LIFE Project Number

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FINAL REPORT

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LIFE PROJECT NAME

Sustainable wastewater purification in Estonian small municipalities

Data Project

Project location	Estonia
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Project end date:	31/12/2005
Total Project duration (in months)	48 months
Total budget	711268 €
EC contribution:	325334
(%) of total costs	45.74
(%) of eligible costs	50.00

Data Beneficiary

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1 Project objectives versus achievements

The current project had two main aims:

- To establish different prototypes of wastewater purification systems (WWPS) to two Estonian rural communities
- To present sustainable purification system as a way for solving local environmental/energy supply problems in Estonia

Both aims concerned various tasks that were executed by carrying out different activities by the project team. During our project three different prototypes for wastewater purification were established. During the second half of the project they were working with full capacity. Hence, we achieved the aim of supplying some Estonia rural areas with sustainable and inexpensive-to-run prototypes for the local environment protection. In our proposal we planned to achieve wastewater quality in the prototype outflow to meet the limits stipulated by Estonian legislation from 1999 – 15 mg N and 2 mg P per litre. During 2004/2005, the average values of water samples from the vegetation filters affirmed that this task was completed at Kambja (7.5 and 0.7 mg N and P per litre, respectively) and at Vohnja (8.0 and 0.9 mg N and P per litre, respectively). Due to the shortage of water in our third prototype site the same monitoring procedure could not be achieved since the ditch to local natural water-body remained dry. For vegetation filter establishment we used in prototypes short rotation trees that have high productivity of biomass in our weather conditions. With this action we also promoted the biomass production for renewable energy purposes in Estonia. This is important to meet the needs of EU targets to increase the renewable energy usage substantially during the next decade. During the project we also disseminated the project methods and results at different levels and worked actively in order to ensure the continuity of the project activities and objectives after the end of the current project. Hence we conclude that all the project objectives were achieved during the project period.

2 Project background and organisation

2.1 Project background

After the collapse of the previous social system in the former Soviet Union the wastewater of smaller communities and rural areas remained nearly untreated for years. Some former centres of collective farms or other more tensely populated areas still have poorly working central canalisation and totally amortised wastewater purification plants. Nitrogen and phosphorus discharged this way to nature are pollutants in lakes and rivers being a serious environmental problem not only in Estonia but also in neighbouring countries. In order to reinforce the environmental protection Estonian legal system tightens restrictions for such disposal from year to year. At the same time living standard in rural areas is not sufficient for establishing high-tech wastewater treatment systems, since they are usually very expensive to run. Therefore inexpensive purification plants with high environmental efficiency are badly needed. As a lot of unused arable land is usually available in such areas the more space demanding wastewater purification methods can be carried out. Therefore we planned to discharge minimally pre-treated wastewater to the fields with short rotation trees planted for bioenergy production. The pre-treatment of wastewater before spreading to the plantation is important for hygienic reasons. Taking into account the local climatic conditions for planting material we chose different broad-leaved short rotation tree species, which are also naturally growing in the region. The additional supply of water and nutrients to the field promotes biomass production. We planned to use the produced biomass in nearby central heating plant diminishing energy rotation in the environment.

2.2 Project organisation

The project organisation consisted of the beneficiary (Estonian Agricultural University) and two commune administrations (Kambja and Kadrina). Estonian Agricultural University (EAU) was the initiator of the project after obtaining expertise of necessary methods from colleagues at Swedish Agricultural University (SLU). The two partners were from different parts of Estonia. They both were actively looking for solutions to solve environmental problems in their rural areas and asked for help from the EAU`s scientists. The general layout of the project organisation is illustrated in Fig. 1.

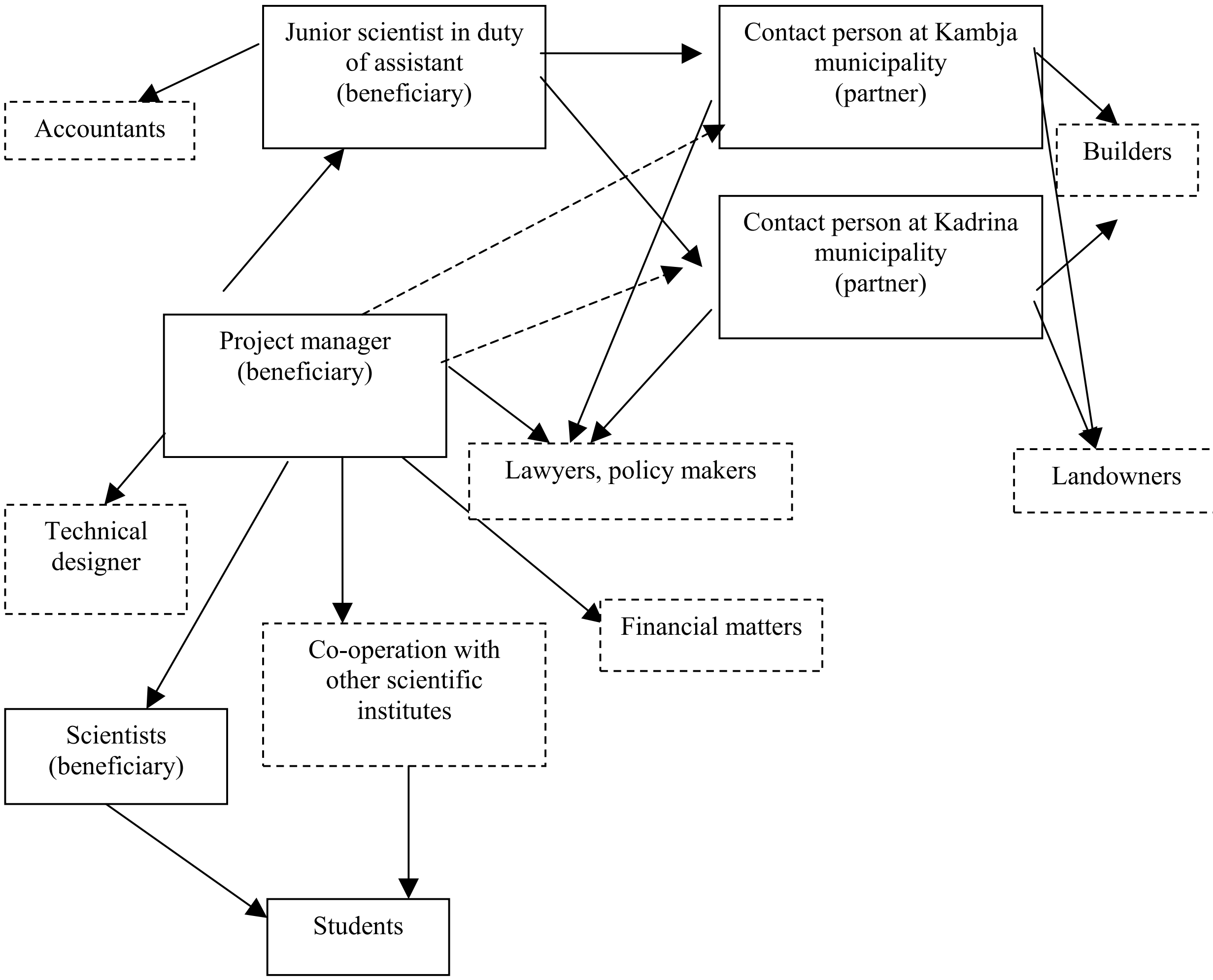

Figure 1. The schematic system of project management. Various project team members (continuous line) were in close co-operation with several specialists of other institutions (dashed line).

3 Activities undertaken with respect to the objectives, actions and work-plan envisaged in the project

In the following part of the report the activities performed are grouped into larger clusters to give a better overview of their significance in achieving the project aims. The same list of activities was foreseen also in our project proposal (T3).

3.1 Vegetation filter planning

The project was first to introduce vegetation filters in Estonia although some experiment plots of short rotation trees were established and some knowledge and experience in fertilising trees with wastewater instead of mineral fertilisers had been obtained by EAU from abroad previously. Therefore the main activities in the first stage of the project were devoted to vegetation filter planning and were divided into four groups of actions:

- Improving knowledge concerning vegetation filters among the members of the project team (both beneficiary and partners) who were engaged in vegetation filter planning. This action contained a lot of working with existing literature, consultations with the specialists and discussions/meetings. The key activity of this action group was the study tour of the representatives of both beneficiary and partners to Sweden, Enköping, where the largest vegetation filter of the Baltic Sea region is managed. In addition to the field trip we held a workshop with staff of local wastewater purification company and were able to gain answers to all our practical questions about running such wastewater purification systems (WWPS). It was extremely important for the representative of the Institute of Water Management of EAU (Dr. Mihkel Gross) to get examine the technology used in WWPS on site in order to gain expertise to be able to consult in the technical planning process of the WWPS prototypes in current project. At the same time the representatives of the partners saw such sustainable WWPS the first time functioning.
- Specification of land area for establishing vegetation filters. At first this meant picking plots of land that was needed for the prototypes establishment. The main factors for choice were: distance from the local wastewater outlet point, relief, distance from natural water-bodies and possibility to lease land. The first drawbacks were experienced: the village Kihlevere had been chosen for prototype establishment but not enough land was available. After discussions with the constructed wetland specialists of the Tartu University (team of Prof. Ü. Mander) we decided to increase the level of wastewater pre-purification in order to be able to diminish the plantation area. For pre-purification we decided to use the method of subsurface gravel filter since this is sustainable and does not have negative environmental impact due to lack of need for purification chemicals and

with low electricity demand. For the other areas this task included mainly negotiations with landowners and land division in order to enable to initiate the technical design procedures.

