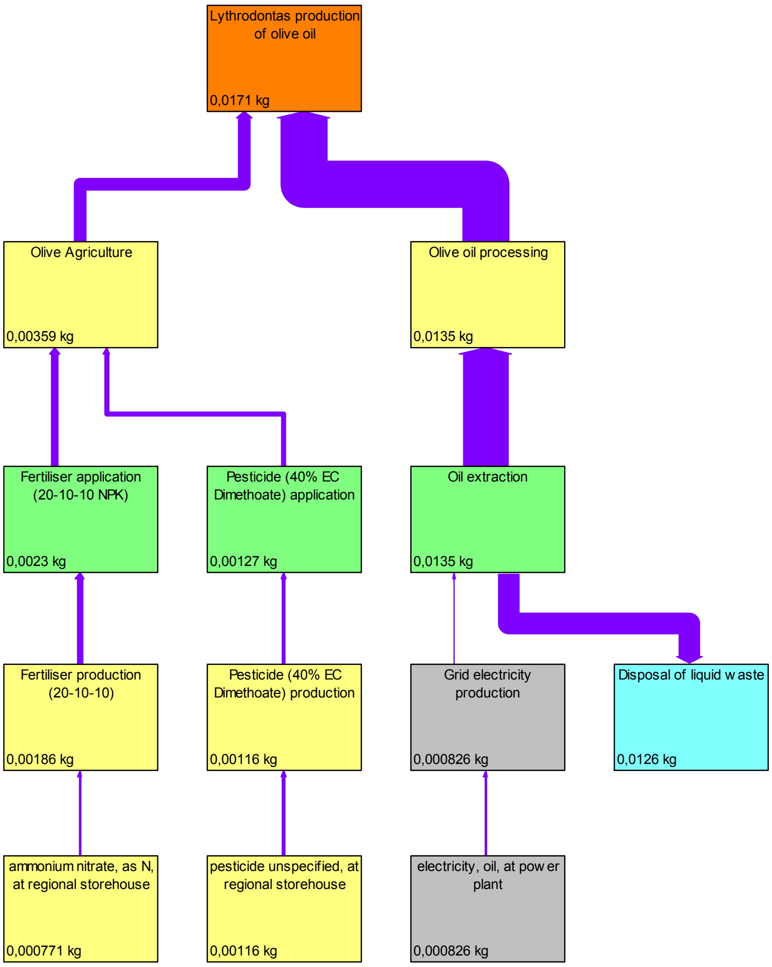

Figure 63 – Flowchart for emissions of COD in kilograms (processes contributing more than 4%)

More than 73% of the total load is released in the environment when liquid wastes from the olive mill are transferred to evaporation lagoons, mainly due to groundwater contamination from leaks in transfer pipes and potentially poor performance of the impermeable layer with which evaporation ponds are supplied. The contribution of the power generation required for the operation of the plant only contributes a moderate 0.8g (4.7%) load.

Within the agricultural stage, fertilisation and pest control are the main sources of COD as they are accountable for the release of 2.3 and 1.3 grams of COD respectively. These are mainly emitted during the industrial production of the chemicals (1.9g and 1.2g of COD during the production of fertilisers and pesticides respectively).

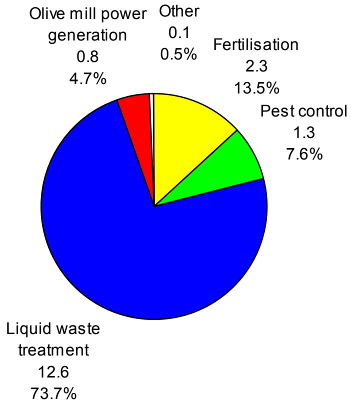

Figure 64 –Emissions of (g) COD for the production of 1 litre of olive oil from production processes

6.3.2 Biological Oxygen Demand

Biological oxygen demand (BOD) is an indicator of the concentration of biodegradable organic matter present in water. The main difference with COD is that BOD indicates organic compounds which can be biologically degraded, whereas in the COD test non-biodegradable compounds can also be oxidised.

According to the analysis of the system, the production of 1 litre of olive oil releases 9.5g of BOD in waters in total. From these, 6.0g (63.1%) are released in the processing stage, as shown in Figure 65.

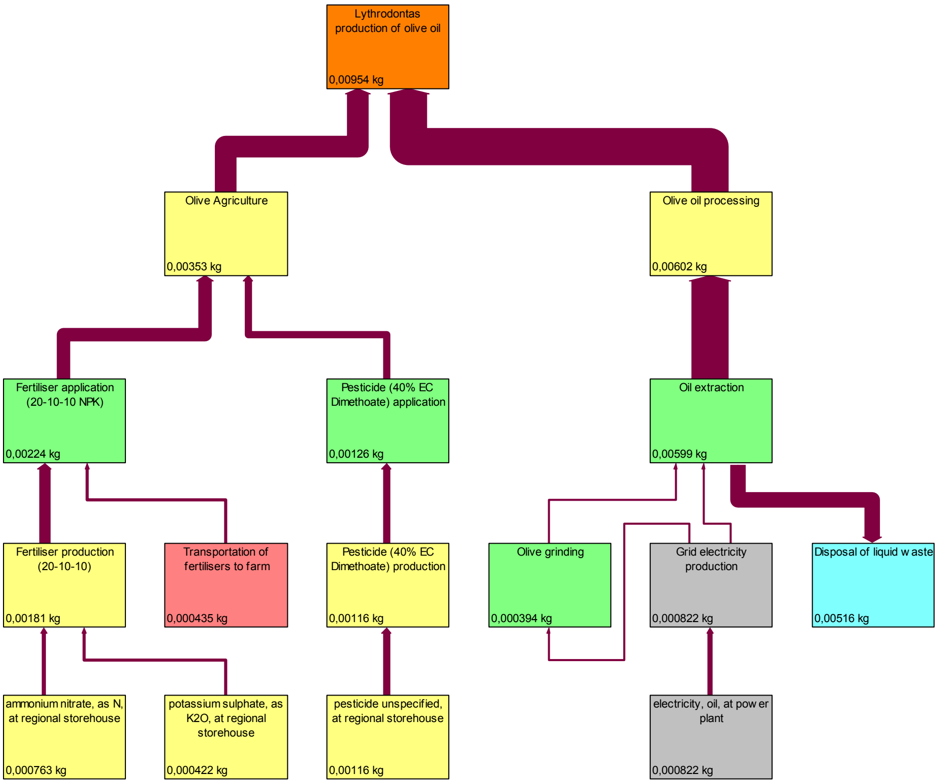

Figure 65 – Flowchart for emissions of BOD in kilograms (processes contributing more than 4%)

The treatment of liquid waste, as it takes place in Lythrodontas, releases 5.2g (54.1%) whereas the generation of 0.84MJ (0.23kWh) of electricity required to process 3.83kg of olives into 1 litre of extra virgin olive oil, release a further 0.8g (8.6%) of BOD, as shown in Figure 66.

Within the agricultural stage, the industrial production of fertilisers and pesticides is for one more time the major source of emissions. The production of fertilisers is responsible for 1.8g released into the aquatic environment. Along with the fertilisers' transportation (including fuel production) and application to the orchards the total contribution of olive tree fertilisation is 2.2g (23.2%). Similarly pest control loads waters with another 1.3g.

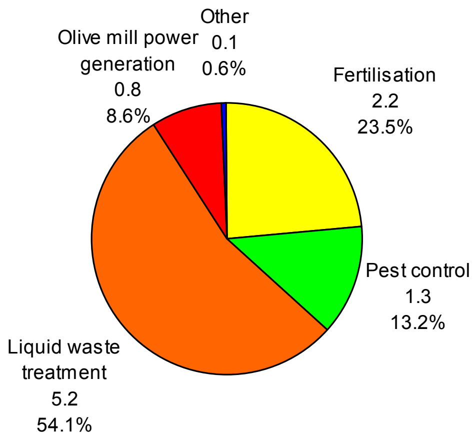

Figure 66 –Emissions of BOD in grams and % process contribution to overall load

When the contribution of processes in BOD and COD loads is compared, it is observed that the contribution of the liquid waste treatment to the overall BOD load (54.1%) is significantly lower than to the COD load (73.7%). This is mainly attributed to the large concentrations of phenolic substances in liquid wastes from olive mills which induce a smaller ratio of biodegradable to non-biodegradable organic matter when compared to wastewaters of several industrial processes.

6.4 Emissions to soil

6.4.1 Lead

Lead is one of the most common heavy metal contaminants of soils. Although lead is naturally present in soils, generally in the range of 15 to 40 parts per million (University of Massachusetts Amherst, 2006), pollution can increase soil lead levels to greater than 300 to 500 parts per million (University of Maine, 2006) with adverse effects to human health.

According to the inventory analysis, the olive oil production system releases to soil 4.03mg of lead per litre of olive oil production, as shown in Figure 67.

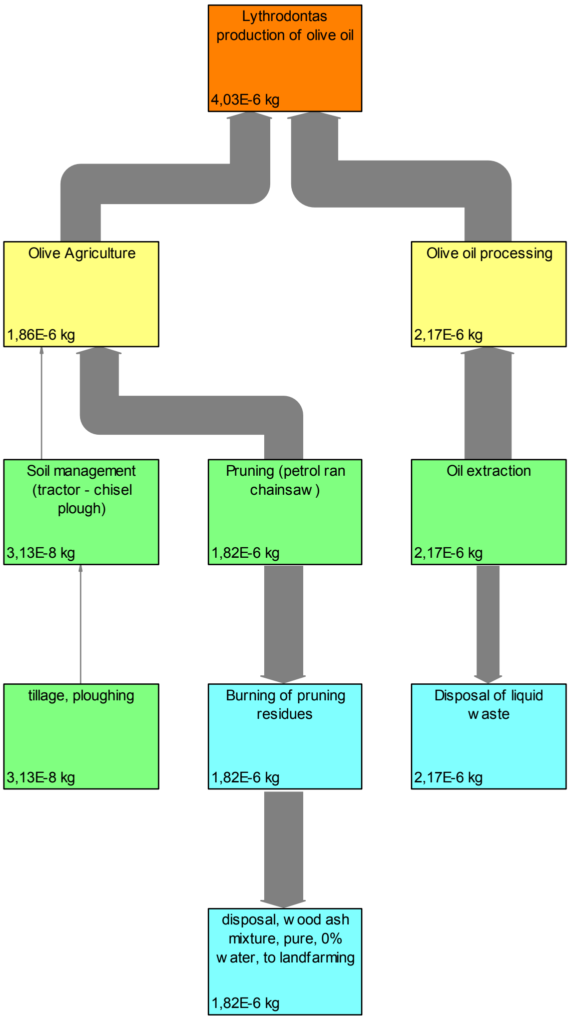

Figure 67 – Flowchart for lead release to soil in kilograms (processes contributing more than 1%)

Within the system, the disposal of liquid waste from the processing stage into evaporation ponds accounts for 2.17mg of lead emissions, which is over half of the total load, as shown in Figure 68. Furthermore the disposal of ash, from burnt pruning residue, to the agricultural land accounts for another 1.82mg of lead emissions (45.2%). Finally, an inferior contributor to lead emissions to soil is the use of agricultural tractors for soil management operations as it only accounts for 0.7% of the overall lead to soil load.

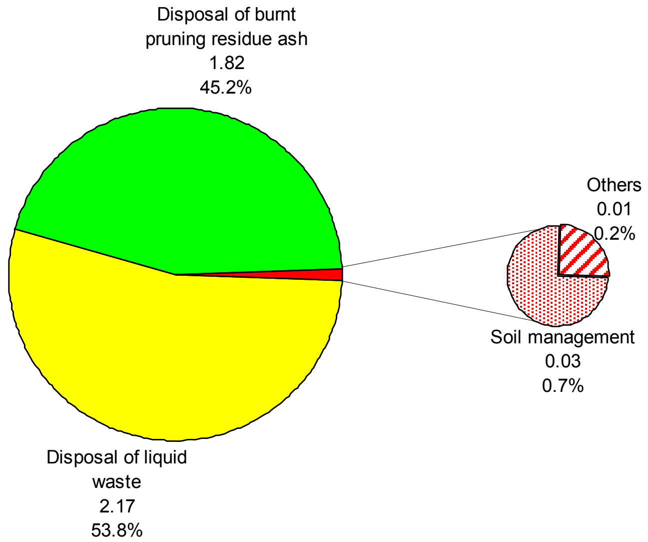

Figure 68 –Emissions of lead to soil in milligrams and % process contribution to overall load

6.4.2 Zinc

Zinc is a heavy metal, the toxicity concerns of which are associated more with plants than with animals or humans. This is because when accumulated in high concentrations most plants would die from its toxic effects long before accumulating a high enough concentration to pose a health risk to an animal (or human) eating that plant.

For the production of 1 litre of olive oil in Lythrodontas, 96.9mg of zinc are emitted to soil, 68.6mg (70.8%) of which from agriculture related processes, as shown in Figure 69.

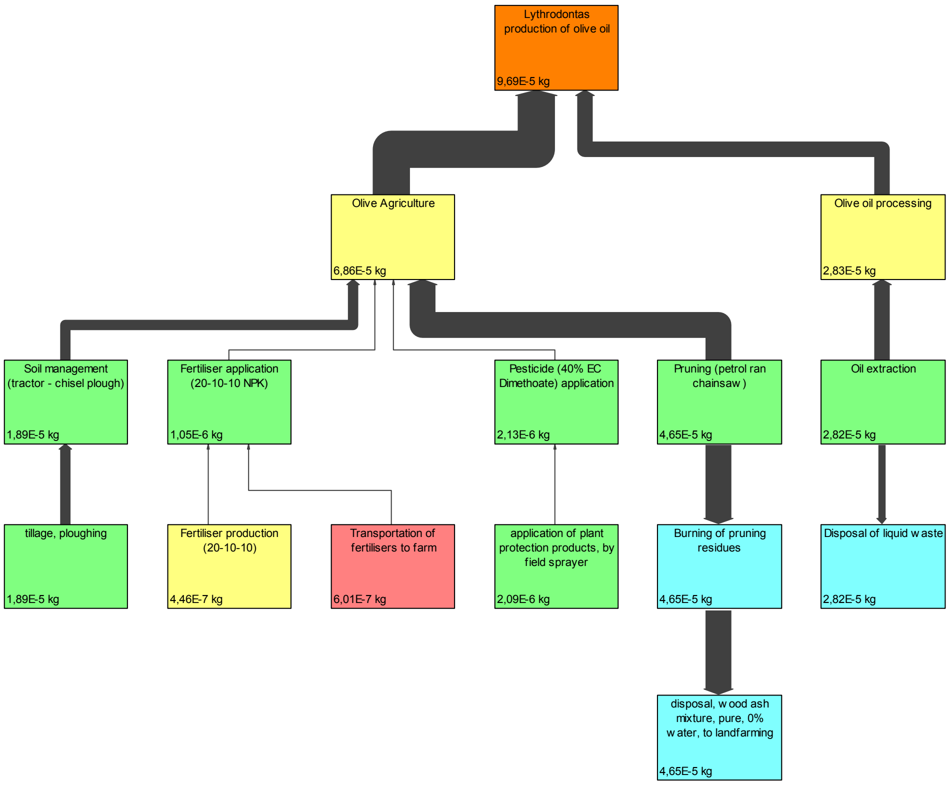

Figure 69 – Flowchart for emissions of zinc in soil in kilograms (processes contributing more than 0.4%)

Pruning, soil management, pest control and fertilisation are the main agriculture related contributors to this load. More specifically the disposal of ash which results from the burning of pruning residues releases 46.5mg of zinc which comprises a 47.8% contribution to the overall system load. Furthermore, the use of agricultural tractors for management of the soil in orchards, which includes direct emissions as well as the production of associated fuel, is credited another 18.9mg (19.4%).