- Choice of planting material. In the first place we were sure that we should plant to our vegetation filters only these species that are naturally growing in Estonia to avoid possible negative environmental impact to our natural biodiversity. Our previous experience had shown good productivity in various willow species (*Salix viminalis, Salix dasyclados*) in Estonian climatic conditions. Data was also available indicating higher productivity of alders (*Alnus incana*) when cultivated than growing in nature. Additionally, we wanted to test the suitability of triploid aspen (*Populus tremula f. gigas*). Evidence on their higher production in the forest compared to other aspens had been noticed. As the only option to multiply this sub-species is by meristem tissues, we ordered the plants for our Kambja plantation as soon as we got the confirmation about our project approval. The problem was that this sub-species is found only in Estonia and the experience of local nursery specialists on meristem multiplication of the specific species was limited. The majority of the plantation areas were planned to plant with willows and the main activities therefore concerned reasonable choice of willow clones. According to existing local knowledge and consulting the foreign specialists main factors that were kept in mind in the choice process were the following: 1) annual shoot biomass productivity in field trials on different soil types in Estonia, 2) frost resistance, 3) tolerance to various pathogens. For obtaining the information, fieldwork in the experimental plots managed by the beneficiary was accelerated during the first stage of the project. In this stage several students of the two universities in Tartu also participated in project implementation. With their help significant new and important information became available. Moreover, as a rule, their fieldwork concluded with writing a course or diploma paper. This guaranteed quick and significant dissemination of the result among various specialists at the early stage of the project. The contacts established this way were very useful for the project implementation afterwards. We are also very thankful to Dr. Ulf Granhall and his PhD student Marianne Cambours from Swedish Agricultural University who conduced additional studies to find out the rate of willow contamination with ice-forming bacteria in Estonian experimental plots. This was extremely important, as we wanted to use the most promising planting material from these fields. Additional international experience was gained at international conferences.

- Technical blueprinting of vegetation filters. This action was started immediately after reliable base information from previous actions had been collected. Co-operation with a private company "Kobras" was indicated in our proposal. This was necessary, as the project team members had no licence for technical blueprinting. This particular company was chosen as it had previously closely co-operated with the scientists of the beneficiary's Water Management Institute. We assumed well-established and functioning working relations being important in order to ensure close co-operation between both parties that helps to avoid and overcome possible problems in such experimental work. During the discussions with the representatives of the construction design company we understood that it is of great importance to develop the project plan and design all systems (both pre-purification part and vegetation filter) as a whole. In this way it was possible to avoid mistakes in the design process and to ensure the compatibility of the various parts. The design itself was performed in close co-operation between the project team members and the company. In order to diminish the risks caused by possible mistakes made in technology planning all the blueprints were sent also to an independent expert Dr. Tõnu Mauring from the Centre of Ecological Engineering Technologies. All his comments were taken into account in the last version of the blueprints.

3.2 Land preparation

Comparing the current situation in Estonia with data from 1992 the area of land used in agriculture has decreased by 611 thousand ha. This is a significant change. Therefore one of the objectives of the current project was to find an alternative usage for this abandoned land. This aim was achieved by using where possible abandoned arable land for vegetation filters. Fulfilling this goal involved some specific unexpected problems: arable land abandoned for over 10 years may be already covered by young trees, harvesting of which needs additional effort. Moreover, the amount and composition of various herbaceous plants and their seeds in soil is unpredictable. As the large-scale growth of weeds during the first year of short-rotation forest has a significant influence on the survival of planted young trees, it is extremely important to control the weeds and diminish their seeds potential. In the period between presenting our project proposal and the establishment of vegetation filters in practice, different herbicides were forbidden to use in Estonia (for example, Expand plus, GardoPrim). This made the weed control and land preparation more difficult than predicted. The only herbicide we were able to use at this stage was glyphosate-based Roundup. This was excellent for controlling the weeds in their active growth stage in the vegetation period, but useless in the late autumn or early spring. Moreover, the seed bank in the soil was not harmed by it at all. Therefore specific land preparation technologies were needed. For example, it is not reasonable to plough the soil after the treatment with glyphosate-based solutions, because the new generation of seeds from the deeper soil layer could be brought up to the surface. All these details were not known to the project team members before the project start. To overcome such problems more effort than foreseen was needed. Another issue related to this action concerned the availability of equipment and staff for land preparation. Simultaneously with the decrease in agricultural land use in Estonia also investments made to acquire agricultural equipment had decreased. In addition, local people have gained other jobs or established small private businesses. Therefore finding suitable tractors and workers at the right time to work on project sites was not always easy. As the right timing has a strong impact on the fieldwork this factor had to be considered seriously at this project stage.

3.3 Planning of pre-treatment plants

Most of the former centres of Estonian collective farms have today amortised central canalisation system and very poorly working or totally depreciated wastewater purification plants. At the same time Estonian legislation demanding to purify wastewater effectively become more severe each year. This has created a strong demand for reconstruction of the wastewater treatment systems. In addition, local low living standard does not allow making large investments to gain needed equipment or to pay the high running costs of traditional WWPS. Therefore it is extremely important to provide these rural areas with new technology, which has ecological benefits and is cheaper to run. With this objective we started to plan the pre-treatment plants of our prototypes. As we assumed the land rent would be low and unused land available, we started to search for technology with the most sustainable options (Fig.

2). Pre-treatment technology was chosen in together with the vegetation filter planning in order to find optimal solutions concerning the prototypes.

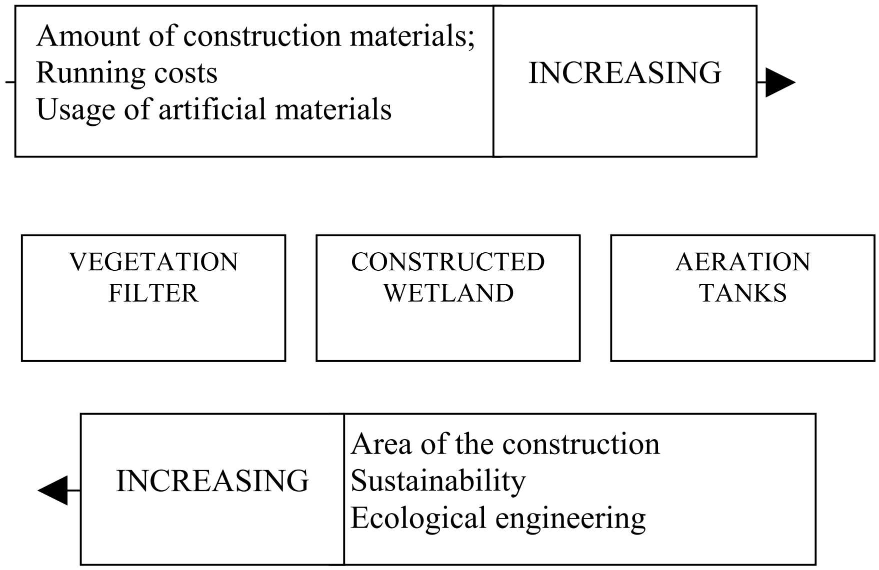

Figure 2. The schematic presentation of general characteristics of different wastewater purification methods.

After long discussions and consideration of all local characteristics (both these of wastewater and land) we were able to create technological schemes for each prototype. At Kambja the available land area was large (18.5 ha), plain and with soil rich of nutrients. Next to the planned field with short rotation trees the amortised wastewater treatment plant was situated. At the same time the volume of wastewater collected from the settlement was quite large (approximately 1000 person equivalents). Therefore we decided to establish a large-scale vegetation filter with different tree species at Kambja. For pre-treatment we decided to establish some modern bioponds. No information on the efficiency of non-aerated bioponds in Estonian climatic conditions was available at the time. Therefore the bioponds of our prototype were created with the option that additional aeration could be added if the passive technology would not meet the limits necessary for environmental protection. During the vegetation period the pre-treated water was planned to discharge to the vegetation filter. In winter the existing old bioponds would be used for additional purification (Fig. 3A). At Vohnja the amount of wastewater was smaller (about 250 person equivalents) and also enough land (4.1 ha) was available for constructing a large-scale vegetation filter. This made applying minimal pre-purification of wastewater possible without exceeding the theoretical optimal load of nutrients, which could be utilised in the vegetation filter. The land area was also plain, but with thinner layer of nutrient-rich soil than at Kambja. Therefore we decided to use here only willows for vegetation filter establishment as the cost of willow planting material and their ecological demands are the lowest on the list of available species. Small amount of wastewater allowed us also to establish bioponds large enough to store all the wastewater produced during the winter period. Therefore no additional options for wintertime wastewater purification were needed (Fig. 3B). At Kihlevere the wastewater amount was that of approximately 200 person equivalents and the canalisation output was very close to the settlement. We were thus able to lease only 2.1 ha of land. Because of these factors we decided to use there a more intensive pre-treatment technology – grave-filter basins typical to constructed wetland system (Fig 3C). Pre-treated wastewater was planned to lead through the willow plantation by a serpentine ditch. This system needs less area, but is more difficult to manage, as the biomass harvesting should be carried out manually because of the irrigation ditch in the willow plantation. On the other hand, the lag time of wastewater being in contact with the vegetation filter rhizosphere is shorter in this case and therefore additional buffer zone was needed to avoid possible environmental risks. Copies of all technical blueprints of the prototypes are presented in Annex 1. All the technical documentation of the prototypes was also verified by certified environmental and construction experts.