Pest control, mainly the application of pesticides through compressed air sprayers connected to tractors, and fertilisation, mainly the production and transportation of the characteristic fertiliser, are also sources of zinc emissions, of secondary importance though, as they contribute 2.1 and 1.1mg respectively, as shown in Figure 70.

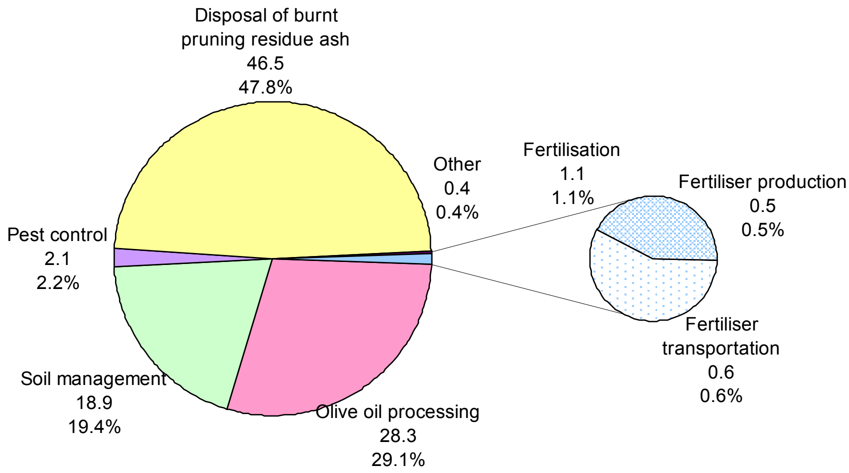

Figure 70 –Emissions of zinc in soil in milligrams and % process contribution to overall load

In the processing stage, zinc disposal to soil is mainly associated with the particular technique used in Lythrodontas to deal with liquid waste. More specifically, the processing stage is associated with the emissions of 28.3mg of zinc from which 28.2mg are associated with the disposal of liquid waste in evaporation ponds.

6.5 Summary of results

The results are summarised in Table 15.

Table 15 – Summary of Life Cycle Inventory results for the production of 1 litre of olive oil production

Parameter	Agricultural stage							Processing stage		Totals		
	Tree planting	Irrigation (incl. fuel production, on-site electricity generation, water extraction and supply)	Soil management (incl. fuel production, tractor operation)	Fertilisation (incl. production, transportation and application)	Pest control (incl. production, transportation and application)	Pruning (incl. fuel production, chainsaw operation and pruning residue management)	Olive collection (incl. fuel production, on-site electricity generation and operation of pneumatic combs)	Transportation of olives	Oil extraction (incl. grid electricity generation, water treatment and supply, liquid and solid waste management)	Agricultural stage TOTAL	Processing stage TOTAL	Olive oil production system TOTAL
Consumption of crude oil	<0.5%	55.9g (11.3%)	74.5g (15.1%)	160g (32.3%)	91.4g (18.5%)	49.7g (10.0%)	<0.5%	<0.5%	59.3g (12.0%)	434g (87.6%)	61.4g (12.4%)	495g (100%)
Consumption of fresh water	<0.5%	1810L (46.2%)	<0.5%	1010L (25.8%)	1040L (26.6%)	<0.5%	<0.5%	<0.5%	53.1L (1.4%)	3860L (98.6%)	54.1L (1.4%)	3914L (100%)
Emissions of fossil carbon dioxide to air	<0.5%	616g (15.8%)	803g (20.6%)	1040g (26.7%)	279g (7.2%)	909g (23.3%)	<0.5%	<0.5%	230g (5.9%)	3660g (93.9%)	237g (6.1%)	3897g (100%)
Emissions of nitrogen oxides to air	<0.5%	11.5g (35.7%)	10.1g (31.4%)	5.3g (16.6%)	0.9g (2.7%)	3.7g (11.5%)	0.3g (0.9%)	<0.5%	0.3g (0.9%)	31.9g (99.1%)	0.3g (0.9%)	32.2g (100%)
Emissions of sulphur dioxide to air	<0.5%	0.6g (4.3%)	0.4g (2.9%)	8.5g (61.7%)	1.3g (9.6%)	1.3g (9.6%)	<0.5%	<0.5%	1.6g (11.3%)	12.1g (88.3%)	1.6g (11.7%)	13.7g (100%)
Chemical Oxygen Demand to waters	<0.5%	<0.5%	<0.5%	2.3g (13.5%)	1.3g (7.6%)	<0.5%	<0.5%	<0.5%	13.5g (78.9%)	3.6g (21.1%)	13.5g (78.9%)	17.1g (100%)
Biological Oxygen Demand to waters	<0.5%	<0.5%	<0.5%	2.2g (23.5%)	1.3g (13.2%)	<0.5%	<0.5%	<0.5%	6.0g (63.1%)	3.5g (36.9%)	6.0g (63.1%)	9.5g (100%)
Lead to soil	<0.5%	<0.5%	0.03mg (0.7%)	<0.5%	<0.5%	1.8mg (45.2%)	<0.5%	<0.5%	2.2mg (53.8%)	1.9mg (46.2%)	2.2mg (53.8%)	4.0mg (100%)
Zinc to soil	<0.5%	<0.5%	18.9mg (19.4%)	1.1mg (1.1%)	2.1mg (2.2%)	46.5mg (47.8%)	<0.5%	<0.5%	28.3mg (29.1%)	68.6mg (70.8%)	28.3mg (29.2%)	96.9mg (100%)

	< 0.99%	1 - 9.99%	10 - 19.99%	20 - 29.99%	>30%
Process contribution key					

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8 Appendix A: Olive Agriculture Questionnaire

LIFE04 ENV/GR/110

Questionnaire

QUESTIONNAIRE No.1

IDENTIFICATION OF THE CHARACTERISTIC CYCLE OF OLIVE OIL PRODUCTION - OLIVE CULTIVATION

This questionnaire has been prepared for use in the research programme ECOIL, co-financed by the E.U., in which the community of Lythrodontas has agreed to participate. The objective is to assist all producers in adopting suitable processes for improvement of the environmental attribution of olive oil production. Information acquired will be used exclusively for research purposes. The grower, if he wishes, may maintain anonymity. By the end of the programme the results will be propagated to all growers as well as other interested parties.

INTERVIEW DETAILS	
Number	
Date	

1. INTERVIEWER'S DETAILS	
Name	
Phone number	
E-mail address	

2. GROWER'S DETAILS	
Name	
Phone number	
E-mail address	

3. CULTIVATION DETAILS		
3.1 Geographical position	*Lythrodontas wider region*	
3.2 Variety	*Cyprus Olive*	
3.3 Number of trees		
3.4 Cultivation area		'=…………………………m ^{2}
3.5 Mean olive production per year		'=………..…………kg/year
3.6 Mean olive oil production per year		'=………..………litres/year
3.8 Maximum age of trees		'=…………………..……years
3.9 Planting method		
3.10 Planted trees per litre of oil	'=……..……..no of planted trees/litre	(3.3)/[(3.6)*(3.8)]
3.11 Use of cultivated land per litre of oil	'=……………………..……m ^{2} /litre	(3.4)/[(3.8)*(3.6)]
4. TILLAGE		
4.1 Applicable?	*YES / NO*	
4.2 Frequency		'=………..…………No/year
4.3 Method		
4.4 Land tillage per litre of oil	'=……………………..……m ^{2} /litre	(3.4)*(4.2)/(3.6)
5. WATER IRRIGATION		
5.1 Applicable?	*YES / NO*	
5.2 Water origin	*Bore-hole / Public water supply (Water Board) / Recycled*	
5.3 Irrigation method	*Flood/ Furrow / Sprinklers/ Hanging drippers/ Surface drip/ Sub-surface drip*	
5.4 Distance of cultivation from source		'=…………..………metres
5.5 Types of mechanical equipment (e.g. pumps)		
5.5 Irrigation frequency		"=………..…………no/year
5.6 Amount of water consumption each time		"=…………………………m ^{3}
5.7 Amount of water consumption per year	"=…………………...……...m ^{3} /year	(5.5)*(5.6)
5.8 Amount of water consumption per litre of oil	"=………………….……....m ^{3} /litre	(5.7)/(3.6)

6. FERTILIZERS		
6.1 Applicable	*YES / NO*	
6.2 Fertilizer (name or type)		
6.3 Fertilizer origin		
6.4 Distance		*"=……………………..…km*
6.5 Transportation means (type and gross weight for road transport)		
6.6 Application method		
6.7 Application frequency		*"=………..………no/year*
6.8 Amount applied each time		*"=…………..…………kg*
6.9 Amount applied per year	*"=……………………………kg/year*	*(6.7)*(6.8)*
6.10 Fertilizer amount per litre of oil	*"=………..…………..……kg/litre*	*(6.9)/(3.6)*
6.11. Fertilizer transportations from the area of preparation to the area of application per litre of oil		
Transportation means (type / gross weight for road transport)	Distance (km)	Distance*(6.10)/1000 (tonnes*km/litre)

7. PESTICIDES		
7.1 Applicable?	YES / NO	
7.2 Method (name or type)		
7.3 Origin		
7.4 Distance		"=……………………..…km
7.5 Transportation means (type and gross weight for road transport)		
7.6 Application method		
7.7 Application frequency		"=………..……….no/year
7.8 Amount applied each time		"=…………..…………kg
7.9 Amount applied per year	"=……………………………kg/year	(7.7)*(7.8)
7.10 Amount of pesticide per litre of oil	"=…………..…………...……kg/litre	(7.9)/(3.6)
7.11. Pesticide transportations from the area of preparation to the area of application per litre of oil		
Transportation means (type / gross weight for road transport)	Distance (km)	Distance*(7.10)/1000 (tonnes*km/litre)

8. HERBICIDES		
8.1 Applicable?	*YES / NO*	
8.2 Herbicide (name or type)		
8.3 Herbicide origin		
8.4 Distance		*"=…………………….….km*
8.5 Transportation means (type and gross weight for road transport)		
8.6 Application method		
8.7 Application frequency		*"=………..………no/year*
8.8 Amount applied each time		*"=…………..………..kg*
8.9 Amount applied per year	*"=……………………………kg/year*	*(8.7)*(8.8)*
8.10 Amount of herbicide per litre of oil	*"=………..…………..……kg/litre*	*(8.9)/(3.6)*
8.11. Herbicide transportations from the area of preparation to the area of application per litre of oil		
Transportation means (type / gross weight for road transport)	Distance (km)	Distance*(8.10)/1000 (tonnes*km/litre)

Questionnaire

LIFE04 ENV/GR/110

9. PRUNING		
9.1 Applicable?	YES / NO	
9.2 Application frequency		"=……..…………….no/year
9.3 Application method		
9.4 Pruned trees per litre of oil	'=….……….no of pruned trees/litre	(3.3)*(9.2)/(3.6)
9.5 Amount of "green waste" per tree pruned		"=………………....kg/tree
9.6 "Green waste" produced by pruning per litre of oil	"=…………..…………..…….kg/litre	(9.4)*(9.5)
9.7 Waste management method		
10. COLLECTION		
10.1 Fruit collection method		
10.2 Olive mill used		
10.3 Distance		"=…………………...…….km
10.4 Type and gross weight of transportation means		
10.5 Amount of collected olives per litre of oil	"=…………..…………..…….kg/litre	(3.5)/(3.6)
Transportation means (type / gross weight for road transport)	Tonnes*km/litre	
		(10.5)*(10.3)/1000

Thank you for your participation. Could we contact you again in about one and a half months for some additional information? *YES / NO*

9 Appendix B: Analysis of survey results

Q No	Assessed Validity	TREES	PLANTING	TREES/OPU	M^2/OPU	M^2*Y/OPU	M^2*Y/KG	TIL METHOD	TIL/YEAR	TIL M^2/OPU	IRRIGATION	W SOURCE	W DIST	W EXT	W M^3/OPU	F METH	F TYPE	F KG/OPU
1	valid	100	hand	0,004	0,4	40	10	tractor	1	40	sprinklers	bore-hole	0	electricity		hand	none	
2	valid	350	hand	0,004	0,05	24,375	5,2	tractor	3	73,1	sprinklers	bore-hole	0	electricity	0,63	hand	other	0,25
3	valid	350	hand	0,005	0,71	107,24	26,76	tractor	2	214	none	-	0			hand	201010	0,046
4	invalid	200	hand	-	-	-	-	tractor	-	-	none	-	0	-	-	hand	manure	-
5	valid	300	hand	0,002	0,11	16	4	tractor	3	48	sprinklers	bore-hole	0	electricity	1,8	hand	manure	
6	invalid	260	hand	-	-	-	-	tractor	-	-	none	-	0	-	-	hand	none	-
7	invalid	200	hand	-	-	-	-	tractor	-	-	none	-	0	-	-	hand	2100	-
8	valid	250	hand	0,008	0,89	89,19	26,76	tractor	1	89,2	none	-	0	-	-	hand	none	
9	valid	150	hand	0,005	-	-	-	tractor	2		none	-	0	-	-	hand	other	2
10	valid	150	hand	0,25	17,84	142,7	35,67	tractor	2	285	sprinklers	bore-hole	0	diesel	-	hand	201010	
11	valid	400	hand	0,0002	0,02	15	3,46	tractor	2	30	none	-	0	-	-	hand	none	
12	valid	200	hand	0,005	6,69	66,85	13,37	tractor	2	133,7	none	-	0	-	-	hand	other	
13	valid	180	hand	0,04	0,8	8,03	2,01	tractor	2	16,1	sprinklers	bore-hole	0	electricity	-	hand	other	1
14	valid	300	hand	0,003	0,15	15	3,33	tractor	3,5	52,5	none	-	0	-	-	hand	201010	1
15	valid	150	hand	0,008	0,15	44,57	9,9	tractor	2	89,1	none	-	0	-	-	hand	2100	0,42
16	valid	300	hand	0,003	0,3	60	13,2	tractor	2	120	none	-	0	-	-	hand	2100	1,1
17	valid	500	hand	0,001	0,15	74,28	16,71	tractor	2	148,6	none	-	0	-	-	hand	201010	0,55
18	valid	200	hand	0,02	3,47	86,67	17,73	tractor	2	173	sprinklers	bore-hole	0	electricity	-	hand	2100	2,22
19	valid	200	hand	0,01	0,96	95,56	22,3	tractor	3	286,7	none	-	0	-	-	hand	201010	0,71
20	valid	700	hand	0,002	0,28	41,5	8,3	tractor	3	124,5	sprinklers	bore-hole	0	diesel	1,125	hand	201010	2
21	valid	200	hand	0,005	1,53	107,96	26,74	tractor	1	107	none	-	0	-	-	hand	2100	1
22	valid	300	hand	0,005	0,25	50	10	tractor	2	100	sprinklers	bore-hole	0	diesel	2,56	hand	201010	3,5
23	valid	1500	hand	0,0011	0,11	33,3	7,41	tractor	2	66,7	flood	bore-hole	0	electricity	1,556	hand	manure	11,1
24	valid	80	hand	0,01	1,5	60,15	17,19	tractor	2	120,3	none	-	0	-	-	hand	none	
25	valid	100	hand	0,006	1,67	66,85	17,83	tractor	2	133,7	none	-	0	-	-	hand	other	
26	valid	250	hand	0,003	0,35	21,3	5,33	tractor	2	42,67	none	-	0	-	-	hand	none	
27	valid	90	hand	0,0007	1,49	44,6	10,04	tractor	2	89,2	none	-	0	-	-	hand	2100	0,33
28	valid	80	hand	0,0005	0,094	18,75	4,55	tractor	2	37,5	none	-	0	-	-	hand	none	
29	valid	110	hand	0,0073	0,27	13,38	3,34	tractor	2	26,75	none	-	0	-	-	hand	manure	12,83

OPU: Olive Production Unit
≡ 3.83kg Olives
≡ 1 Litre Olive Oil

Data was judged as inaccurate, thus it was not included in calculations.

Q No: Questionnaire Number
TREES: Number of trees
PLANTING: Planting technique
TREES/OPU: Number of trees planted per OPU
M^2/OPU: Land area used per OPU
M^2*Y/OPU: Land area used for 1 year per OPU
M^2*Y/KG: Land area used for 1 year per kilo of olives produced
TIL METHOD: Tillage method
TIL/YEAR: Tillage: times applied per year

TIL M^2/OPU: Tillage area per OPU
IRRIGATION: Irrigation method
W SOURCE: Water source
W DIST: Distance of water source from orchard
W EXT: Water extraction equipment type
W M^3/OPU: Water consumption (in m^3) per OPU
F METH: Fertiliser application method
F TYPE: Fertiliser type
F KG/OPU: Amount of fertiliser used per OPU

Q No	Assessed Validity	TREES	PEST METHOD	P TYPE	P KG/OPU	HERB METHOD	H TYPE	H KG/OPU	PRUN METHOD	P TR/OPU	P T/YEAR	PW METHOD	COLLECTION METHOD	C KG/OPU	C TRANS
1	valid	100	-	-	-	weed control through tillage	-	-	chainsaw	0,4	1	burned	hand-held pneumatic combs	4	transport van
2	valid	350	manual sprayer	Dimethoate based	0,003	weed control through tillage	-	-	air compressor	0,05	0,25	burned	hand-held pneumatic combs	4,7	transport van
3	valid	350	-		-	weed control through tillage	-	-	saw/scissors	0,35	0,5	burned	hand-held pneumatic combs	4	transport van
4	invalid	200	compressed air sprayer	Dimethoate based	-	weed control through tillage	-	-	air compressor		1	burned	hand-held pneumatic combs	-	lorry
5	valid	300	-	-	-	weed control through tillage	-	-	air compressor	0,07	0,25	burned	poles	4	transport van
6	invalid	260	-	-	-	weed control through tillage	-	-	-	-	0,2	burned	-	-	-
7	invalid	200	manual sprayer	-	-	weed control through tillage	-	-	chainsaw	-	1	burned	hand rakes	-	transport van
8	valid	250	-	-	-	weed control through tillage	-	-	saw/scissors	0,63	0,25	burned	hand rakes	3,33	transport van
9	valid	150	bait	Dimethoate based	-	weed control through tillage	-	-	air compressor	0,03	0,33	burned	hand-held pneumatic combs	4,2	transport van
10	valid	150	manual sprayer	-	-	weed control through tillage	-	-	saw/scissors	2	1	burned	hand rakes	4	transport van
11	valid	400	bait	Dimethoate based	-	weed control through tillage	-	-	chainsaw	0,13	1	burned	poles	4,3	transport van
12	valid	200	bait	Dimethoate based	-	weed control through tillage	-	-	chainsaw	0,66	0,33	burned	hand rakes	5	transport van
13	valid	180	manual sprayer	-	-	weed control through tillage	-	-	saw/scissors	0,36	1	burned	hand rakes	4	transport van
14	valid	300	compressed air sprayer	Dimethoate based	0,005	compressed air sprayer	-	0,005	air compressor	0,3	1	burned	hand-held pneumatic combs	4,5	lorry
15	valid	150	-	-	-	weed control through tillage	-	-	chainsaw	0,06	0,25	burned	hand-held pneumatic combs	4,5	transport van
16	valid	300	bait	-	-	weed control through tillage	-	-	chainsaw	0,27	0,5	burned	hand rakes	4,5	transport van
17	valid	500	compressed air sprayer	Dimethoate based	0,08	weed control through tillage	-	-	air compressor	0,27	0,5	burned	hand-held pneumatic combs	4,4	transport van
18	valid	200	manual sprayer	-	0,03	weed control through tillage	-	-	saw/scissors	0,15	0,33	burned	hand rakes	4,9	transport van
19	valid	200	compressed air sprayer	Dimethoate based	-	weed control through tillage	-	-	chainsaw	0,47	0,5	burned	hand-held pneumatic combs	4,3	transport van
20	valid	700	compressed air sprayer	Dimethoate based	0,007	compressed air sprayer	gramoxol	0,004	air compressor	0,35	1	burned	hand-held pneumatic combs	5	transport van
21	valid	200	manual sprayer	Dimethoate based	0,008	weed control through tillage	-	-	chainsaw	0,4	1	burned	hand-held pneumatic combs	4	transport van
22	valid	300	compressed air sprayer	Dimethoate based	0,13	weed control through tillage	-	-	chainsaw	1	1	burned	hand-held pneumatic combs	5	transport van
23	valid	1500	bait	Lambda-cyhalothrin	-	weed control through tillage	-	-	chainsaw	0,33	1	burned	hand-held pneumatic combs	4,5	lorry
24	valid	80	-	-	-	weed control through tillage	-	-	chainsaw	0,4	1	burned	hand rakes	3,5	transport van
25	valid	100	compressed air sprayer	-	-	weed control through tillage	-	-	chainsaw	0,25	1	burned	hand rakes	3,75	transport van
26	valid	250	-	-	-	weed control through tillage	-	-	saw/scissors	0,17	1	burned	hand-held pneumatic combs	4	transport van
27	valid	90	-	-	-	weed control through tillage	-	-	saw/scissors	0,2	1	burned	hand rakes	4,44	transport van
28	valid	80	-	-	-	weed control through tillage	-	-	chainsaw	0,2	0,5	burned	hand-held pneumatic combs	4,125	transport van
29	valid	110	-	-	-	weed control through tillage	-	-	saw/scissors	0,18	0,5	burned	poles	4	transport van
Total		8150													

PEST METHOD: Pesticide method
P TYPE: Pesticide type
P KG/OPU: Amount of pesticide used per OPU
HERB METHOD: Herbicide method
H TYPE: Herbicide type
H KG/OPU: Amount of herbicide used per OPU
PRUN METHOD: Pruning method

P TR/OPU: Number of pruned trees per OPU
P T/YEAR: Pruning: Times applied per year
PW METHOD: Pruning waste management method
COLLECTION METHOD: Collection method
C KG/OPU: Collected olives (in kg) per OPU
C TRANS: Collected olives transportation

Number of Trees planted per OPU

Q No	Trees	Trees/OPU
1	100	0,004
2	350	0,004
3	350	0,005
5	300	0,002
8	250	0,008
9	150	0,005
10	150	0,25
11	400	0,0002
12	200	0,005
13	180	0,04
14	300	0,003
15	150	0,008
16	300	0,003
17	500	0,001
18	200	0,02
19	200	0,01
20	700	0,002
21	200	0,005
22	300	0,005
23	1500	0,0011
24	80	0,01
25	100	0,006
26	250	0,003
27	90	0,0007
28	80	0,0005
29	110	0,0073
Average		0,009450734
Range of Values		0,0002 - 0,25
St. Deviation 1		0,035027272
St. Deviation 2		0,048449845

Number of Pruned Trees per OPU

Q No	Trees	Pruned Trees/OPU
1	100	0,4
2	350	0,05
3	350	0,35
5	300	0,07
8	250	0,63
9	150	0,03
10	150	2
11	400	0,13
12	200	0,66
13	180	0,36
14	300	0,3
15	150	0,06
16	300	0,27
17	500	0,27
18	200	0,15
19	200	0,47
20	700	0,35
21	200	0,4
22	300	1
23	1500	0,33
24	80	0,4
25	100	0,25
26	250	0,17
27	90	0,2
28	80	0,2
29	110	0,18
Average		0,35034713
Range of Values		0,03 - 2
St. Deviation 1		0,308061686
St. Deviation 2		0,395163841

Land Area Used (in m^2) per OPU

Q No	Trees	Land m^2/OPU
1	100	0,4
2	350	0,05
3	350	0,71
5	300	0,11
8	250	0,89
11	400	0,02
13	180	0,8
14	300	0,15
15	150	0,15
16	300	0,3
17	500	0,15
18	200	3,47
19	200	0,96
20	700	0,28
21	200	1,53
22	300	0,25
23	1500	0,11
24	80	1,5
25	100	1,67
26	250	0,35
27	90	1,49
28	80	0,094
29	110	0,27
Average		0,44632618
Range of Values		0,02 - 3,47
St. Deviation 1		0,841380358
St. Deviation 2		0,835033561

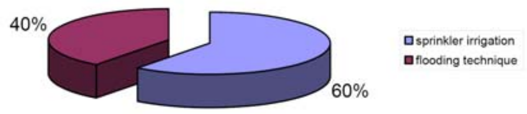
Land Tillage (in m^2) per OPU

Q No	Trees	Tillage m^2/OPU
1	100	40
2	350	73,1
3	350	214
5	300	48
8	250	89,2
11	400	30
13	180	16,1
14	300	52,5
15	150	89,1
16	300	120
17	500	148,6
18	200	173
19	200	286,7
20	700	124,5
21	200	107
22	300	100
23	1500	66,7
24	80	120,3
25	100	133,7
26	250	42,67
27	90	89,2
28	80	37,5
29	110	26,75
Average		96,37625179
Range of Values		16,1 - 286,7
St. Deviation 1		57,75276191
St. Deviation 2		65,07406449

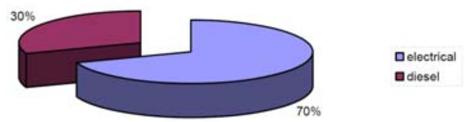
Irrigation Method

Q No	Trees	Irrigation Method
1	100	sprinkler irrigation
2	350	sprinkler irrigation
3	350	none
5	300	sprinkler irrigation
8	250	none
9	150	none
10	150	sprinkler irrigation
11	400	none
12	200	none
13	180	sprinkler irrigation
14	300	none
15	150	none
16	300	none
17	500	none
18	200	sprinkler irrigation
19	200	none
20	700	sprinkler irrigation
21	200	none
22	300	sprinkler irrigation
23	1500	flooding technique
24	80	none
25	100	none
26	250	none
27	90	none
28	80	none
29	110	none

Irrigation Method	Trees
sprinkler irrigation	2280
flooding technique	1500



Pump Type	Trees
electrical	2630
diesel	1150



Water origin and Water Extraction Equipment (pump) Type

Q No	Trees	W origin	W EXT (Pump Type)
1	100	bore-hole	electrical
2	350	bore-hole	electrical
5	300	bore-hole	electrical
10	150	bore-hole	diesel
13	180	bore-hole	electrical
18	200	bore-hole	electrical
20	700	bore-hole	diesel
22	300	bore-hole	diesel
23	1500	bore-hole	electrical

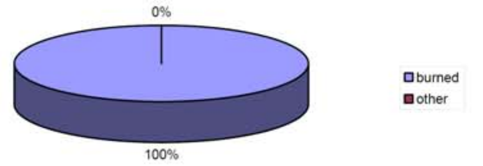
Amount of Water Used per OPU

Q No	Trees	Irrigation Method	m^3/ OPU
1	100	sprinkler irrigation	-
2	350	sprinkler irrigation	0,63
5	300	sprinkler irrigation	1,8
10	150	sprinkler irrigation	-
13	180	sprinkler irrigation	-
18	200	sprinkler irrigation	-
20	700	sprinkler irrigation	1,125
22	300	sprinkler irrigation	2,56
23	1500	flooding technique	1,556
Average for flooding technique			1,556
Average for sprinkler irrigation			1,403636364
St.Deviation 1 for sprinkler irrigation			0,657148351
St.Deviation 2 for sprinkler irrigation			0,838216112

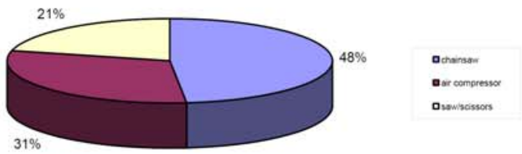
Pruning and Waste Management Method

Q No	Trees	Pruning Method	Waste Management Method
1	100	chainsaw	burned
2	350	air compressor	burned
3	350	saw/scissors	burned
5	300	air compressor	burned
8	250	saw/scissors	burned
9	150	air compressor	burned
10	150	saw/scissors	burned
11	400	chainsaw	burned
12	200	chainsaw	burned
13	180	saw/scissors	burned
14	300	air compressor	burned
15	150	chainsaw	burned
16	300	chainsaw	burned
17	500	air compressor	burned
18	200	saw/scissors	burned
19	200	chainsaw	burned
20	700	air compressor	burned
21	200	chainsaw	burned
22	300	chainsaw	burned
23	1500	chainsaw	burned
24	80	chainsaw	burned
25	100	chainsaw	burned
26	250	saw/scissors	burned
27	90	saw/scissors	burned
28	80	chainsaw	burned
29	110	saw/scissors	burned

Waste Management Method	Trees
burned	7490
other	0



Pruning Method	Trees
chainsaw	3610
air compressor	2300
saw/scissors	1580



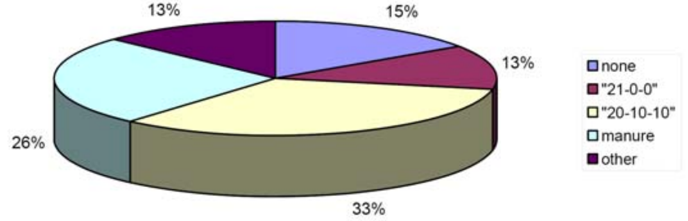
Pruning: Application Times per Year

Q No	Trees	P t/year
1	100	1
2	350	0,25
3	350	0,5
5	300	0,25
8	250	0,25
9	150	0,33
10	150	1
11	400	1
12	200	0,33
13	180	1
14	300	1
15	150	0,25
16	300	0,5
17	500	0,5
18	200	0,33
19	200	0,5
20	700	1
21	200	1
22	300	1
23	1500	1
24	80	1
25	100	1
26	250	1
27	90	1
28	80	0,5
29	110	0,5
Average		0,74286

Fertiliser Type and Amount Used per OPU

Q No	Trees	F Type	F kg/ OPU
1	100	none	-
2	350	other	0,25
3	350	"20-10-10"	0,046
5	300	manure	-
8	250	none	-
9	150	other	2
10	150	"20-10-10"	-
11	400	none	-
12	200	other	-
13	180	other	1
14	300	"20-10-10"	1
15	150	"21-0-0"	0,42
16	300	"21-0-0"	1,1
17	500	"20-10-10"	0,55
18	200	"21-0-0"	2,22
19	200	"20-10-10"	0,71
20	700	"20-10-10"	2
21	200	"21-0-0"	1
22	300	"20-10-10"	3,5
23	1500	manure	11.1
24	80	none	-
25	100	other	-
26	250	none	-
27	90	"21-0-0"	0,33
28	80	none	-
29	110	manure	12,83