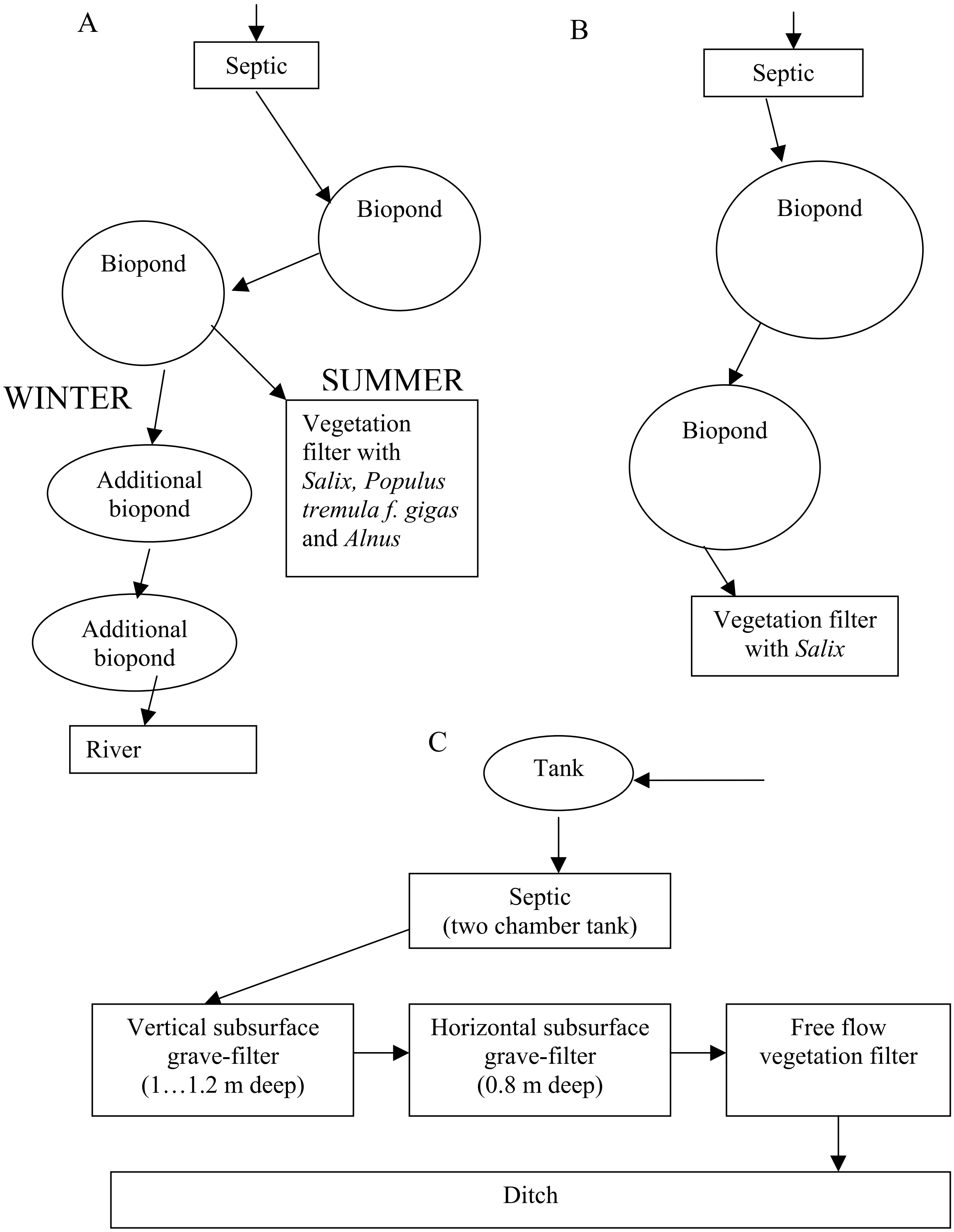

Figure 3. Technological schemes of the prototypes. A – Kambja; B – Vohnja; C - Kihlevere.

3.4 Construction of pre-treatment plant

Immediately after completing prototypes' technical documentation, a state procurement was conduced by both partners. This activity was necessary to meet the needs of changed Estonian legislation (for documentation see also Annex 10). In the state procurement documentation it was stated that both the proposed cost of prototypes and the existence of previous expertise (ISO certificates) of building companies would be evaluated. The potential constructor was expected to give a guarantee for at least two years to all construction works after finishing the building. One private construction company "Hüdroehitus" won both state procurements. During the construction process the representative of this company cooperated closely with the representatives of the partners. Every time when any important issue had to be solved the representatives of the design company and the beneficiary were involved in the discussions. There were only some minor problems with Kambja prototype establishment that were on the responsibility of the construction company (stealing of some equipment during construction works) or were easy to fix (the water distribution pipes were on some plots not inside the double-row of the plants, but between them). Therefore this was the first prototype finished by the construction company. Before the official take-over of it by the project team, the construction supervisory company controlled all the technical details of the prototype and gave to the constructor very valuable suggestions about some details that were not foreseen in the prototype design process – change of angle of transport pipe before the pumping system and the need for a aeration valve in it, for example. These suggestions were taken into account by the constructor in order to avoid the standstills of the prototype in the future. At Kihlevere the greatest risk during the construction works was connected with the choice of filter material to the grave filters. The quality and characteristics of this material was controlled by Dr. Tõnu Mauring from Estonian Centre of Environmental Technologies (ECET), as he is the best expert on this topic in Estonia. Because of the very careful work of all participants the construction work of Kihlevere prototype was also finished in time without any significant drawbacks. At Vohnja the main problems concerned the establishment of the bioponds. According to the technical documentation the established modern bioponds should be isolated from the ground with waterproof geotextile layer. This solution was chosen to diminish the environmental risks for the groundwater. Additionally the design company suggested to cover the geotextile with a layer of soil to avoid the mechanical damages while cleaning the ponds in the future. In order to decrease the cost of the project and to reduce the influence on the landscape both ponds were planned to establish on the same place as the old ponds. Therefore no additional geological studies were performed before the construction work. Unfortunately during the cleaning and deepening of one of the old ponds a leakage of freshwater from the deeper ground layer occurred. Most probably it was caused by the water pressure between the limestone layers caused by the neighbourhood river. After the extensive pumping of water out from the pond it was clear that it was impossible to eliminate this leakage by covering the base of biopond with geotextile and additional weight of ground on it. Therefore all participants of the project construction works and management team had a meeting with invited experts (Dr. Toomas Tamm from EAU and Dr. Tõnu Mauring from ECET). The final suggestion of this meeting was to use a thicker layer of clay in the bottom of ponds instead of geotextile. As the ponds with wastewater were existing there already for decades, it was assumed that this water canals has not any connection with the ground water and the wastewater in process would not therefore reach the wells of closest households. This assumption was also affirmed by the local geographical situation – the prototype was established downhill compared the closest households. This was a serious decision and the partner asked for permission to change the design of the prototype also from the environmental authorities of the local county. After their acceptation the construction works at Vohnja continued according to the changed plans. All construction works were finished by the autumn, 2003.

3.5 Weed control in plantations

According to the international practice the control of the weeds during the first years of the short rotation forest is critical. The problem is that the usual weeds have a growth strategy of quick spreading on available land. This is possible due to their low rate of resource deposition to the storage tissues. Broad-leaved trees in our climate, just opposite, put much of their resources to the tissues that are necessary to perform during a long life cycle. Therefore the cuttings of willows build up a strong root system during the first year, compared with quite poor aboveground part. If there will be not enough light available for the young willow plants during that time, they are not able to produce enough biomass for the root system nor for the leaves. This would lead of poor growth and low survival probability of the plants. As already mentioned in the subchapter 3.2. these risks were significant while using arable land areas that had been abandoned for years already. Nobody in Estonia had the practice how to handle this problem in such large-scale plantations as those foreseen in our prototypes. Therefore we tried to get rid of the weeds in our plantations with different technologies. We consulted with the largest Estonian herbicide company Kemira Growhow to find some chemicals for this purpose. As growing trees in agricultural land is quite a new topic for Estonia, they did not have very good suggestions. They supported the project with some chemicals that we used in small plots, but the low loads of herbicides did not help a lot. Increase of the load ended with the dieback of the cultivation as well. We tried also the mechanical option by digging over the area between the plant rows. But due to the very hardened upper soil-layer during the summer months this harmed also the root system of the willows, as they are also mostly located in the upper 10 cm of soil. Therefore the best option was found to be the weeding of plants in rows and chemical treatment between the rows. The project team is very thankful to the numerous schoolchildren who spent their summer holidays in our plantations working in very warm climate of summer, 2003. All the schoolchildren were continuously instructed and supervised by the project team and therefore weed control was the main activity of the whole team in summer 2003. After all we are happy to report that most of our plantation areas had the number of willow plants high enough to go on with our project. Into some areas we replanted the willows manually in spring 2004.