F Type	Trees
none	1160
"21-0-0"	940
"20-10-10"	2500
manure	1910
other	980



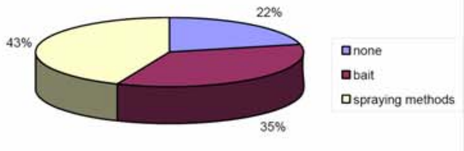
Amount of Fertiliser "20-10-10" Used per OPU

Q No	Trees	F Type	F kg/ OPU
3	350	"20-10-10"	0,046
10	150	"20-10-10"	-
14	300	"20-10-10"	1
17	500	"20-10-10"	0,55
19	200	"20-10-10"	0,71
20	700	"20-10-10"	2
22	300	"20-10-10"	3,5
Average			1,354510638
Range of Values			0,046 - 3,5
St. Deviation 1			1,075337481
St. Deviation 2			1,257227903

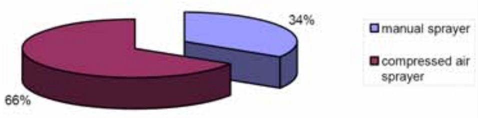
Pesticide Method and Type

Q No	Trees	Pesticide Method	P Type
1	100	none	
2	350	manual sprayer	Dimethoate based
3	350	none	
5	300	none	
8	250	none	
9	150	δόλωμα	Dimethoate based
10	150	manual sprayer	
11	400	δόλωμα	Dimethoate based
12	200	δόλωμα	Dimethoate based
13	180	manual sprayer	
14	300	compressed air sprayer	Dimethoate based
15	150	none	
16	300	δόλωμα	
17	500	compressed air sprayer	Dimethoate based
18	200	manual sprayer	
19	200	compressed air sprayer	Dimethoate based
20	700	compressed air sprayer	Dimethoate based
21	200	manual sprayer	Dimethoate based
22	300	compressed air sprayer	Dimethoate based
23	1500	δόλωμα	Lambda-cyhalothrin
24	80	none	
25	100	compressed air sprayer	
26	250	none	
27	90	none	

Pesticide Method	Trees
none	1570
bait	2550
spraying methods	3180



Spraying Techniques	Trees
manual sprayer	1080
compressed air sprayer	2100



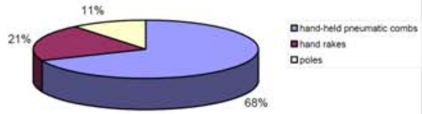
Amount of Pesticide Used per OPU

Q No	Trees	Pesticide Method	P Type	P kg/OPU
2	350	manual sprayer	Dimethoate based	0,003
14	300	compressed air sprayer	Dimethoate based	0,005
17	500	compressed air sprayer	Dimethoate based	0,08
18	200	manual sprayer	Dimethoate based	0,03
20	700	compressed air sprayer	Dimethoate based	0,007
21	200	manual sprayer	Dimethoate based	0,008
22	300	compressed air sprayer	Dimethoate based	0,13
		Average		0,036882353
		St. Deviation 1		0,044461667
		St. Deviation 2		0,04910145
		Range of Values		0,003 - 0,13

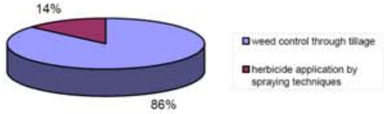
Herbicide Method and Amount Used per OPU

Q No	Trees	Herbicide Method	H Type	H kg/ OPU
1	100	weed control through tillage	-	-
2	350	weed control through tillage	-	-
3	350	weed control through tillage	-	-
5	300	weed control through tillage	-	-
8	250	weed control through tillage	-	-
9	150	weed control through tillage	-	-
10	150	weed control through tillage	-	-
11	400	weed control through tillage	-	-
12	200	weed control through tillage	-	-
13	180	weed control through tillage	-	-
14	300	spraying techniques	-	0,005
15	150	weed control through tillage	-	-
16	300	weed control through tillage	-	-
17	500	weed control through tillage	-	-
18	200	weed control through tillage	-	-
19	200	weed control through tillage	-	-
20	700	spraying techniques	gramoxol	0,004
21	200	weed control through tillage	-	-
22	300	weed control through tillage	-	-
23	1500	weed control through tillage	-	-
24	80	weed control through tillage	-	-
25	100	weed control through tillage	-	-
26	250	weed control through tillage	-	-
27	90	weed control through tillage	-	-

Collection Method	Trees
hand-held pneumatic combs	5130
hand rakes	1550
poles	810



Herbicide Method	Trees
weed control through tillage	6300
herbicide application by spraying techniques	1000



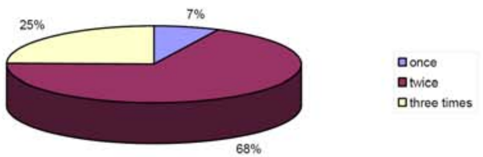
Collection Method and Olive Transportation

Q No	Trees	Collection Method	Olive Trasnportation
1	100	hand-held pneumatic combs	transport van
2	350	hand-held pneumatic combs	transport van
3	350	hand-held pneumatic combs	transport van
5	300	poles	transport van
8	250	hand rakes	transport van
9	150	hand-held pneumatic combs	transport van
10	150	hand rakes	transport van
11	400	poles	transport van
12	200	hand rakes	transport van
13	180	hand rakes	transport van
14	300	hand-held pneumatic combs	lorry
15	150	hand-held pneumatic combs	transport van
16	300	hand rakes	transport van
17	500	hand-held pneumatic combs	transport van
18	200	hand rakes	transport van
19	200	hand-held pneumatic combs	transport van
20	700	hand-held pneumatic combs	transport van
21	200	hand-held pneumatic combs	transport van
22	300	hand-held pneumatic combs	transport van
23	1500	hand-held pneumatic combs	lorry
24	80	hand rakes	transport van
25	100	hand rakes	transport van
26	250	hand-held pneumatic combs	transport van
27	90	hand rakes	transport van
28	80	hand-held pneumatic combs	transport van
29	110	poles	transport van

Tillage: Times Applied per Annum

Q No	Trees	Tillage Times
1	100	1
2	350	3
3	350	2
5	300	3
8	250	1
9	150	2
10	150	2
11	400	2
12	200	2
13	180	2
14	300	3
15	150	2
16	300	2
17	500	2
18	200	2
19	200	3
20	700	3
21	200	1
22	300	2
23	1500	2
24	80	2
25	100	2
26	250	2
27	90	2
28	80	2
29	110	2

Tillage: Times Applied per Annum	Trees
once	550
twice	5090
three times	1850

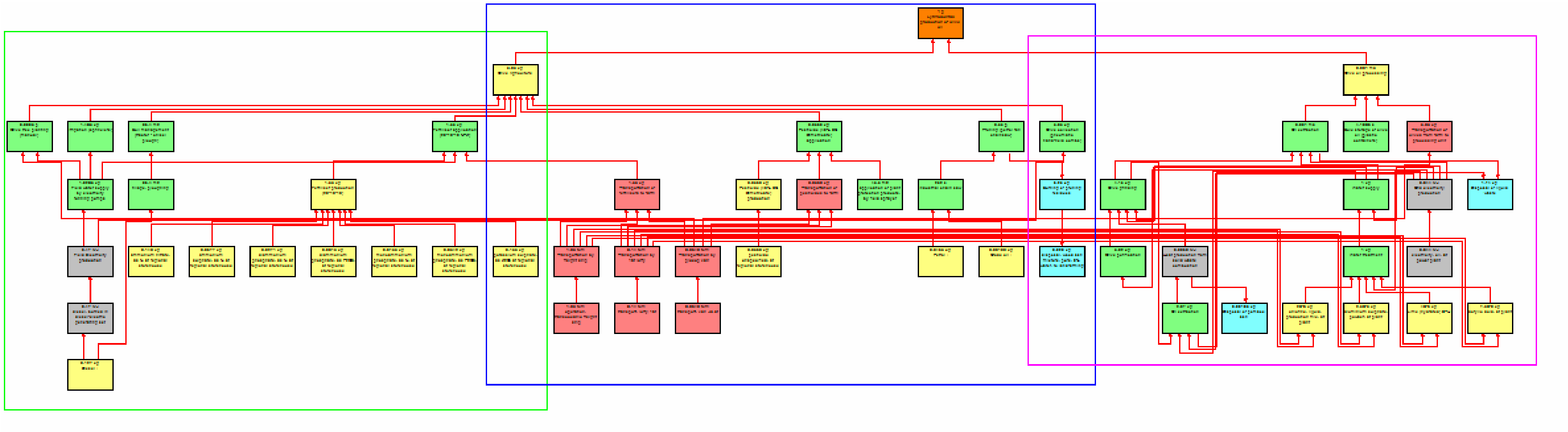


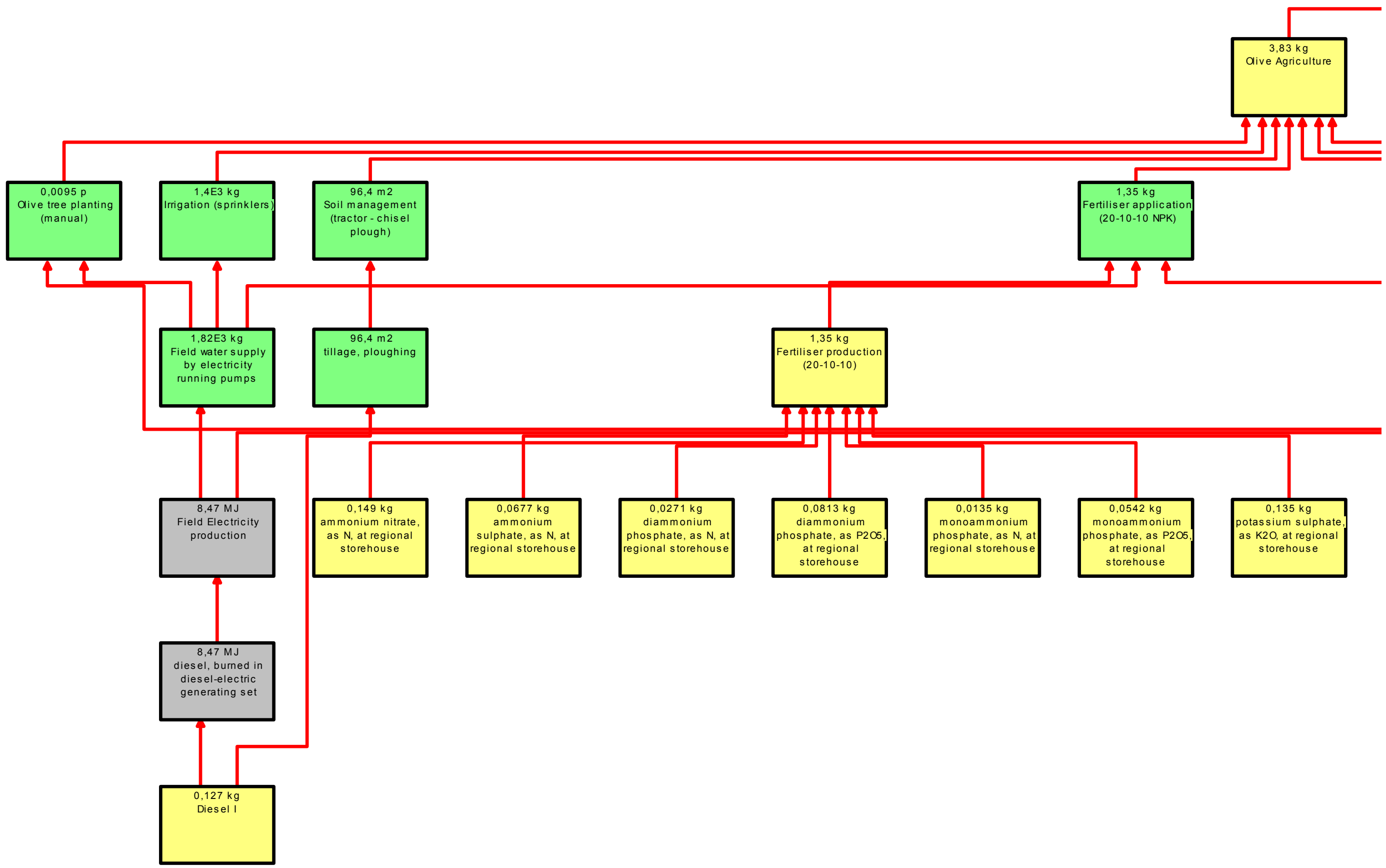
Land Use

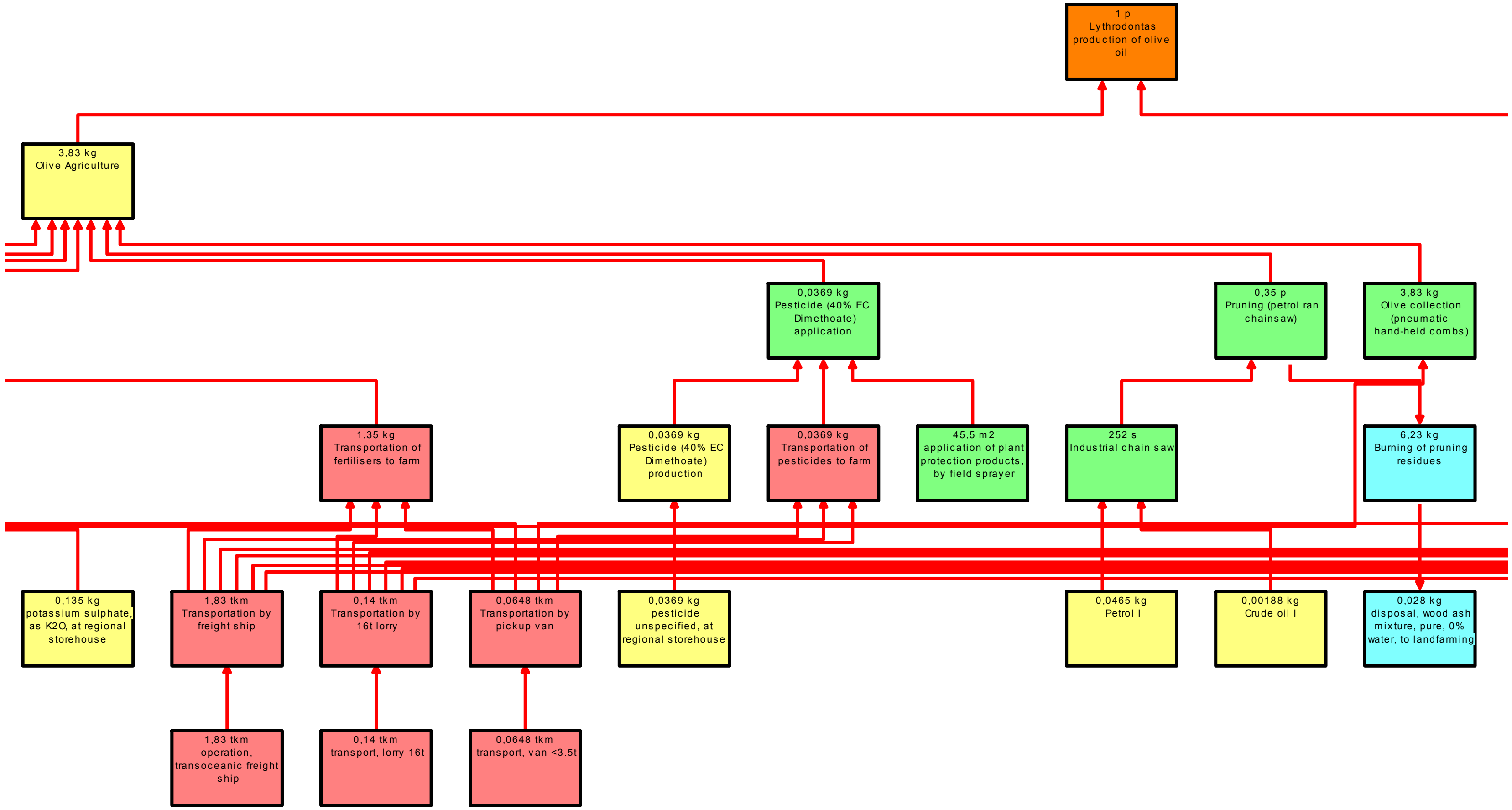
Q No	Trees	m^2*year/OPU
1	100	40
2	350	24,375
3	350	107,24
5	300	16
8	250	89,19
10	150	142,7
11	400	15
12	200	66,85
13	180	8,03
14	300	15
15	150	44,57
16	300	60
17	500	74,28
18	200	86,67
19	200	95,56
20	700	41,5
21	200	107,96
22	300	50
23	1500	33,3
24	80	60,15
25	100	66,85
26	250	21,3
27	90	44,6
28	80	18,75
29	110	13,38
Average		49,25809946
Range of Values		8,03 - 142,7
St. Deviation 1		31,44887146
St. Deviation 2		35,86609194