3.6 Planting of willows and other trees to the plantations

The main area of plantations was planted with 25…30 cm willow cuttings. The planting material was ordered from the Estonian farmers, if possible. They were preparing it from the experimental short rotation forests locating on their land but established by the beneficiary institution years ago for research purposes. These willows were originating from the previous Estonian-Swedish scientific co-operation in terms of planting material selection and not protected with the breed ownership licenses. For the new plantations we decided to use from our collection clones number 78021, 78112, 78183, 79097, 81090 and 82007 according to the Swedish clone numbering system. Such solution was economically efficient, as the plants in Estonia were cheaper than imported from abroad. Moreover, this was the first signal to the Estonian farmers that cultivating willows can be one option for income in our agriculture. As some breeds from the collection of Swedish company "Agrobränsle" have also performed well in our previous experiments and showed a very rapid growth, we decided to order the cuttings of clones "Tora" and "Gudrun" for Kambja and Vohnja plantations. The plants were imported with the certificate from the breeding company about the asepsis of the plant material. The risk of planting material damages during delivery was avoided by close co-operation of the beneficiary and the representatives of the Swedish company. The planting machine for large-scale plantations was rented from "Agrobränsle". The planting of the willow was biologically reasonable to perform during the high season of agricultural activities in spring 2003. Therefore we had minor problems to hire a suitable tractor for this purpose at Kambja. Fortunately the weather during this time was favourable and therefore we managed to accomplish willow planting at Kambja without any significant negative influence to the project quality. As soon as planting at Kambja was finished the rented planting equipment was delivered to Kadrina. The planting both at Vohnja and Kihlevere was accomplished without any problems. In Kambja prototype we had planned to plant also a smaller area with alders (*Alnus incana*) and poplars (*Populus tremula f. gigas*). This was important to compare the growth and purification efficiency of different planting material. The alders were ordered from one of the largest plant nursery "Juhani puukool" already half a year before the experiment. Here we met a problem as the workers of the nursery had taken the plants out of the cold storage-house already earlier not knowing that we had no time to deal with them before we have finished the willow planting at Kambja. Due to that the delivered plants had already leaves on them. We complained about the bad quality of the plants to the owner of the company, but as there were no more plants of this species available for this planting season it was not possible to replace them immediately. We got an agreement that if the plants do not survive, we should get additional planting material for free in the next spring. The alder plants were planted by the local schoolchildren manually. Their activity was also important to increase knowledge and their partnership in local events and to prevent the possible actions of vandalism in prototype. Unfortunately a lot of the planted alders did not survive in 2003 and therefore an additional planting action was performed in spring 2004. The delivery of *Populus tremula f. gigas* plants was complicated as this is the sub-species that is growing only in Estonia. At the same time the local meristem breeding specialists did not have much experience with this species. After checking the quality of possible planting material in spring 2003 the beneficiary decided not to plant and wait for better samples. The quality of seedlings was achieved by spring 2004. However, the risk of very strong competition in the field with the weed was still too big. Therefore this planting material was preserved for one more year in plant nursery and planted to the vegetation filter in spring 2005. We have to report that we were not able to foresee this drawback and to prevent its occurrence in our project and the results we achieved with this action represent the current situation on this topic. Finally all planting activities were carried out as supposed. As the area of aspens and alders was very small compared with the rest of plantation of willows, the problems with their planting did not affect significantly the effectiveness of vegetation filter purification capacity nor the cost of prototype establishment.

3.7 Purification of sewage in the pre-treatment plants

The sewage of the domestic households contains mainly three different compounds that can damage the environment. These are:

- organic compounds – usually characterised by biological or chemical oxygen demand (BOD or COD, respectively);
- nitrogen compounds – usually characterised by the concentration of total N that include both the reduced (NH_4^+) and the oxide forms ($NO2^-$, $NO3^-$)
- phosphorus compounds – usually characterised by the concentration of total P.

The first two groups of compounds originate mainly from the excrements of animals or humans, the last one can be connected mostly with the usage of different cleaning chemicals (washing powder, soap etc.). There is strong evidence that the concentration of P in domestic wastewater is decreasing in time, as the modern domestic chemicals are more ecological. The ratio between N and P in the domestic wastewater is quite similar to that of mineral fertilisers used to increase the growth rate of most of plant species. Therefore it has been proved that irrigation of plants with wastewater increase their production as well. The only problem here is the organic compounds – they can contain also pathogenic microbes that should not be spread. So usage of wastewater or its sludge in the agricultural lands where the food or feed crops are produced is forbidden in most of European countries. There are no widespread restrictions about usage of them in short rotation forests. However the loads of different compounds to the fields must be under control not to pollute the groundwater. Moreover, irresponsible spreading of pathogens to the large areas may cause diseases and cannot be a part of sensible farming. According to this it was also very important in our project to carry out the pre-purification in order to provide our vegetation filters with water during the next stage. As already mentioned above, our aim was to make it economically reasonable with low running costs and ecologically sustainable. Therefore in two cases we chose the pre-treatment with passive bioponds. At the same time it was very difficult to predict the chemical and biological processes in the wastewater in ponds. Hence, the results of the first wastewater analyses were crucial for the next actions. All pre-treatment plants were ready in autumn 2003. From Kambja and Kihlevere the first water-samples were collected in November 2003. From Vohnja were we able to get the first measurable sample in February 2004, when the system was filled with water. Since these dates till the end of project all the pre-treatment systems worked continuously with minor problems and the wastewater samples were analysed monthly. At Kambja the main problem has been connected with the mechanical septic before the ponds. Different larger particles (clothes, timber etc.) have clogged the filter and harmed the automatic cleaning system of it. Repeated checking and regular maintenance of this part of prototype surpassed the problem. In the long term this problem could be avoided by repairing the canalisation system of the settlement by covering all access possibilities for solid wastes outside the system. At the same time the waste management habits of local inhabitants should be improved by focussing on this problem in the local media. At Kihlevere and Vohnja we met the problem that the concentration of various solid compounds was very high and according to the local partner the amount of water reaching to the canalisation system significantly lower than in other regions. This may indicate both the perforation of canalisation system and the low living standard of local people – there is a significant correlation between the average income of people and the wastewater they produce (from showers, baths etc.). Although, this problem was foreseen in our project we were not able to adjust with it, because the constructed facilities had to correspond to the average standards.

The results of the water analysis from the pre-treatment facilities show that the purification efficiency of passive bioponds is higher than expected (Fig. 4 A and C).

On the other hand the purification efficiency of vertical filter was lower than in the similar pre-purification facilities. Such results give a lot of information to the scientists, engineers, constructors and environmental specialists. It can be possible that the efficiency of the ponds will decrease during the next years of running the prototype after the experiment due to the mud that will be deposited in the ponds. Therefore monitoring of the system will be an important part of after-LIFE activities. However, cleaning of ponds was not needed throughout two years of experiment in the current project and therefore the running cost could be even lower than expected.

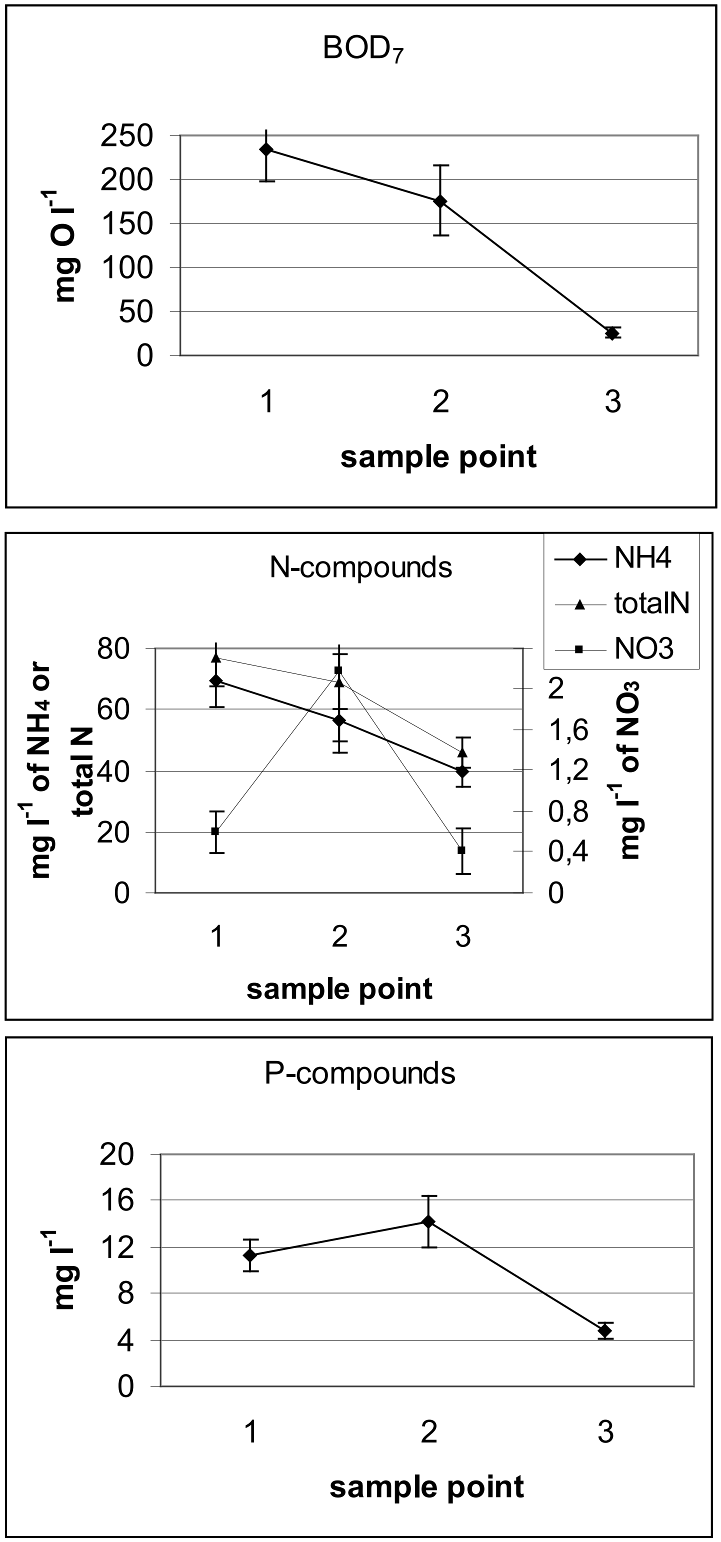

Figure 4. Purification efficiency of the treatment plants 2003-2005. A. Kambja. Sample points: 1- inlet point of the system, 2 – well between the two bioponds, 3 – inlet point to the vegetation filter. Bars indicate the standard errors of 21 samples.

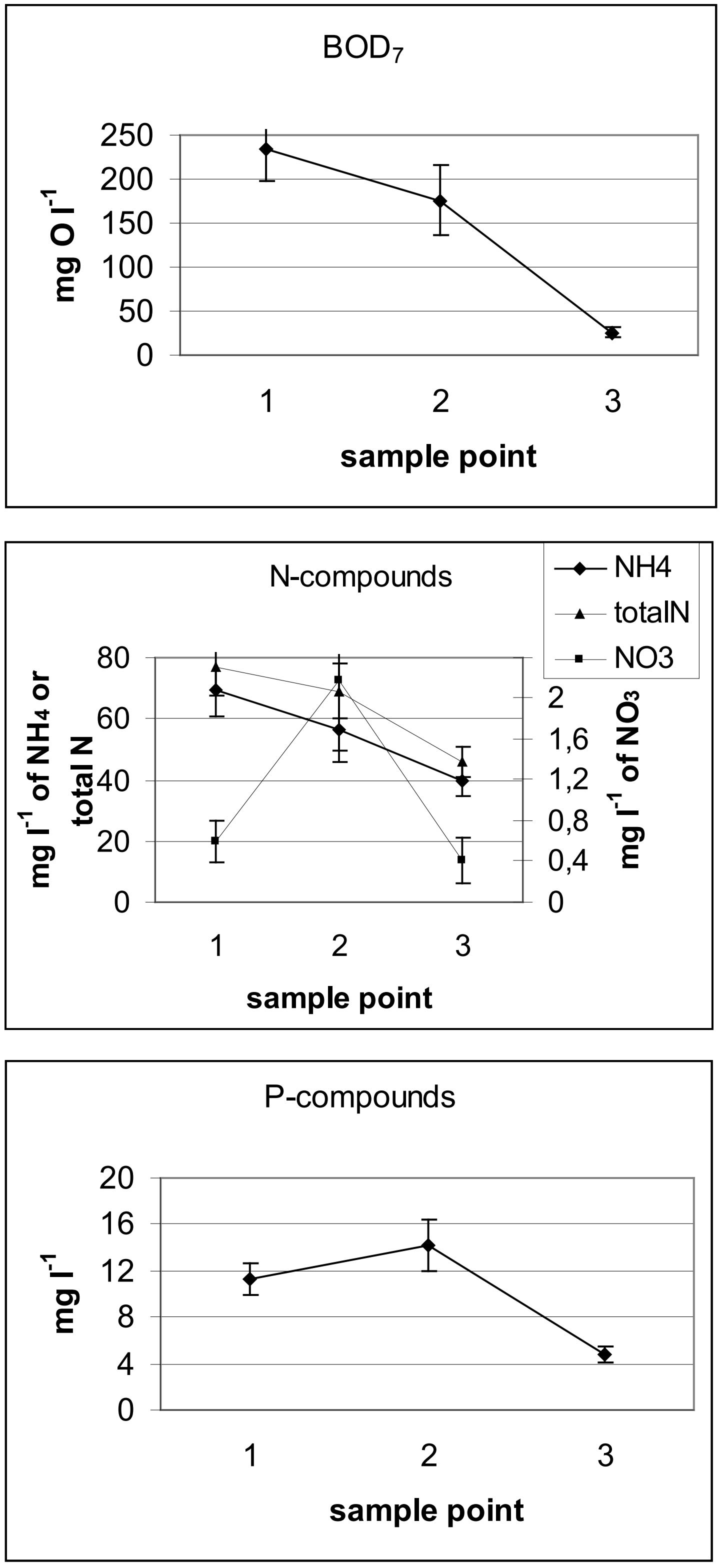

Figure 4. Purification efficiency of the treatment plants 2003…2005 B. Kihlevere. Sample points: 1 – inlet point of the system, 2 – well between the vertical and horizontal grave-filter, 3 – inlet point to the vegetation filter. Bars indicate the standard errors of 21 samples.

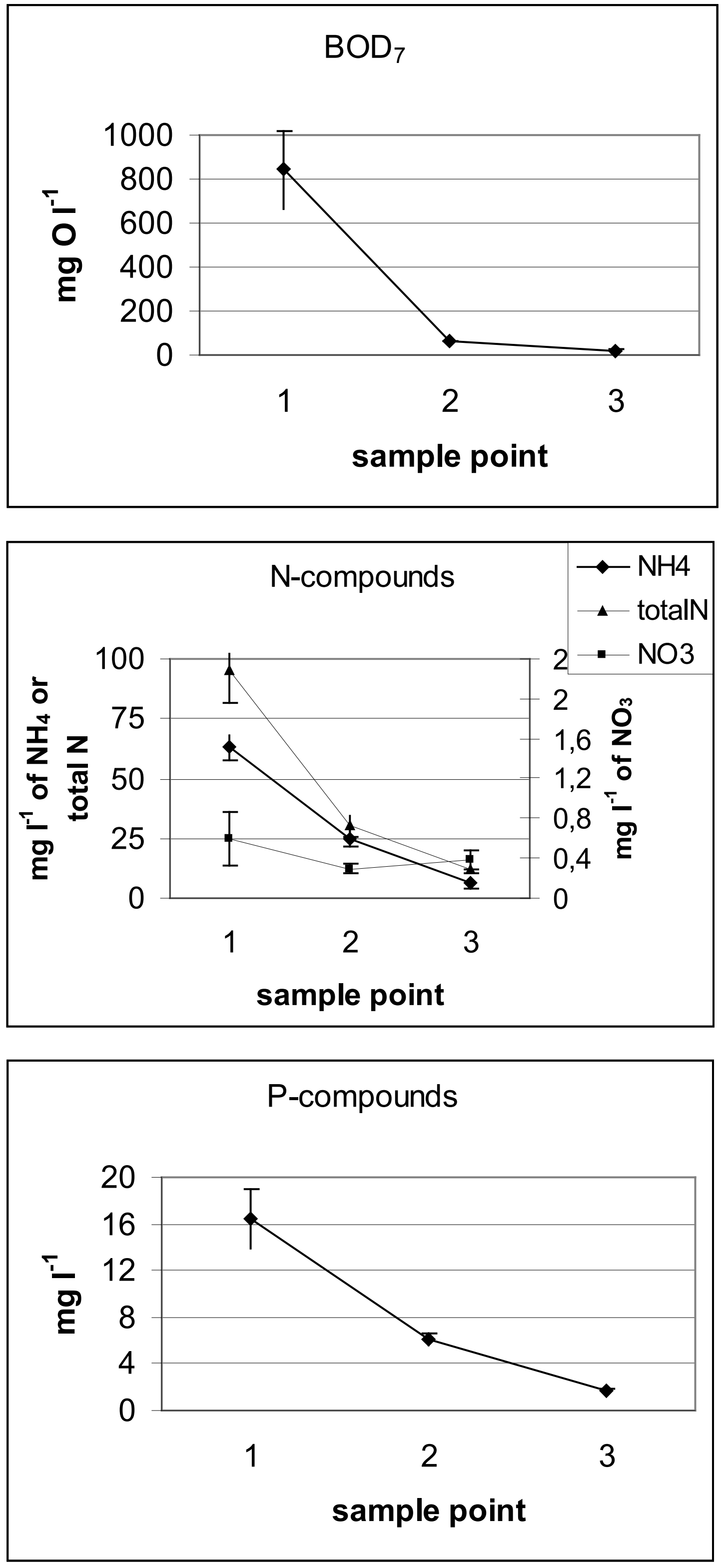

Figure 4. Purification efficiency of the treatment plants 2003…2005. C. Vohnja. Sample points: 1 – inlet point of the system, 2 – well between the two bioponds, 3 – inlet point to the vegetation filter. Bars indicate the standard errors of 17 samples.