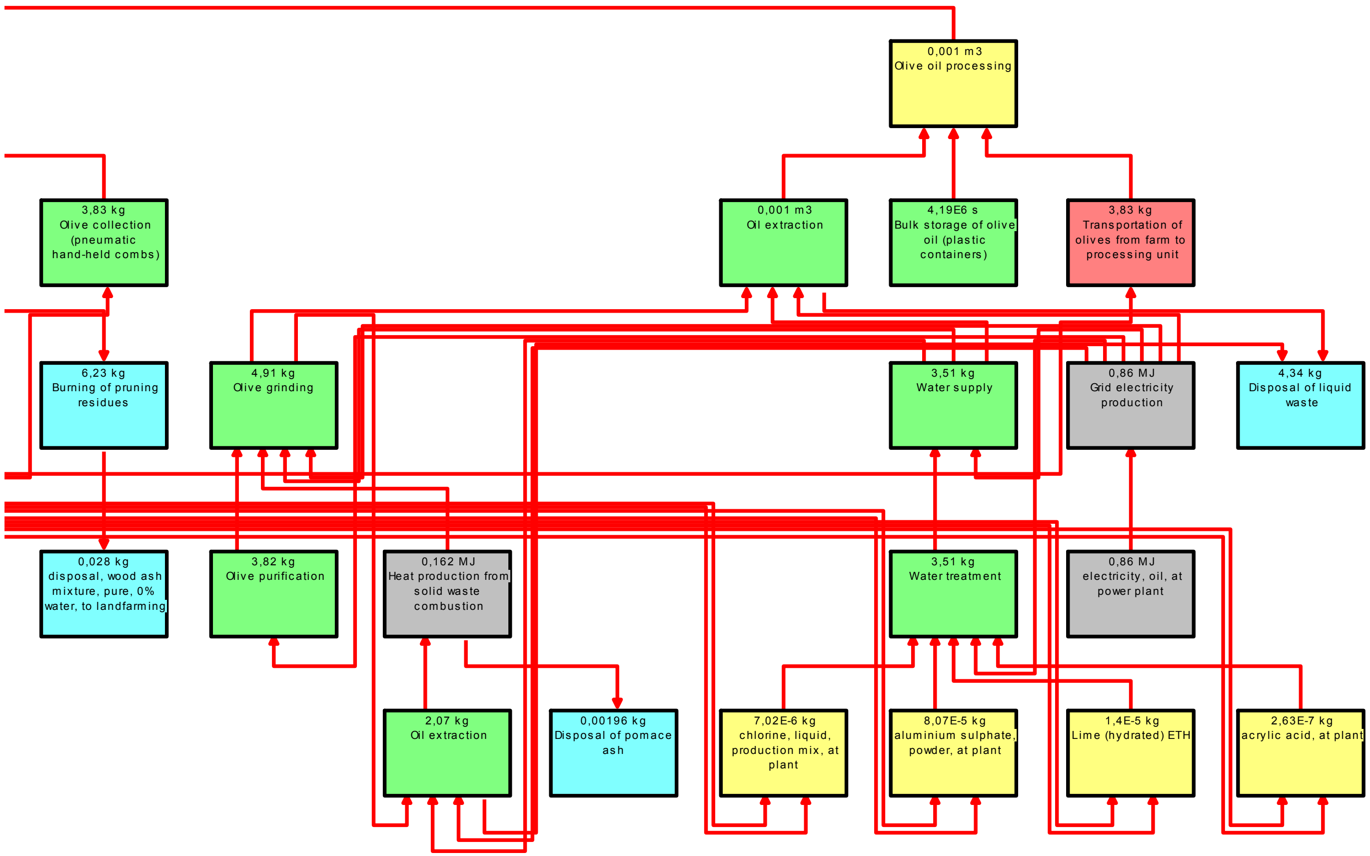
Q No	Trees	m^2*year/ 1kg Olives
1	100	10
2	350	5,2
3	350	26,76
5	300	4
8	250	26,76
10	150	35,67
11	400	3,46
12	200	13,37
13	180	2,01
14	300	3,33
15	150	9,9
16	300	13,2
17	500	16,71
18	200	17,73
19	200	22,3
20	700	8,3
21	200	26,74
22	300	10
23	1500	7,41
24	80	17,19
25	100	17,83
26	250	5,33
27	90	10,04
28	80	4,55
29	110	3,34
Average		11,4509537
Range of Values		2,01 - 35,67
St. Deviation 1		8,0358002
St. Deviation 2		9,13983685

10 Appendix C: Lythrodontas Olive Oil Life Cycle Network Diagram




3,83 kg
Olive Agriculture
0,0095 p
Olive tree planting (manual)
1,4E3 kg
Irrigation (sprinklers)
96,4 m2
Soil management (tractor - chisel plough)
1,35 kg
Fertiliser application (20-10-10 NPK)
1,82E3 kg
Field water supply by electricity running pumps
96,4 m2
tillage, ploughing
1,35 kg
Fertiliser production (20-10-10)
8,47 MJ
Field Electricity production
0,149 kg
ammonium nitrate, as N, at regional storehouse
0,0677 kg
ammonium sulphate, as N, at regional storehouse
0,0271 kg
diammonium phosphate, as N, at regional storehouse
0,0813 kg
diammonium phosphate, as P2O5, at regional storehouse
0,0135 kg
monoammonium phosphate, as N, at regional storehouse
0,0542 kg
monoammonium phosphate, as P2O5, at regional storehouse
0,135 kg
potassium sulphate, as K2O, at regional storehouse
8,47 MJ
diesel, burned in diesel-electric generating set
0,127 kg
Diesel I


1 p
Lythrodontas production of olive oil
3,83 kg
Olive Agriculture
0,0369 kg
Pesticide (40% EC Dimethoate) application
0,35 p
Pruning (petrol ran chainsaw)
3,83 kg
Olive collection (pneumatic hand-held combs)
1,35 kg
Transportation of fertilisers to farm
0,0369 kg
Pesticide (40% EC Dimethoate) production
0,0369 kg
Transportation of pesticides to farm
45,5 m2
application of plant protection products, by field sprayer
252 s
Industrial chain saw
6,23 kg
Burning of pruning residues
0,135 kg
potassium sulphate, as K2O, at regional storehouse
1,83 tkm
Transportation by freight ship
0,14 tkm
Transportation by 16t lorry
0,0648 tkm
Transportation by pickup van
0,0369 kg
pesticide unspecified, at regional storehouse
0,0465 kg
Petrol I
0,00188 kg
Crude oil I
0,028 kg
disposal, wood ash mixture, pure, 0% water, to landfarming
1,83 tkm
operation, transoceanic freight ship
0,14 tkm
transport, lorry 16t
0,0648 tkm
transport, van <3.5t


0,001 m3
Olive oil processing
3,83 kg
Olive collection (pneumatic hand-held combs)
0,001 m3
Oil extraction
4,19E6 s
Bulk storage of olive oil (plastic containers)
3,83 kg
Transportation of olives from farm to processing unit
6,23 kg
Burning of pruning residues
4,91 kg
Olive grinding
3,51 kg
Water supply
0,86 MJ
Grid electricity production
4,34 kg
Disposal of liquid waste
0,028 kg
disposal, wood ash mixture, pure, 0% water, to landfarming
3,82 kg
Olive purification
0,162 MJ
Heat production from solid waste combustion
3,51 kg
Water treatment
0,86 MJ
electricity, oil, at power plant
2,07 kg
Oil extraction
0,00196 kg
Disposal of pomace ash
7,02E-6 kg
chlorine, liquid, production mix, at plant
8,07E-5 kg
aluminium sulphate, powder, at plant
1,4E-5 kg
Lime (hydrated) ETH
2,63E-7 kg
acrylic acid, at plant

11 Appendix D: Lythrodontas Olive Oil Life Cycle Inventory

No	Substance	Compartment	Unit	Total	Agriculture	Processing
1	Aluminium, 24% in bauxite, 11% in crude ore, in ground	Raw	mg	37.00	21.40	15.70
2	Anhydrite, in ground	Raw	µg	3.08	2.77	0.31
3	Barite, 15% in crude ore, in ground	Raw	mg	5.34	5.29	0.04
4	Basalt, in ground	Raw	µg	190.00	185.00	4.83
5	Bauxite, in ground	Raw	mg	60.10	60.10	0.00
6	Borax, in ground	Raw	µg	1.10	1.08	0.02
7	Calcite, in ground	Raw	g	32.80	29.60	3.16
8	Carbon dioxide, in air	Raw	kg	3.36	3.36	0.00
9	Chromium, 25.5 in chromite, 11.6% in crude ore, in ground	Raw	mg	1.40	1.38	0.02
10	Chrysotile, in ground	Raw	µg	55.70	55.30	0.41
11	Cinnabar, in ground	Raw	µg	5.15	5.11	0.04
12	Clay, bentonite, in ground	Raw	mg	15.30	15.10	0.22
13	Clay, unspecified, in ground	Raw	mg	301.00	301.00	0.60
14	Coal, brown, in ground	Raw	g	67.80	66.90	0.94
15	Coal, hard, unspecified, in ground	Raw	g	51.50	51.00	0.53
16	Cobalt, in ground	Raw	µg	1.51	1.46	0.05
17	Colemanite, in ground	Raw	µg	27.50	27.10	0.38
18	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground	Raw	µg	5.41	5.23	0.18
19	Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore, in ground	Raw	µg	27.90	27.20	0.72
20	Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground	Raw	µg	7.39	7.20	0.19
21	Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground	Raw	µg	36.70	35.70	0.95
22	Copper, in ground	Raw	ng	220.00	0.00	220.00
23	Diatomite, in ground	Raw	ng	1.23	1.21	0.02
24	Dolomite, in ground	Raw	µg	20.90	20.30	0.57
25	Energy, gross calorific value, in biomass	Raw	kJ	44.60	44.20	0.42
26	Energy, kinetic, flow, in wind	Raw	kJ	49.80	49.10	0.69
27	Energy, potential, stock, in barrage water	Raw	kJ	313.00	309.00	3.99
28	Energy, solar	Raw	J	659.00	649.00	9.06
29	Energy, unspecified	Raw	kJ	162.00	162.00	0.00
30	Feldspar, in ground	Raw	ng	3.83	3.36	0.46
31	Fluorine, 4.5% in apatite, 1% in crude ore, in ground	Raw	mg	5.56	5.53	0.03
32	Fluorine, 4.5% in apatite, 3% in crude ore, in ground	Raw	g	16.30	16.30	0.00
33	Fluorspar, 92%, in ground	Raw	mg	144.00	143.00	0.83
34	Gas, mine, off-gas, process, coal mining/kg	Raw	µg	10.70	0.00	10.70
35	Gas, mine, off-gas, process, coal mining/m3	Raw	cm3	500.00	495.00	5.20
36	Gas, natural, in ground	Raw	l	331.00	328.00	2.95
37	Gas, petroleum, 35 MJ per m3, in ground	Raw	mm3	11.40	0.00	11.40
38	Granite, in ground	Raw	ng	59.80	58.30	1.50
39	Gravel, in ground	Raw	g	3.12	3.12	0.00
40	Gypsum, in ground	Raw	µg	21.80	20.90	0.87
41	Iron, 46% in ore, 25% in crude ore, in ground	Raw	mg	34.60	34.40	0.20
42	Kaolinite, 24% in crude ore, in ground	Raw	µg	321.00	316.00	4.59
43	Kieserite, 25% in crude ore, in ground	Raw	µg	1.04	1.02	0.01

No	Substance	Compartment	Unit	Total	Agriculture	Processing
44	Land use II-III	Raw	mm2a	0.05	0.00	0.05
45	Land use II-III, sea floor	Raw	mm2a	0.03	0.00	0.03
46	Land use II-IV	Raw	mm2a	0.01	0.00	0.01
47	Land use II-IV, sea floor	Raw	mm2a	0.00	0.00	0.00
48	Land use III-IV	Raw	mm2a	0.01	0.00	0.01
49	Land use IV-IV	Raw	mm2a	0.00	0.00	0.00
50	Lead, 5%, in sulfide, Pb 2.97% and Zn 5.34% in crude ore, in ground	Raw	µg	84.50	83.10	1.45
51	Lead, in ground	Raw	ng	60.40	0.00	60.40
52	Limestone, in ground	Raw	mg	17.80	17.80	0.00
53	Magnesite, 60% in crude ore, in ground	Raw	µg	357.00	355.00	1.76
54	Magnesium, 0.13% in water	Raw	pg	814.00	797.00	17.80
55	Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground	Raw	µg	16.60	16.20	0.34
56	Marl, in ground	Raw	mg	21.20	0.00	21.20
57	Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground	Raw	ng	682.00	664.00	17.60
58	Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground	Raw	ng	97.00	94.50	2.51
59	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground	Raw	µg	20.60	20.00	0.59
60	Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground	Raw	ng	356.00	347.00	9.20
61	Molybdenum, 0.11% in sulfide, Mo 4.1E-2% and Cu 0.36% in crude ore, in ground	Raw	µg	41.50	40.30	1.19
62	Molybdenum, in ground	Raw	pg	0.34	0.00	0.34
63	Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground	Raw	mg	98.90	98.80	0.06
64	Nickel, 1.98% in silicates, 1.04% in crude ore, in ground	Raw	mg	2.31	2.28	0.03
65	Nickel, in ground	Raw	ng	15.40	0.00	15.40
66	Occupation, arable, non-irrigated	Raw	mm2a	0.73	0.71	0.01
67	Occupation, construction site	Raw	mm2a	378.00	378.00	0.16
68	Occupation, dump site	Raw	cm2a	15.10	15.10	0.03
69	Occupation, dump site, benthos	Raw	mm2a	0.03	0.03	0.00
70	Occupation, forest, intensive	Raw	mm2a	27.80	27.60	0.20
71	Occupation, forest, intensive, normal	Raw	mm2a	456.00	450.00	6.32
72	Occupation, industrial area	Raw	cm2a	10.70	10.70	0.03
73	Occupation, industrial area, benthos	Raw	mm2a	0.00	0.00	0.00
74	Occupation, industrial area, built up	Raw	mm2a	0.20	0.20	0.01
75	Occupation, industrial area, vegetation	Raw	mm2a	0.08	0.08	0.00
76	Occupation, mineral extraction site	Raw	cm2a	22.00	22.00	0.03
77	Occupation, permanent crop, fruit	Raw	m2a	49.30	49.30	0.00
78	Occupation, permanent crop, fruit, intensive	Raw	mm2a	549.00	549.00	0.23
79	Occupation, shrub land, sclerophyllous	Raw	mm2a	202.00	202.00	0.02
80	Occupation, traffic area, rail embankment	Raw	mm2a	0.09	0.09	0.00
81	Occupation, traffic area, rail network	Raw	mm2a	0.10	0.10	0.00
82	Occupation, traffic area, road embankment	Raw	mm2a	4.98	4.91	0.07
83	Occupation, traffic area, road network	Raw	mm2a	0.40	0.40	0.01
84	Occupation, urban, discontinuously built	Raw	mm2a	0.00	0.00	0.00
85	Occupation, water bodies, artificial	Raw	mm2a	388.00	383.00	5.16