3.8 Establishment of pipes and pumps network

In large areas of vegetation filter wastewater should mainly be distributed with the network of pumps and pipes. Design of this network needs a detailed analysis of the local geographical conditions and the plain areas should be preferred therefore to minimise the cost of pumps. As the distribution should be as even as possible, a reasonable balance between the density of pipe network in the field and the amount of water spread through one outlet-point should be achieved. In our previous experiments we have found a theoretical area of vegetation filter that can be supplied from one outlet-point (dependent on local soil structure). Therefore at Vohnja and one part of Kambja prototype we planned the distance between the pipes 4.5 meters. In the second part of Kambja prototype we doubled the distance between the pipes up to 9 m. This was done in order to decrease the cost of the pipes network. On the other hand it made possible to compare the influence of different wastewater distribution schemes on the productivity of the trees. In both Kambja and Vohnja prototypes only one pump was used to transport the wastewater to the vegetation filter. Pipes network was supplied with an electronic device that led the water to different transport pipes according to the created program. Therefore each plot of vegetation filter could be irrigated separately and the amount of wastewater spread to different plots could be calculated by multiplication of the irrigation time with the pump's power. At Vohnja there occurred some problems during 2004. The main problem concerned with the pump water supply system – if the pump stopped working in some cases the pipe between pond and pump run out of water. Therefore in the beginning of next pumping cycle the water did not reach the pump again. The problem was overcome by adding an additional valve to the system to stop the water reflux to pond. At Kihlevere we decided to distribute wastewater to the vegetation filter through a serpentine ditch. This was possible because of the smaller size of the plantation. According to the local geographical conditions the wastewater flow from the grave-filters through the ditch freely. The only pump needed here located therefore before the mechanical treatment.

All the installations of pumps and pipes were performed by the construction company "Hüdroehitus" according to the blueprints designed in private company "Kobras". These blueprints were the part of the design of the whole prototype and therefore passed through technical expertise process of an independent building specialist. No significant problems during the establishment of this network occurred. The only mistake was done during mechanical weed control by a local worker at Kambja who damaged some of the irrigation pipes with tractor. These pipes were replaced without any significant influence to the project as a whole. The pipes were established to the field in summer 2003. In summer 2005 we mentioned the first time that in some places the holes of the irrigation pipes were clogged with the weeds. Therefore the local partners organised the check up of the situation in the field after the end of the vegetation period and clean the holes where needed.

3.9 Purification of wastewater in the plantation

Purification of wastewater in the vegetation filters can be efficient only during the vegetation period. Such restrictions are connected to the biological processes in the local environment – uptake of nutrients by short rotation trees is possible mainly with water transport. The transport system in plant ends with the stomata of the leaves. Therefore no significant movement of water and nutrients to upper parts is possible without photosynthesis and evaporation in leaves. Although, it is possible to extend the period of irrigation of vegetation filter with wastewater for some weeks in spring or autumn if the average soil temperature is above zero. The latest studies on vegetation filters reveal that the substantial part of both N- and P-compounds from this wastewater are not taken up by the plants themselves but decomposed by the microorganisms living in the rhizosphere of the plants. As the microbial activity is very closely connected with the soil temperature, this advance can be exploited during vegetation filter running. This knowledge is extremely important in the Nordic countries, like Estonia, where the vegetation period is short.

At Kambja and Kihlevere prototypes the distribution of wastewater to the vegetation filters started in spring, 2004. During the winter period of 2004/2005 we checked up the pipe system in these fields for possible damages due to the frost or ice forming inside the pipe. Fortunately no cracks in the pipes or other damages were noticed. Therefore we conclude that the chosen technical characteristics of the pipes that remain on the ground during the winter corresponded to the needs and the same type can be used in vegetation filters elsewhere as well. To prevent possible damages we had also drilled the holes into the pipe lower part. This enabled also depletion of the pipes before winter.

At Vohnja the purification of wastewater in vegetation filter started in spring 2004 also. During the first vegetation period we had some problems with the automatic system as mentioned already earlier. After all this shortage was overcame during the second half of the vegetation period and before the end of the vegetation period the bioponds were empty enough to store the wastewater produced during the next winter. Within the vegetation period the irrigation systems at Kambja and Vohnja worked daily. The usual automatic scheme pumped wastewater for one hour per day per plot. The exceptions were made during the very rainy periods – the pump was switched of manually and during the very warm periods with intensive plant growth – then the pump worked for two hours per plot per day. Another exception was made also at Kambja in summer 2005 during the extremely warm period – due to very high evapotransporation in July the ponds appeared to contain less than critical amount of water that should be kept in the ponds to prevent their microbiological activity. After some weeks the normal irrigation schedule was re-established again. If possible the irrigation cycle was planned to the early morning hours. One reason for that was to use the nighttime cheaper electricity as much as possible. At the same time irrigation during midday may decrease the photosynthesis rate and hence also the productivity of plants. The daily irrigation system is illustrated with Fig. 5.

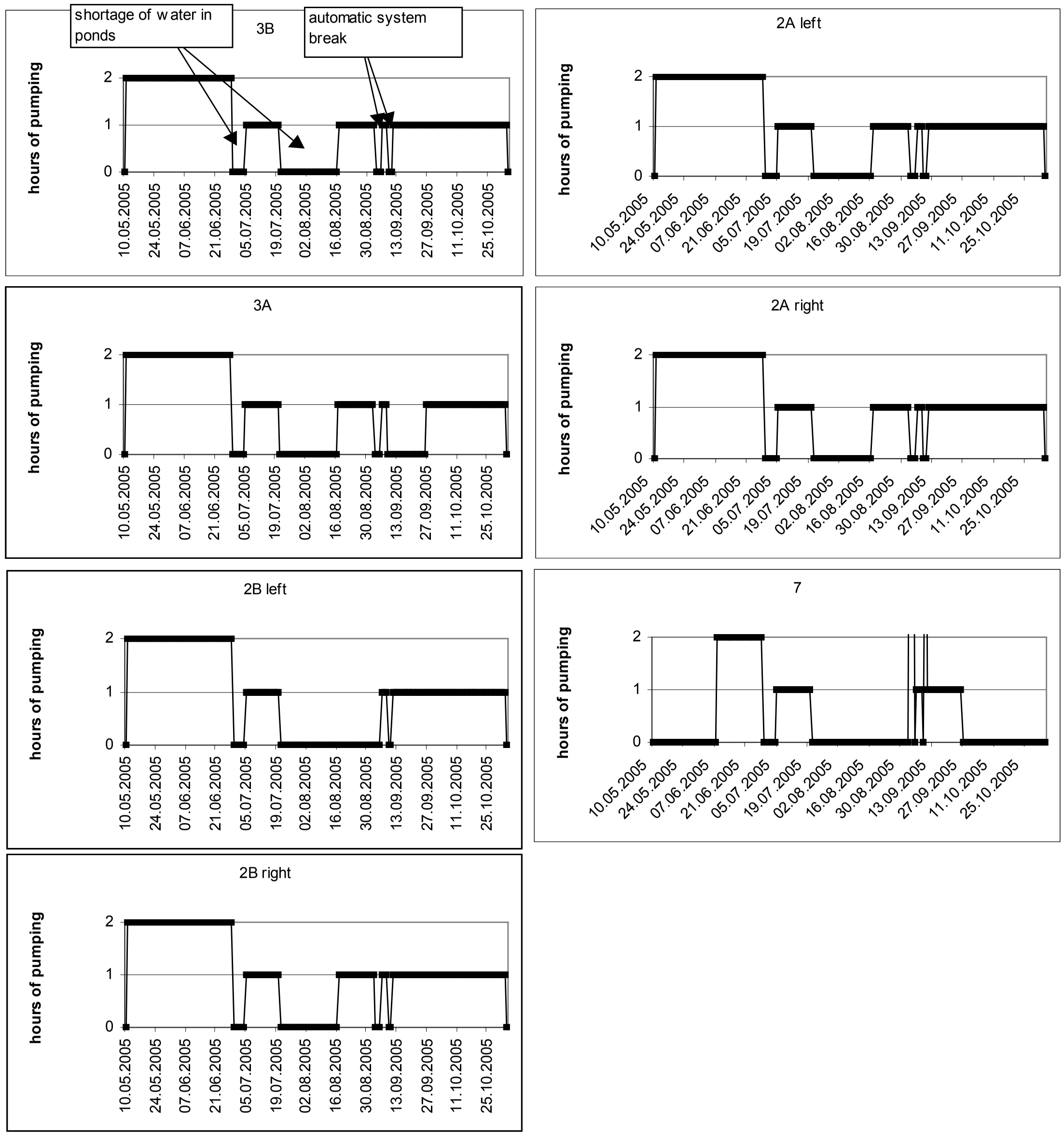

Figure 5. Irrigation scheme of Kambja prototype in 2005. Chart titles indicate the different plots of the vegetation filter (for details see also Annex 2). Plots 2A left, 2A right, 2B right and 3B got water during 187, plot 3A 171, 2B left 170, and 7 during 108 hours.