No	Substance	Compartment	Unit	Total	Agriculture	Processing
86	Occupation, water courses, artificial	Raw	mm2a	193.00	191.00	2.56
87	Oil, crude, in ground	Raw	g	495.00	434.00	61.40
88	Olivine, in ground	Raw	ng	987.00	887.00	100.00
89	Palladium, in ground	Raw	pg	0.04	0.00	0.04
90	Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw	µg	1.45	1.37	0.09
91	Pd, Pd 7.3E-4%, Pt 2.5E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw	µg	3.49	3.28	0.21
92	Peat, in ground	Raw	µg	341.00	340.00	1.47
93	Phosphorus, 18% in apatite, 12% in crude ore, in ground	Raw	g	65.00	65.00	0.00
94	Phosphorus, 18% in apatite, 4% in crude ore, in ground	Raw	mg	22.20	22.10	0.12
95	Platinum, in ground	Raw	pg	0.05	0.00	0.05
96	Pt, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw	ng	33.40	31.40	2.01
97	Pt, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw	ng	120.00	113.00	7.21
98	Rh, Rh 2.0E-5%, Pt 2.5E-4%, Pd 7.3E-4%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw	ng	33.20	31.20	2.00
99	Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw	ng	104.00	97.80	6.25
100	Rhenium, in crude ore, in ground	Raw	ng	31.00	27.30	3.69
101	Rhenium, in ground	Raw	pg	0.04	0.00	0.04
102	Rhodium, in ground	Raw	pg	0.04	0.00	0.04
103	Rutile, in ground	Raw	ng	3.82	3.36	0.46
104	Sand, unspecified, in ground	Raw	µg	78.30	57.00	21.30
105	Shale, in ground	Raw	µg	8.74	7.85	0.89
106	Silver, 0.01% in crude ore, in ground	Raw	pg	147.00	144.00	2.27
107	Silver, in ground	Raw	pg	519.00	0.00	519.00
108	Sodium chloride, in ground	Raw	g	2.40	2.38	0.02
109	Sodium sulphate, various forms, in ground	Raw	mg	46.60	46.30	0.26
110	Stibnite, in ground	Raw	pg	128.00	126.00	1.78
111	Sulfur, in ground	Raw	µg	63.00	56.60	6.41
112	Sylvite, 25 % in sylvinite, in ground	Raw	g	264.00	264.00	0.00
113	Talc, in ground	Raw	µg	41.60	41.00	0.52
114	Tin, 79% in cassiterite, 0.1% in crude ore, in ground	Raw	ng	199.00	195.00	4.42
115	Tin, in ground	Raw	pg	289.00	0.00	289.00
116	TiO2, 45-60% in Ilmenite, in ground	Raw	mg	90.10	89.60	0.54
117	Transformation, from arable	Raw	mm2	0.01	0.00	0.00
118	Transformation, from arable, non-irrigated	Raw	mm2	1.34	1.31	0.02
119	Transformation, from arable, non-irrigated, fallow	Raw	mm2	0.00	0.00	0.00
120	Transformation, from dump site, inert material landfill	Raw	mm2	0.00	0.00	0.00
121	Transformation, from dump site, residual material landfill	Raw	mm2	40.30	40.30	0.00
122	Transformation, from dump site, sanitary landfill	Raw	mm2	0.04	0.03	0.00

No	Substance	Compartment	Unit	Total	Agriculture	Processing
123	Transformation, from dump site, slag compartment	Raw	mm2	0.00	0.00	0.00
124	Transformation, from forest	Raw	mm2	0.30	0.28	0.02
125	Transformation, from forest, extensive	Raw	mm2	14.70	14.60	0.06
126	Transformation, from industrial area	Raw	mm2	0.38	0.35	0.03
127	Transformation, from industrial area, benthos	Raw	mm2	0.00	0.00	0.00
128	Transformation, from industrial area, built up	Raw	mm2	0.01	0.01	0.00
129	Transformation, from industrial area, vegetation	Raw	mm2	0.01	0.01	0.00
130	Transformation, from mineral extraction site	Raw	mm2	103.00	103.00	0.07
131	Transformation, from pasture and meadow	Raw	mm2	141.00	141.00	0.04
132	Transformation, from pasture and meadow, intensive	Raw	mm2	0.00	0.00	0.00
133	Transformation, from sea and ocean	Raw	mm2	0.03	0.03	0.00
134	Transformation, from shrub land, sclerophyllous	Raw	mm2	41.50	41.50	0.02
135	Transformation, from unknown	Raw	mm2	10.80	10.70	0.12
136	Transformation, to arable	Raw	mm2	2.96	2.92	0.04
137	Transformation, to arable, non-irrigated	Raw	mm2	1.34	1.31	0.02
138	Transformation, to arable, non-irrigated, fallow	Raw	mm2	0.00	0.00	0.00
139	Transformation, to dump site	Raw	mm2	2.52	2.50	0.02
140	Transformation, to dump site, benthos	Raw	mm2	0.03	0.03	0.00
141	Transformation, to dump site, inert material landfill	Raw	mm2	0.00	0.00	0.00
142	Transformation, to dump site, residual material landfill	Raw	mm2	40.30	40.30	0.00
143	Transformation, to dump site, sanitary landfill	Raw	mm2	0.04	0.03	0.00
144	Transformation, to dump site, slag compartment	Raw	mm2	0.00	0.00	0.00
145	Transformation, to forest	Raw	mm2	40.80	40.80	0.03
146	Transformation, to forest, intensive	Raw	mm2	0.19	0.18	0.00
147	Transformation, to forest, intensive, normal	Raw	mm2	3.51	3.47	0.05
148	Transformation, to heterogeneous, agricultural	Raw	mm2	0.00	0.00	0.00
149	Transformation, to industrial area	Raw	mm2	3.78	3.74	0.03
150	Transformation, to industrial area, benthos	Raw	mm2	0.00	0.00	0.00
151	Transformation, to industrial area, built up	Raw	mm2	0.07	0.07	0.00
152	Transformation, to industrial area, vegetation	Raw	mm2	0.01	0.01	0.00
153	Transformation, to mineral extraction site	Raw	mm2	105.00	105.00	0.08
154	Transformation, to pasture and meadow	Raw	mm2	99.70	99.70	0.00
155	Transformation, to permanent crop, fruit, intensive	Raw	mm2	11.00	11.00	0.00
156	Transformation, to sea and ocean	Raw	mm2	0.00	0.00	0.00
157	Transformation, to shrub land, sclerophyllous	Raw	mm2	40.30	40.30	0.00
158	Transformation, to traffic area, rail embankment	Raw	mm2	0.00	0.00	0.00
159	Transformation, to traffic area, rail network	Raw	mm2	0.00	0.00	0.00
160	Transformation, to traffic area, road embankment	Raw	mm2	0.04	0.04	0.00
161	Transformation, to traffic area, road network	Raw	mm2	0.00	0.00	0.00
162	Transformation, to unknown	Raw	mm2	0.40	0.37	0.03
163	Transformation, to urban, discontinuously built	Raw	mm2	0.00	0.00	0.00
164	Transformation, to water bodies, artificial	Raw	mm2	2.71	2.67	0.03

No	Substance	Compartment	Unit	Total	Agriculture	Processing
165	Transformation, to water courses, artificial	Raw	mm2	2.39	2.36	0.03
166	Ulexite, in ground	Raw	ng	12.60	12.40	0.20
167	Uranium, 560 GJ per kg, in ground	Raw	ng	9.45	0.00	9.45
168	Uranium, in ground	Raw	mg	3.50	3.45	0.05
169	Vermiculite, in ground	Raw	ng	5.61	4.96	0.65
170	Volume occupied, final repository for low-active radioactive waste	Raw	mm3	7.25	7.15	0.10
171	Volume occupied, final repository for radioactive waste	Raw	mm3	1.82	1.80	0.03
172	Volume occupied, reservoir	Raw	m3day	1.75	1.73	0.02
173	Volume occupied, underground deposit	Raw	mm3	12.20	11.70	0.49
174	Water, cooling, unspecified natural origin/m3	Raw	cm3	7.84	7.84	0.00
175	Water, lake	Raw	mm3	4.32	4.32	0.00
176	Water, river	Raw	cm3	1.52	1.52	0.00
177	Water, salt, ocean	Raw	cm3	542.00	520.00	21.90
178	Water, salt, sole	Raw	cm3	248.00	199.00	48.70
179	Water, turbine use, unspecified natural origin	Raw	l	1.25	1.25	0.00
180	Water, unspecified natural origin/m3	Raw	m3	3.91	3.86	0.05
181	Wood, dry matter	Raw	µg	13.40	0.00	13.40
182	Wood, hard, standing	Raw	mm3	821.00	809.00	11.30
183	Wood, soft, standing	Raw	cm3	2.17	2.14	0.03
184	Wood, unspecified, standing/m3	Raw	mm3	0.01	0.00	0.00
185	Zinc 9%, in sulfide, Zn 5.34% and Pb 2.97% in crude ore, in ground	Raw	µg	137.00	125.00	12.30
186	Zinc, in ground	Raw	ng	1.71	0.00	1.71
187	Acenaphthene	Air	pg	453.00	447.00	6.25
188	Acetaldehyde	Air	mg	1.30	0.82	0.48
189	Acetic acid	Air	g	13.10	13.10	0.00
190	Acetone	Air	mg	1.32	0.84	0.48
191	Acrolein	Air	ng	632.00	624.00	7.09
192	Actinides, radioactive, unspecified	Air	nBq	77.60	76.60	1.07
193	Aerosols, radioactive, unspecified	Air	mBq	1.50	1.48	0.02
194	Aldehydes, unspecified	Air	g	18.70	18.70	0.00
195	Aluminum	Air	mg	83.30	83.30	0.08
196	Americium-241	Air	nBq	0.07	0.00	0.07
197	Ammonia	Air	g	21.20	21.20	0.00
198	Ammonium carbonate	Air	ng	7.88	6.95	0.93
199	Anthracene	Air	mg	67.00	65.40	1.62
200	Antimony	Air	µg	1.60	1.59	0.02
201	Antimony-124	Air	nBq	7.29	7.19	0.10
202	Antimony-125	Air	nBq	76.10	75.10	1.01
203	Argon-41	Air	mBq	948.00	935.00	13.10
204	Arsenic	Air	µg	123.00	84.90	38.50
205	Barium	Air	µg	48.80	48.50	0.31
206	Barium-140	Air	µBq	4.95	4.88	0.07
207	Benzaldehyde	Air	ng	312.00	308.00	3.45
208	Benzene	Air	g	14.40	14.30	0.01
209	Benzene, ethyl-	Air	µg	467.00	379.00	87.70
210	Benzene, hexachloro-	Air	pg	240.00	200.00	40.50
211	Benzene, pentachloro-	Air	pg	457.00	357.00	99.30
212	Benzo(a)anthracene	Air	mg	7.48	7.48	0.00

No	Substance	Compartment	Unit	Total	Agriculture	Processing
213	Benzo(a)pyrene	Air	mg	16.50	16.50	0.00
214	Benzo(b)fluoranthene	Air	mg	17.40	17.40	0.00
215	Benzo(ghi)perylene	Air	mg	34.40	34.40	0.00
216	Beryllium	Air	ng	423.00	296.00	127.00
217	Boron	Air	mg	2.27	2.24	0.03
218	Bromine	Air	mg	3.16	3.15	0.00
219	Butadiene	Air	mg	1.65	0.00	1.65
220	Butane	Air	mg	26.80	23.20	3.60
221	Butene	Air	µg	419.00	337.00	81.60
222	Cadmium	Air	µg	202.00	182.00	19.90
223	Calcium	Air	mg	59.90	59.80	0.08
224	Carbon-14	Air	Bq	6.25	6.16	0.09
225	Carbon dioxide, biogenic	Air	g	3.25	3.18	0.07
226	Carbon dioxide, fossil	Air	kg	3.90	3.66	0.24
227	Carbon disulfide	Air	µg	673.00	670.00	3.11
228	Carbon monoxide, biogenic	Air	µg	467.00	455.00	11.70
229	Carbon monoxide, fossil	Air	kg	1.44	1.44	0.00
230	Catechol	Air	g	3.11	3.11	0.00
231	Cerium-141	Air	µBq	1.20	1.18	0.02
232	Cerium-144	Air	nBq	0.78	0.00	0.78
233	Cesium-134	Air	nBq	60.20	56.70	3.52
234	Cesium-137	Air	µBq	1.02	1.01	0.02
235	Chlorine	Air	mg	654.00	654.00	0.01
236	Chloroform	Air	ng	65.40	64.50	0.90
237	Chromium	Air	mg	9.60	9.54	0.07
238	Chromium-51	Air	nBq	76.90	75.90	1.03
239	Chromium VI	Air	µg	2.64	1.91	0.72
240	Chrysene	Air	mg	32.70	32.70	0.00
241	Cobalt	Air	µg	477.00	276.00	201.00
242	Cobalt-57	Air	nBq	0.00	0.00	0.00
243	Cobalt-58	Air	nBq	107.00	106.00	1.52
244	Cobalt-60	Air	nBq	946.00	933.00	12.70
245	Copper	Air	mg	4.86	4.59	0.27
246	Cumene	Air	µg	19.90	17.40	2.47
247	Curium-242	Air	nBq	0.00	0.00	0.00
248	Curium-244	Air	nBq	0.00	0.00	0.00
249	Curium alpha	Air	nBq	0.12	0.00	0.12
250	Cyanide	Air	µg	51.80	51.70	0.16
251	Dibenz(a,h)anthracene	Air	mg	4.05	4.05	0.00
252	Dibenzo[a,h]pyrene-7,14-dione	Air	mg	4.05	4.05	0.00
253	Dimethoate	Air	g	26.50	26.50	0.00
254	Dinitrogen monoxide	Air	g	7.76	7.74	0.02
255	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	pg	78.40	54.30	24.10
256	Ethane	Air	mg	60.60	55.80	4.75
257	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	µg	294.00	293.00	0.72
258	Ethane, 1,2-dichloro-	Air	µg	484.00	484.00	0.08
259	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	µg	1.45	1.43	0.02
260	Ethane, dichloro-	Air	pg	47.90	0.00	47.90
261	Ethane, hexafluoro-, HFC-116	Air	ng	64.40	63.50	0.94