3.10 Monitoring of purification efficiency

According to the Estonian law contaminants in the wastewater that could be led to the natural environment are limited. The concentration of various compounds depends on the amount of wastewater. The rules that are mainly set to larger settlements are usually used also in the water usage permission for smaller settlements. The main limits that are difficult to cope with for the smaller settlements without any significant industry are usually the following: BOD_7 should be kept lower than 15 mg O l^{-1} and total P lower than 1,5 ml l^{-1}. The concentration of N-compounds is limited case by case and the straightest restriction is to keep it under 10 mg per litre. Therefore these numbers were also taken into account while creating our prototypes.

According to Estonian environmental monitoring system the wastewater quality is analysed from the outlet point of a wastewater purification plant once in every three months. None of probes is allowed to exceed the water usage permission limits without any consequences. This system is significantly different from the practice of other countries – for example in Sweden the annual average values of contaminants concentration is the indicator. Such system enables to focus on the summertime wastewater purification that is easier due to the climatic conditions. The other problem what we had to cope with to meet the restrictions of Estonian law concerned the outlet point definition of a vegetation filter. The idea of our technology was to spread the wastewater to the field with fast growing plants and large leaf area index to utilise the water through evapotranspiration. Therefore no direct outlet for wastewater from the vegetation filter was foreseen. After negotiations with the local environmental officers we found a compromise and two different methods for vegetation filter purification efficiency studies were used.

The first one was established in Kambja prototype. As the field has no drainage system, we constructed six lysimeters during prototype construction works there. Each lysimeter means an area of 6 m^2 of the vegetation filter that is isolated on the depth of 40 cm from the other parts of the vegetation filter with geotextile. Two drainage pipes with 44 mm diameter led the gravitational water that is collected on the surface of waterproof geotextile to a well where it is collected to hermetic bag. The system is working like small-scale drainage and enables to monitor the water, which is going through to the vegetation filter towards the ground water. The water samples from these lysimeters revealed that the wastewater spreading method was used in this prototype did not pollute the natural environment. For example, the average data of chemical analysis of this wastewater were 0.7 and 7.5 mg P and N per litre, respectively. However, the water, collected with this method, contained both wastewater that is spread by the pipes and natural precipitation. For better understanding the biological and chemical processes of the wastewater in the field we collected also additional water samples from different soil layers by vacuum pumping. This was possible to carry out only in favourable weather conditions – if there has been a rain during a week, we assumed that the water analyse may contain it in a gathered samples and stopped pumping. The results from 2004 revealed that irrigational water had a low nitrogen content (around 13 mg N l^{-1} of which up to 99% was NH4-N) that was diluted with excessive precipitation. Thus the considerable plume of nitrogen distribution in measurement nodes was no found. However there was recognised the temporal pattern of nitrate leaching as nitrates appeared in lower measurement notes in the end of vegetation period when NH4-N concentration ceased. As the second half of 2004 was quite rainy the monitoring was processed also during vegetation period of 2005.

The monitoring procedures will be continued in this prototype also during the next years. At first, this is a task that should be performed according to the water usage permission. At the same time Kambja prototype will be also the main object of a project of Estonian Science Foundation (leader Dr. Toomas Tamm from EAU) with the main aim to improve the knowledge about the horizontal and vertical distribution of wastewater and its different components in a vegetation filter.

At Vohnja the vegetation filter purification efficiency was monitored according to the proposal with small-scale transportable lysimeters (0.6 m^2 each) in 2005. There were serious difficulties of collecting the water samples as the summer was very warm and not enough water moved to the lower soil parts to enable the chemical analyses. The water samples collected in autumn did not reveal any significant difference with the usual rainwater.

At Kihlevere the wastewater was led to the natural water-body through a ditch. Therefore no problems with the outlet definition existed there. However, the water load at Kihlevere was significantly smaller than expected (reported in subchapter 3.9). Therefore the willows around the serpentine ditch that should lead the wastewater to the natural water-body are suffering from drought during summer months and no water is reaching to the natural water-body. Therefore monitoring of vegetation filter purification efficiency has been impossible there. On the other hand, shortage of water (and therefore water-soluble contaminants) reveals that no additional pollution can be occurred due to vegetation filter usage as a part of wastewater purification system.

3.11 Monitoring of plantation state

Vegetation filters are used in different countries (Sweden, the Netherlands, Ireland etc.) for wastewater or its sludge utilisation. The main problem in their management is to find out the reasonable species and optimum load of wastes in the field. The results of different studies on this topic cannot be transferred to another region directly without careful checking of both local legislation and environmental issues. The first are necessary to keep posted continuously as the laws can differ in time. At the same time they are easy to find out; for example, growing of several alien poplar species is forbidden in Estonia as a rule and therefore before changes in law the experimental plots of for example *Populus deltoides* for future application make no sense. Quite opposite, in order to evaluate the influence of local soil, weather and pre-purification stage to the plants in the field different applied research studies are needed.

In the current project we planned to evaluate the suitability of short rotation trees species to wastewater application. The vegetation filters of the current prototypes are the first large-scale fields for energy crops growing in Estonia – totally more than 20 ha compared with 2,5 ha experimental plots we had before, different kind of studies were needed in order to apply the prototype methodology into large-scale practice. In comparison with the project proposal the focus of these studies changed more from the purification mechanisms to the applicability. One of the purposes has been mentioned in subchapter 4.1 – there was a shortage of good specialists on some topics. On the other hand, the situation on the energy market has changed a lot during the different stages of the project and the targets of renewable energy ratio increase have resulted in greater interest of decision makers, local politicians and farmers towards the usage of vegetation filter biomass for energy purposes. Therefore additional studies in order to improve the knowledge on this topic as a whole were needed.

In the large scale the plantation monitoring can be divided into five groups of actions:

- Studies on biomass yield. These studies are important for different reasons. At first larger plants are having larger Leaf Area Index. Furthermore, large plants need more nutrients, that can be taken up from the wastewater, at the same time they have usually larger root systems that are necessary for the microbiological activity. Hence, we monitored carefully the productivity of different plants under different growing conditions (density of plantation, differences in pipe network layout etc.). Unfortunately the usual production monitoring method we were able to carry out only on willows. The generalised data of the measurements is summarised in Table 1 and 2. The small number of plants and their low biomass in some areas should be analysed and the growing practice improved in the future.

The alders are not resprouting from the root system and due to their low planting density in the field we did not want to cut them down in order to measure the allometric relations between shoot diameter and dry weight. Because of the young age of both alder and aspen trees their dry weight in the field was not possible to measure by using ordinary forestry methods as well. Therefore only average height and diameter is known for these plants so far (Table 3). The significant difference in the plant characteristics in irrigated and control plots is most probably caused by the different age of the trees. As mentioned already in subchapter 3.6 we had to plant alders in two years.

Table 1. Average biomass of willow plants (g of dry weight) in Vohnja plantation in autumn 2005. S.E. – standard error of measurements, No of plants – living and measured plants in 2 * 30 rows of each.

Clone	plot index	average biomass	S.E.	No of plants
21	28	349	48	44
21	32	829	52	92
21	**total**	**674**	**43**	**136**
83	22	319	24	87
83	28	113	12	71
83	**total**	**227**	**16**	**158**
90	30	16	2	27
90	34	228	101	11
90	**total**	**77**	**32**	**38**
Gudrun	24	73	5	82
Gudrun	32	147	14	28
Gudrun	**total**	**92**	**6**	**110**
Tora	30	20	6	8
Tora	34	1106	119	54
Tora	**total**	**966**	**113**	**62**

Table 2. Average biomass (g of dry weight) of willow plants in Kambja plantation in autumn 2005. Plot index corresponds to the map in Annex 2. S.E. – standard error of measurements, No of plants – living and measured plants in 2* 30 rows of each plot.

clone	plot	Average biomass	S.E.	No of plants
7	1A	161	18	59
7	1B	187	19	63
7	2A1	218	37	43
7	2B	509	79	38
7	3A	110	12	56
7	3B	97	13	43
7	**total**	**200**	**15**	**302**
12	1A	273	25	84
12	1B	201	18	61
12	2A1	688	89	63
12	2B	644	46	67
12	3A	227	26	90
12	3B	176	18	66
12	**total**	**357**	**20**	**431**
21	1A	159	17	52
21	1B	218	20	57
21	2A1	306	37	65
21	2B	281	40	35
21	3A	175	43	72
21	3B	225	20	64
21	**total**	**225**	**14**	**345**
83	1A	288	22	103
83	1B	351	27	72
83	2A1	764	57	104
83	2B	899	63	72
83	3A	1136	85	95
83	3B	944	63	89
83	**total**	**731**	**27**	**535**
90	1A	199	16	85
90	1B	357	27	66
90	2A1	394	47	82
90	2B	744	44	69
90	3A	616	67	84
90	3B	657	50	80
90	**total**	**490**	**21**	**466**
97	1A	228	19	88
97	1B	385	36	75
97	2A1	964	104	72
97	2B	794	60	78
97	3A	301	23	102
97	3B	295	23	85
97	**total**	**472**	**23**	**500**
Gudrun	1A	229	13	99
Gudrun	1B	339	21	79
Gudrun	2A	921	78	65
Gudrun	2A1	283	25	104
Gudrun	3A	436	49	80
Gudrun	3B	322	30	75
Gudrun	**total**	**394**	**18**	**502**
Tora	1A	249	28	46
Tora	1B	380	39	37
Tora	2A1	419	62	21
Tora	2B	1465	154	34
Tora	3A	407	55	53
Tora	3B	520	57	65
Tora	**total**	**545**	**37**	**256**

Table 3. Measured parameters of alders in Kambja plantation in autumn 2005. Average height – the height of the aboveground part of a tree, average diameter – measured at 55 cm from the ground. S.E. – standard error of 30 measurements.