No	Substance	Compartment	Unit	Total	Agriculture	Processing
262	Ethanol	Air	mg	2.60	1.62	0.97
263	Ethene	Air	mg	79.50	1.34	78.20
264	Ethene, chloro-	Air	µg	1.58	1.55	0.03
265	Ethylene diamine	Air	pg	28.30	27.90	0.41
266	Ethylene oxide	Air	ng	290.00	258.00	32.00
267	Ethyne	Air	mg	24.90	0.11	24.80
268	Fluoranthene	Air	mg	131.00	131.00	0.00
269	Fluorene	Air	mg	53.10	53.10	0.00
270	Fluorine	Air	µg	1.29	1.27	0.03
271	Fluosilicic acid	Air	ng	75.30	74.20	1.09
272	Formaldehyde	Air	mg	4.77	3.31	1.46
273	Formic acid	Air	mg	436.00	436.00	0.00
274	Furan	Air	g	5.76	5.76	0.00
275	Heat, waste	Air	MJ	45.70	44.40	1.37
276	Helium	Air	µg	780.00	636.00	144.00
277	Heptane	Air	mg	4.18	3.36	0.82
278	Hexane	Air	mg	11.20	7.71	3.44
279	Hydrocarbons, aliphatic, alkanes, cyclic	Air	ng	10.20	9.66	0.55
280	Hydrocarbons, aliphatic, alkanes, unspecified	Air	mg	10.40	8.20	2.20
281	Hydrocarbons, aliphatic, alkenes, unspecified	Air	ng	15.70	0.00	15.70
282	Hydrocarbons, aliphatic, unsaturated	Air	µg	922.00	792.00	130.00
283	Hydrocarbons, aromatic	Air	mg	2.63	2.57	0.06
284	Hydrocarbons, chlorinated	Air	µg	2.92	2.90	0.01
285	Hydrocarbons, unspecified	Air	g	17.30	17.30	0.00
286	Hydrogen	Air	mg	5.07	5.04	0.03
287	Hydrogen-3, Tritium	Air	Bq	36.00	35.50	0.50
288	Hydrogen chloride	Air	mg	29.40	29.00	0.36
289	Hydrogen fluoride	Air	mg	14.40	14.30	0.11
290	Hydrogen sulfide	Air	mg	7.64	7.64	0.01
291	Iodine	Air	µg	75.10	74.10	1.01
292	Iodine-129	Air	mBq	6.33	6.24	0.09
293	Iodine-131	Air	mBq	375.00	370.00	5.18
294	Iodine-133	Air	µBq	5.92	5.84	0.08
295	Iodine-135	Air	nBq	1.91	0.00	1.91
296	Iron	Air	mg	18.60	18.50	0.17
297	Iron-59	Air	nBq	0.00	0.00	0.00
298	Isocyanic acid	Air	ng	14.80	14.60	0.24
299	Krypton-85	Air	Bq	3.32	2.93	0.40
300	Krypton-85m	Air	mBq	119.00	117.00	1.60
301	Krypton-87	Air	mBq	52.00	51.30	0.71
302	Krypton-88	Air	mBq	49.20	48.50	0.68
303	Krypton-89	Air	mBq	11.30	11.10	0.15
304	Lanthanum	Air	pg	93.10	0.00	93.10
305	Lanthanum-140	Air	nBq	423.00	417.00	5.60
306	Lead	Air	mg	10.20	10.00	0.20
307	Lead-210	Air	mBq	479.00	479.00	0.38
308	m-Xylene	Air	µg	2.64	2.60	0.04
309	Magnesium	Air	mg	10.90	10.90	0.00
310	Manganese	Air	mg	12.80	12.70	0.06
311	Manganese-54	Air	nBq	39.40	38.90	0.52
312	Mercury	Air	µg	16.10	15.20	0.94

No	Substance	Compartment	Unit	Total	Agriculture	Processing
313	Metals, unspecified	Air	µg	146.00	146.00	0.00
314	Methane, biogenic	Air	mg	116.00	20.40	95.50
315	Methane, bromochlorodifluoro-, Halon 1211	Air	µg	15.40	15.40	0.02
316	Methane, bromotrifluoro-, Halon 1301	Air	µg	10.90	8.81	2.11
317	Methane, chlorodifluoro-, HCFC-22	Air	µg	55.20	55.10	0.10
318	Methane, chlorotrifluoro-, CFC-13	Air	pg	0.40	0.00	0.40
319	Methane, dichloro-, HCC-30	Air	ng	1.96	1.94	0.03
320	Methane, dichlorodifluoro-, CFC-12	Air	ng	159.00	159.00	0.32
321	Methane, dichlorofluoro-, HCFC-21	Air	pg	223.00	0.00	223.00
322	Methane, fossil	Air	g	124.00	124.00	0.20
323	Methane, monochloro-, R-40	Air	pg	0.00	0.00	0.00
324	Methane, tetrachloro-, CFC-10	Air	ng	845.00	818.00	27.00
325	Methane, tetrafluoro-, FC-14	Air	ng	580.00	572.00	8.45
326	Methane, trichlorofluoro-, CFC-11	Air	pg	2.99	0.00	2.99
327	Methane, trifluoro-, HFC-23	Air	pg	0.02	0.02	0.00
328	Methanol	Air	mg	9.41	8.42	0.99
329	Molybdenum	Air	µg	134.00	89.80	44.10
330	Monoethanolamine	Air	ng	412.00	406.00	5.73
331	Naphthalene	Air	g	5.74	5.73	0.01
332	Neptunium-237	Air	nBq	0.00	0.00	0.00
333	Nickel	Air	mg	8.41	6.81	1.60
334	Niobium-95	Air	nBq	4.67	4.61	0.06
335	Nitrate	Air	ng	261.00	257.00	3.75
336	Nitrogen	Air	ng	208.00	0.00	208.00
337	Nitrogen oxides	Air	g	32.20	31.90	0.30
338	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	g	2.17	2.09	0.08
339	Noble gases, radioactive, unspecified	Air	Bq	60800.00	60000.00	840.00
340	Ozone	Air	mg	1.94	1.92	0.03
341	PAH, polycyclic aromatic hydrocarbons	Air	µg	969.00	964.00	5.23
342	Paraffins	Air	pg	0.79	0.77	0.02
343	Particulates	Air	g	115.00	115.00	0.00
344	Particulates, < 10 um (mobile)	Air	ng	70.50	0.00	70.50
345	Particulates, < 10 um (stationary)	Air	ng	225.00	0.00	225.00
346	Particulates, < 2.5 um	Air	g	3.42	3.38	0.04
347	Particulates, > 10 um	Air	mg	810.00	747.00	62.80
348	Particulates, > 10 um (process)	Air	µg	198.00	0.00	198.00
349	Particulates, > 2.5 um, and < 10um	Air	mg	389.00	358.00	30.50
350	Particulates, SPM	Air	mg	57.70	57.70	0.00
351	Pentane	Air	mg	32.70	28.20	4.43
352	Phenanthrene	Air	mg	106.00	106.00	0.00
353	Phenol	Air	g	16.60	3.12	13.50
354	Phenol, pentachloro-	Air	µg	2.26	2.23	0.03
355	Phosphorus	Air	µg	32.50	32.30	0.19
356	Phosphorus, total	Air	ng	2.86	0.00	2.86
357	Platinum	Air	ng	1.43	1.25	0.18
358	Plutonium-238	Air	nBq	0.86	0.85	0.01
359	Plutonium-241	Air	nBq	6.36	0.00	6.36
360	Plutonium-alpha	Air	nBq	2.21	1.95	0.26
361	Polonium-210	Air	mBq	547.00	546.00	0.67
362	Polychlorinated biphenyls	Air	pg	105.00	103.00	1.91

No	Substance	Compartment	Unit	Total	Agriculture	Processing
363	Potassium	Air	mg	278.00	278.00	0.01
364	Potassium-40	Air	mBq	13.70	13.60	0.08
365	Promethium-147	Air	nBq	1.97	0.00	1.97
366	Propanal	Air	ng	312.00	308.00	3.45
367	Propane	Air	mg	35.80	32.10	3.74
368	Propene	Air	mg	2.67	0.81	1.86
369	Propionic acid	Air	µg	163.00	163.00	0.19
370	Propylene oxide	Air	µg	2.02	1.88	0.15
371	Protactinium-234	Air	µBq	858.00	846.00	11.80
372	Pyrene	Air	mg	99.10	99.10	0.00
373	Radioactive species, other beta emitters	Air	mBq	2.02	1.99	0.03
374	Radium-226	Air	mBq	789.00	788.00	0.48
375	Radium-228	Air	mBq	16.30	16.30	0.03
376	Radon-220	Air	µBq	226.00	219.00	6.54
377	Radon-222	Air	kBq	114.00	113.00	1.57
378	Ruthenium-103	Air	nBq	1.03	1.01	0.01
379	Ruthenium-106	Air	nBq	23.20	0.00	23.20
380	Scandium	Air	ng	276.00	276.00	0.10
381	Selenium	Air	µg	116.00	86.60	29.50
382	Silicon	Air	mg	102.00	102.00	0.00
383	Silicon tetrafluoride	Air	ng	168.00	167.00	0.93
384	Silver	Air	ng	10.00	9.99	0.01
385	Silver-110	Air	nBq	10.20	10.00	0.14
386	Sodium	Air	mg	70.40	69.70	0.73
387	Sodium chlorate	Air	µg	1.91	1.90	0.01
388	Sodium dichromate	Air	ng	3.31	3.29	0.02
389	Sodium formate	Air	ng	6.35	6.30	0.04
390	Soot	Air	mg	112.00	112.00	0.00
391	Strontium	Air	µg	62.30	62.00	0.30
392	Strontium-89	Air	nBq	0.01	0.00	0.01
393	Strontium-90	Air	nBq	3.82	0.00	3.82
394	Styrene	Air	ng	28.80	28.40	0.40
395	Sulfate	Air	g	2.07	2.07	0.00
396	Sulfur dioxide	Air	g	13.70	12.10	1.58
397	Sulfur hexafluoride	Air	µg	31.00	30.60	0.43
398	Sulfur oxides	Air	µg	20.90	0.00	20.90
399	t-Butyl methyl ether	Air	µg	115.00	101.00	14.30
400	Technetium-99	Air	nBq	0.00	0.00	0.00
401	Tellurium-123m	Air	nBq	0.02	0.00	0.02
402	Thallium	Air	ng	357.00	357.00	0.22
403	Thorium	Air	ng	417.00	417.00	0.17
404	Thorium-228	Air	mBq	3.61	3.59	0.02
405	Thorium-230	Air	mBq	654.00	653.00	0.05
406	Thorium-232	Air	mBq	9.43	9.41	0.02
407	Thorium-234	Air	µBq	858.00	846.00	11.80
408	Tin	Air	ng	721.00	714.00	7.18
409	Titanium	Air	mg	9.55	9.55	0.00
410	Toluene	Air	g	3.59	3.59	0.00
411	Uranium	Air	ng	555.00	555.00	0.21
412	Uranium-234	Air	mBq	660.00	660.00	0.14
413	Uranium-235	Air	µBq	486.00	479.00	6.71

No	Substance	Compartment	Unit	Total	Agriculture	Processing
414	Uranium-238	Air	mBq	672.00	671.00	0.20
415	Uranium alpha	Air	mBq	46.80	46.20	0.65
416	Vanadium	Air	mg	31.70	25.90	5.73
417	VOC, volatile organic compounds	Air	g	106.00	106.00	0.00
418	Water	Air	kg	409.00	408.00	1.25
419	Xenon-131m	Air	mBq	235.00	232.00	3.20
420	Xenon-133	Air	Bq	7.35	7.25	0.10
421	Xenon-133m	Air	mBq	34.90	34.50	0.48
422	Xenon-135	Air	Bq	3.02	2.98	0.04
423	Xenon-135m	Air	Bq	1.77	1.74	0.02
424	Xenon-137	Air	mBq	30.90	30.50	0.41
425	Xenon-138	Air	mBq	284.00	280.00	3.82
426	Xylene	Air	mg	9.11	8.18	0.93
427	Zinc	Air	mg	28.20	28.10	0.15
428	Zinc-65	Air	nBq	197.00	194.00	2.61
429	Zirconium	Air	pg	28.10	27.20	0.94
430	Zirconium-95	Air	nBq	192.00	190.00	2.54
431	Acenaphthene	Water	ng	124.00	99.60	24.40
432	Acenaphthylene	Water	ng	8.01	6.23	1.78
433	Acetic acid	Water	µg	4.03	3.51	0.53
434	Acidity, unspecified	Water	µg	11.50	10.50	0.97
435	Acids, unspecified	Water	pg	89.40	0.00	89.40
436	Actinides, radioactive, unspecified	Water	mBq	10.30	10.10	0.14
437	Aluminum	Water	mg	205.00	201.00	4.16
438	Americium-241	Water	nBq	9.59	0.00	9.59
439	Ammonia	Water	µg	465.00	465.00	0.02
440	Ammonium, ion	Water	mg	114.00	114.00	0.16
441	Antimony	Water	µg	73.20	71.50	1.61
442	Antimony-122	Water	µBq	2.94	2.90	0.04
443	Antimony-124	Water	mBq	1.61	1.59	0.02
444	Antimony-125	Water	mBq	1.38	1.36	0.02
445	AOX, Adsorbable Organic Halogen as Cl	Water	µg	28.20	15.00	13.30
446	Arsenic, ion	Water	mg	9.99	9.99	0.00
447	Barite	Water	µg	21.90	21.20	0.60
448	Barium	Water	mg	20.80	17.30	3.47
449	Barium-140	Water	µBq	12.90	12.70	0.17
450	Benzene	Water	mg	1.40	1.13	0.27
451	Benzene, chloro-	Water	pg	0.00	0.00	0.00
452	Benzene, ethyl-	Water	µg	479.00	384.00	94.10
453	Beryllium	Water	µg	25.80	25.50	0.34
454	BOD5, Biological Oxygen Demand	Water	g	9.54	3.53	6.02
455	Boron	Water	mg	4.71	4.63	0.08
456	Bromate	Water	µg	295.00	292.00	2.15
457	Bromine	Water	mg	14.10	11.30	2.75
458	Butene	Water	µg	1.88	1.87	0.00
459	Cadmium-109	Water	nBq	0.00	0.00	0.00
460	Cadmium, ion	Water	mg	4.98	4.11	0.87
461	Calcium, ion	Water	g	164.00	164.00	0.18
462	Carbon-14	Water	nBq	486.00	0.00	486.00
463	Carbonate	Water	µg	160.00	154.00	6.57
464	Carboxylic acids, unspecified	Water	mg	85.50	68.70	16.80

No	Substance	Compartment	Unit	Total	Agriculture	Processing
465	Cerium-141	Water	µBq	5.15	5.08	0.07
466	Cerium-144	Water	µBq	1.79	1.55	0.24
467	Cesium	Water	µg	19.90	16.00	3.92
468	Cesium-134	Water	mBq	1.27	1.25	0.02
469	Cesium-136	Water	nBq	914.00	902.00	12.10
470	Cesium-137	Water	Bq	1.18	1.17	0.02
471	Chlorate	Water	mg	2.35	2.33	0.02
472	Chloride	Water	g	348.00	346.00	2.03
473	Chlorinated solvents, unspecified	Water	ng	720.00	714.00	6.12
474	Chlorine	Water	mg	13.50	0.03	13.50
475	Chloroform	Water	pg	15.00	0.00	15.00
476	Chromium	Water	µg	868.00	x	868.00
477	Chromium-51	Water	mBq	1.57	1.55	0.02
478	Chromium VI	Water	µg	372.00	367.00	4.22
479	Chromium, ion	Water	mg	4.10	4.08	0.02
480	Cobalt	Water	µg	971.00	966.00	5.63
481	Cobalt-57	Water	µBq	29.00	28.60	0.38
482	Cobalt-58	Water	mBq	12.20	12.00	0.17
483	Cobalt-60	Water	mBq	9.54	9.41	0.13
484	COD, Chemical Oxygen Demand	Water	g	17.10	3.59	13.50
485	Copper, ion	Water	mg	5.81	5.30	0.51
486	Crude oil	Water	µg	65.70	65.70	0.00
487	Cumene	Water	µg	47.80	41.90	5.93
488	Curium alpha	Water	nBq	12.70	0.00	12.70
489	Cyanide	Water	µg	75.50	68.00	7.48
490	Dichromate	Water	ng	1.26	1.21	0.05
491	DOC, Dissolved Organic Carbon	Water	g	1.36	1.11	0.26
492	Ethane, 1,1,1-trichloro-, HCFC-140	Water	pg	0.06	0.00	0.06
493	Ethane, 1,2-dichloro-	Water	mg	1.15	1.15	0.00
494	Ethane, dichloro-	Water	pg	24.60	0.00	24.60
495	Ethane, hexachloro-	Water	pg	0.00	0.00	0.00
496	Ethene	Water	µg	19.70	17.20	2.49
497	Ethene, chloro-	Water	ng	5.45	4.83	0.62
498	Ethene, tetrachloro-	Water	pg	0.06	0.00	0.06
499	Ethene, trichloro-	Water	pg	4.10	0.00	4.10
500	Ethylene diamine	Water	pg	68.50	67.50	0.98
501	Ethylene oxide	Water	pg	605.00	597.00	8.42
502	Fatty acids as C	Water	ng	43.50	0.00	43.50
503	Fluoride	Water	g	1.71	1.70	0.00
504	Fluosilicic acid	Water	ng	136.00	134.00	1.96
505	Formaldehyde	Water	µg	7.22	6.36	0.85
506	Glutaraldehyde	Water	ng	2.70	2.62	0.07
507	Heat, waste	Water	kJ	914.00	357.00	557.00
508	Hydrocarbons, aliphatic, alkanes, unspecified	Water	mg	2.59	2.08	0.51
509	Hydrocarbons, aliphatic, alkenes, unspecified	Water	pg	108.00	0.00	108.00
510	Hydrocarbons, aliphatic, unsaturated	Water	µg	239.00	192.00	47.10
511	Hydrocarbons, aromatic	Water	mg	10.60	8.50	2.07
512	Hydrocarbons, unspecified	Water	mg	3.73	3.63	0.10
513	Hydrogen	Water	mg	3.92	3.92	0.00
514	Hydrogen-3, Tritium	Water	Bq	2710.00	2670.00	37.40
515	Hydrogen peroxide	Water	ng	749.00	748.00	1.30

No	Substance	Compartment	Unit	Total	Agriculture	Processing
516	Hydrogen sulfide	Water	µg	206.00	81.70	124.00
517	Hydroxide	Water	ng	2.47	2.43	0.04
518	Hypochlorite	Water	mg	1.78	0.19	1.59
519	Hypochlorous acid	Water	ng	1.51	0.00	1.51
520	Iodide	Water	mg	2.00	1.61	0.39
521	Iodine-129	Water	µBq	1.39	0.00	1.39
522	Iodine-131	Water	µBq	290.00	286.00	3.99
523	Iodine-133	Water	µBq	8.08	7.98	0.11
524	Iron	Water	µg	1.09	0.00	1.09
525	Iron-59	Water	µBq	2.22	2.19	0.03
526	Iron, ion	Water	mg	235.00	228.00	7.39
527	Lanthanum-140	Water	µBq	13.70	13.50	0.18
528	Lead	Water	mg	3.71	3.66	0.05
529	Lead-210	Water	Bq	423.00	423.00	0.00
530	Magnesium	Water	g	5.40	5.36	0.05
531	Manganese	Water	mg	9.51	8.44	1.07
532	Manganese-54	Water	µBq	742.00	731.00	10.40
533	Mercury	Water	µg	571.00	570.00	0.38
534	Metallic ions, unspecified	Water	µg	693.00	693.00	0.00
535	Methane, dichloro-, HCC-30	Water	ng	36.80	36.20	0.60
536	Methane, tetrachloro-, CFC-10	Water	pg	0.10	0.00	0.10
537	Methanol	Water	µg	217.00	217.00	0.50
538	Molybdenum	Water	µg	184.00	181.00	2.95
539	Molybdenum-99	Water	µBq	4.73	4.67	0.06
540	Neptunium-237	Water	nBq	0.61	0.00	0.61
541	Nickel	Water	µg	868.00	x	868.00
542	Nickel, ion	Water	mg	10.20	10.00	0.19
543	Niobium-95	Water	µBq	95.40	94.10	1.31
544	Nitrate	Water	g	180.00	180.00	0.00
545	Nitrite	Water	µg	64.70	64.00	0.65
546	Nitrogen	Water	g	1.18	0.07	1.10
547	Nitrogen, organic bound	Water	mg	4.67	3.91	0.76
548	Nitrogen, total	Water	µg	127.00	127.00	0.01
549	Oils, unspecified	Water	g	1.35	1.08	0.27
550	PAH, polycyclic aromatic hydrocarbons	Water	µg	117.00	94.30	22.80
551	Paraffins	Water	pg	2.30	2.24	0.06
552	Phenol	Water	mg	306.00	1.56	304.00
553	Phosphate	Water	g	15.30	15.30	0.00
554	Phosphorus	Water	mg	50.00	4.81	45.20
555	Phosphorus compounds, unspecified	Water	pg	10.40	0.00	10.40
556	Phthalate, dioctyl-	Water	pg	0.00	0.00	0.00
557	Phthalate, p-dibutyl-	Water	pg	0.03	0.00	0.03
558	Phthalate, p-dimethyl-	Water	pg	0.16	0.00	0.16
559	Plutonium-241	Water	nBq	948.00	0.00	948.00
560	Plutonium-alpha	Water	nBq	38.20	0.00	38.20
561	Polonium-210	Water	Bq	645.00	645.00	0.00
562	Potassium	Water	mg	212.00	0.00	212.00
563	Potassium-40	Water	Bq	51.10	51.10	0.00
564	Potassium, ion	Water	g	4.41	4.39	0.02
565	Propene	Water	µg	25.80	23.30	2.47
566	Propylene oxide	Water	µg	4.87	4.51	0.36

No	Substance	Compartment	Unit	Total	Agriculture	Processing
567	Protactinium-234	Water	mBq	15.90	15.70	0.22
568	Radioactive species, alpha emitters	Water	mBq	227.00	227.00	0.00
569	Radioactive species, from fission and activation	Water	nBq	28.20	0.00	28.20
570	Radioactive species, Nuclides, unspecified	Water	Bq	6.17	6.08	0.09
571	Radium-224	Water	mBq	997.00	801.00	196.00
572	Radium-226	Water	Bq	487.00	487.00	0.45
573	Radium-228	Water	Bq	1.99	1.60	0.39
574	Rubidium	Water	µg	200.00	161.00	39.20
575	Ruthenium	Water	pg	88.90	0.00	88.90
576	Ruthenium-103	Water	nBq	998.00	985.00	13.20
577	Ruthenium-106	Water	µBq	2.32	0.00	2.32
578	Salts, unspecified	Water	ng	514.00	0.00	514.00
579	Scandium	Water	µg	49.00	48.50	0.50
580	Selenium	Water	µg	50.40	49.10	1.30
581	Silicon	Water	g	2.07	2.05	0.02
582	Silver	Water	pg	5.95	0.00	5.95
583	Silver-110	Water	mBq	9.14	9.02	0.12
584	Silver, ion	Water	µg	17.80	14.70	3.15
585	Sodium-24	Water	µBq	35.80	35.30	0.48
586	Sodium formate	Water	ng	15.30	15.10	0.11
587	Sodium, ion	Water	g	203.00	201.00	1.24
588	Solids, inorganic	Water	mg	267.00	264.00	3.46
589	Solved solids	Water	mg	490.00	490.00	0.15
590	Solved substances	Water	µg	1.22	0.00	1.22
591	Strontium	Water	mg	123.00	99.10	23.60
592	Strontium-89	Water	µBq	142.00	140.00	1.92
593	Strontium-90	Water	Bq	10.40	10.20	0.14
594	Sulfate	Water	g	419.00	419.00	0.48
595	Sulfide	Water	µg	165.00	38.90	126.00
596	Sulfite	Water	mg	4.59	0.48	4.10
597	Sulfur	Water	g	1.75	1.75	0.01
598	Sulfur trioxide	Water	pg	385.00	0.00	385.00
599	Suspended solids, unspecified	Water	mg	521.00	513.00	7.52
600	t-Butyl methyl ether	Water	µg	58.90	50.10	8.76
601	Technetium-99	Water	nBq	243.00	0.00	243.00
602	Technetium-99m	Water	µBq	110.00	108.00	1.45
603	Tellurium-123m	Water	µBq	169.00	167.00	2.34
604	Tellurium-132	Water	nBq	274.00	270.00	3.62
605	Thallium	Water	µg	12.40	3.94	8.47
606	Thorium-228	Water	Bq	9.17	8.38	0.78
607	Thorium-230	Water	Bq	2.17	2.14	0.03
608	Thorium-232	Water	mBq	2.70	2.66	0.04
609	Thorium-234	Water	mBq	15.90	15.70	0.22
610	Tin, ion	Water	µg	105.00	102.00	2.93
611	Titanium, ion	Water	mg	6.97	6.78	0.19
612	TOC, Total Organic Carbon	Water	g	1.38	1.12	0.26
613	Toluene	Water	mg	2.55	2.07	0.48
614	Tributyltin	Water	pg	74.30	0.00	74.30
615	Tributyltin compounds	Water	µg	45.70	42.00	3.76
616	Triethylene glycol	Water	µg	178.00	178.00	0.21

No	Substance	Compartment	Unit	Total	Agriculture	Processing
617	Tungsten	Water	µg	45.50	44.90	0.59
618	Undissolved substances	Water	µg	1.20	0.00	1.20
619	Uranium-234	Water	mBq	19.10	18.80	0.26
620	Uranium-235	Water	mBq	31.40	31.00	0.43
621	Uranium-238	Water	Bq	217.00	217.00	0.00
622	Uranium alpha	Water	mBq	915.00	902.00	12.60
623	Vanadium, ion	Water	µg	770.00	598.00	172.00
624	VOC, volatile organic compounds, unspecified origin	Water	mg	7.02	5.64	1.37
625	Water	Water	kg	4.23	x	4.23
626	Xylene	Water	mg	2.05	1.65	0.40
627	Yttrium-90	Water	nBq	0.01	0.00	0.01
628	Zinc-65	Water	µBq	485.00	479.00	6.41
629	Zinc, ion	Water	mg	18.40	17.10	1.27
630	Zirconium-95	Water	µBq	5.64	5.54	0.09
631	Mineral waste	Waste	mg	9.13	9.13	0.00
632	Pomace	Waste	g	910.00	x	910.00
633	Slags	Waste	mg	321.00	321.00	0.00
634	Sludge	Waste	kg	1.23	0.00	1.23
635	Waste, final, inert	Waste	mg	280.00	280.00	0.00
636	Wood waste	Waste	g	10.00	x	10.00
637	Aclonifen	Soil	pg	940.00	916.00	23.80
638	Aluminum	Soil	mg	630.00	583.00	47.20
639	Antimony	Soil	pg	2.44	2.41	0.03
640	Arsenic	Soil	µg	188.00	188.00	0.00
641	Atrazine	Soil	pg	195.00	192.00	2.79
642	Barium	Soil	ng	882.00	839.00	42.30
643	Bentazone	Soil	pg	479.00	467.00	12.10
644	Boron	Soil	ng	66.30	56.50	9.74
645	Cadmium	Soil	mg	34.30	0.41	33.90
646	Calcium	Soil	g	9.78	7.96	1.82
647	Carbetamide	Soil	pg	316.00	309.00	6.33
648	Carbon	Soil	mg	628.00	337.00	291.00
649	Chloride	Soil	mg	89.70	89.70	0.00
650	Chlorine	Soil	mg	531.00	x	531.00
651	Chlorothalonil	Soil	ng	146.00	144.00	2.04
652	Chromium	Soil	mg	43.70	5.48	38.20
653	Chromium VI	Soil	ng	41.40	40.80	0.63
654	Cobalt	Soil	µg	505.00	505.00	0.00
655	Copper	Soil	mg	19.40	4.60	14.80
656	Cypermethrin	Soil	pg	11.10	10.90	0.20
657	Dimethoate	Soil	mg	73.80	73.80	0.00
658	Dinoseb	Soil	ng	39.70	39.10	0.55
659	Fenpiclonil	Soil	ng	5.78	5.70	0.08
660	Fluoride	Soil	ng	100.00	99.00	1.28
661	Glyphosate	Soil	ng	6.68	6.52	0.17
662	Heat, waste	Soil	kJ	59.70	59.40	0.36
663	Iron	Soil	mg	875.00	714.00	162.00
664	Lead	Soil	mg	4.03	1.86	2.17
665	Linuron	Soil	ng	7.28	7.09	0.19
666	Magnesium	Soil	g	1.85	0.90	0.95

No	Substance	Compartment	Unit	Total	Agriculture	Processing
667	Mancozeb	Soil	ng	190.00	187.00	2.65
668	Manganese	Soil	mg	647.00	561.00	86.60
669	Mercury	Soil	µg	2.81	2.81	0.00
670	Metaldehyde	Soil	pg	96.40	94.70	1.71
671	Metolachlor	Soil	ng	52.80	51.40	1.34
672	Metribuzin	Soil	ng	6.68	6.59	0.09
673	Molybdenum	Soil	µg	104.00	104.00	0.00
674	Napropamide	Soil	pg	171.00	168.00	3.02
675	Nickel	Soil	mg	27.60	1.56	26.00
676	Nitrogen	Soil	g	42.30	0.00	42.30
677	Oils, biogenic	Soil	µg	5.27	5.19	0.07
678	Oils, unspecified	Soil	g	1.69	1.40	0.28
679	Orbencarb	Soil	ng	36.00	35.50	0.50
680	Phenol	Soil	g	12.00	x	12.00
681	Phosphorus	Soil	g	2.06	0.28	1.79
682	Pirimicarb	Soil	pg	45.40	44.20	1.15
683	Potassium	Soil	g	10.20	1.53	8.67
684	Silicon	Soil	g	2.53	2.32	0.21
685	Silver	Soil	pg	131.00	127.00	3.33
686	Sodium	Soil	g	2.00	0.00	2.00
687	Strontium	Soil	ng	598.00	474.00	124.00
688	Sulfur	Soil	mg	544.00	258.00	286.00
689	Tebutam	Soil	pg	404.00	397.00	7.16
690	Teflubenzuron	Soil	pg	445.00	439.00	6.21
691	Tin	Soil	ng	28.50	28.10	0.35
692	Titanium	Soil	mg	40.00	38.70	1.27
693	Vanadium	Soil	mg	1.11	1.11	0.00
694	Zinc	Soil	mg	96.90	68.60	28.30