	Average height	S.E.	Average diameter	S.E.
irrigated	1,24	0,06	8,21	0,57
control	1,97	0,08	19,66	1,27
total	**1,61**	**0,10**	**13,94**	**1,44**

- Studies on biomass production mechanisms. These are important for this project mainly from the water usage point of view. Therefore the beneficiary institution started its fieldwork on this topic at Kambja, where the closest prototype for the daily transport of the equipment during the studies from the university is located. The studies of water use efficiency (WUE) of the vegetation filter trees were performed at Kambja prototype in summer 2005. The two main objectives were: 1) to clarify the causes of the differences in WUE between the clones/species and the causes of the seasonal changes in WUE. For that reason, the correlations between WUE and several other characteristics (that can possibly determine WUE) were analysed; 2) to find out markers for selection of the most suitable clones/species for vegetation filters in the local climate. For that reason, the correlations between WUE, the other characteristics and the productivity of the clones/species were analysed. WUE and several other characteristics were measured in top and basal shoots of foliages in all the 8 *Salix* clones and in *Alnus* and *Populus* plants at the beginning of the growing season (at the beginning of June) and at the last month of the growing season (in the middle of August). The following characteristics were measured: transpiration intensity; stomatal conductance; stomatal sensitivity to changes in leaf water potential, in air humidity, in light intensity or in CO_2 concentration of the ambient air; the net assimilation at several different light intensities (0 – 2000 μmol $m^{-2}s^{-1}$) and CO_2 concentrations of the ambient air (0 – 2000 ppm); nitrogen, chlorophyll and abscisic acid content in the leaves; and the shoot hydraulic conductance. As the results were interesting and useful for other specialists in this area, the scientific material gathered will be analysed and published in some international applied research journal during next years. The research on this topic will be continued towards more basic issues in Kambja prototype next years – Estonian Science Foundation granted it for 2006…2009.

- Studies on different pathogens in the field. These studies are urgently needed in Estonia right now as the interest of farmers in the new crop has increased substantially. At the same time quite little is known about the possible pathogens of this monoculture. Moreover, lack of information about the options for warding off the pathogens in sustainable way is a problem also in other countries. Therefore international co-operation with the specialists from Swedish Agricultural University was started already in the beginning of the project. During the project one postgraduate student of the beneficiary institution has finished her Master Thesis on this topic and will be the specialist in this field. The data collected from the different prototypes have enabled to publish two applied research articles in this field (one accepted in the international journal Biomass and Bioenergy; the other in the Proceedings of Estonian Academy of Sciences). Kambja vegetation filter is less infected by leaf rust than the older plantations in Estonia. However, this result may be caused by the young age of the plantation as the only older experimental plot of vegetation filter existing in Estonia showed significantly higher number of leaf rust *Uredinia spp*. per leaf area than the other plantations. Additional studies during next years will be needed in order to find out if this is an influence of much higher plant density in this plot than at Kambja or if the higher air humidity in the plantation will increase the distribution of leaf rust to the prototypes as well. In order of diminishing the risk of ice-forming bacteria in the vegetation filters disease-resistant clones should be used.
- Studies of irrigation systems have been one of the major applied research activities of the project and will continued in different after-LIFE projects. The summary of the current information is presented in Annex 9.
- Studies on microbial activity in the prototypes. In the situation, where about 80 % of P and N is utilised by the microbes in the soil, much attention should be paid to the better understanding about their ecological needs and possible changes in their community during vegetation filter running. The initial microbiological status of soil in Kambja willow plantation was determined at the end of September 2003 and in autumn 2005. The field was divided into eight sub-areas and two control areas. At each area from 0…10 cm soil layer one sample as close as possible to

the willow plant and the other from the bulk soil between willow rows was taken. In one sample area and one control area the soil profile (0…10 cm, 10…20 cm, and 20…30 cm) was taken for the analyses. Metabolically active microbial biomass C using substrate induced respiration (SIR) method and total microbial biomass C, N and P using fumigation-extraction method were determined. Microbial respiration rate, N-mineralization, potential nitrification, acid and alkaline phosphatase activities, and community level metabolic profile with BiologEco microplates were determined. From the chemical parameters the soil pH, total N, P, K and total carbon were measured. The initial analyses indicated that active microbial biomass was larger, and the N-mineralization, the overall metabolic activity and diversity were significantly higher in samples containing willow roots already after one growing season. Phosphatase activity was higher in soil samples taken between rows. In general the highest biomass of microbes was found in 20…30 cm soil layer. The same studies were carried out in late autumn 2005 after the end of microbial activity in vegetation filter. The preliminary data of these analyses are concluded to Annex 3.

3.12 Dissemination of knowledge

This has been a very important activity throughout the project and the project team has done their best to meet the needs. Our project diary of dissemination activities has more than 100 records. As the various knowledge dissemination actions could differ from each other a lot, it is better to divide these into different groups:

- Dissemination of sustainable way of life and wastewater purification to the general public. To pay attention to this was important in order to notice in a very quickly developing country, like Estonia is, that beside very expensive methods and high-tech solutions also sustainable methods, that may solve the problems, are available and useful for different purposes. Therefore the start of the project and establishment of prototypes were used to get public attention to the project aims. This resulted in various newspaper articles, media interviews etc (for examples see also Annex 4). The opening ceremony of Kambja prototype was joined by Estonian Minister of the Environment and demonstrated in national TV. Another increase of public attention was caused by the activities of beneficiary to create a national bioenergy programme. This action was possible only after establishing the vegetation filters of project prototypes. On this topic also numerous interviews were given to the different newspapers. National radio and TV were also used for dissemination in this case. In 2003 we created project's homepage www.zbi.ee/life where the main information about the project is available.

- Dissemination of LIFE project as a whole (its aims, management, techniques etc) among the partners' municipality citizens and other people who were interested in the close co-operation inside European Union. By the number of events this was most probably the largest group of actions during the project. In 2002, before joining EU, not very much was known about EC-project-based actions at local level. Therefore the main efforts of the beneficiary in 2002 concerned the dissemination of the project management needs, methods and possibilities to the partners. There were different topics that had to be discussed with various authorities in local and regional level, as some of their habits and ways of thinking needed to be changed. Further on the representatives of the partners took this activity over. Throughout the project the possibilities to implement a project, rules of the management and options to find solutions to environmental problems were discussed with the authorities of different counties and countries (Latvia, Finland, the Ukraine). According to the characteristics and volumes of needed information different project team members have been active.
- Dissemination of sustainable wastewater purification technology to the specialists on this topic and to the students who can be the specialists of this area in the future. After getting the expertise during the current project, the team members have been invited to disseminate their knowledge about the used method in different national and international workshops. A lot of support in such activities we have got from the foundation of Enterprise Estonia. Besides co-financing the current project, they have also been very active in organising various seminars and workshops on this topic and including us to the list of speakers. For example, there was a section seminar of wastewater purification technologies at Tartu in August 2003. Therefore the project team was able to introduce the working prototypes in the frames of this action and organise an analogous seminar themselves in other part of Estonia with a tour to the prototypes at Vohnja and Kihlevere. The same material was also published in a journal of Enterprise Estonia. A little bit more practical overview of used technologies was published

by the beneficiary in the journal "Keskkonnatehnika" (Environmental technologies) (Annex 4). For quicker dissemination a leaflet with project technologies was also created in 2003. This has been distributed among participants of different workshops where the project was introduced (including INTERREG, PHARE etc.). The large volume of dissemination activities of technologies and management influenced also significantly students' attention. During the project the project leader, Dr. Katrin Heinsoo, has been supervising more than ten different course, Bachelor and Master level papers of students from two universities on topics focusing sustainable wastewater purification. Several representatives of the beneficiary have provided general overviews of various aspects of wastewater purification within different lecture courses. This has improved the knowledge of specialists in future. Several postgraduate students (K. Jürgens, T. Tilger, J. Šmeljova, B. Holm) are qualified to transfer project results and disseminate project details on their own.

- International dissemination of project methods to the specialists on the same topic in other countries. Especially during the first stage of the project it was extremely useful and helped to improve the project quality and to learn from international practice. The key-action here was the workshop of the project team with the team managing the largest vegetation filter in Scandinavia, Enköping, Sweden. Other significant actions were conduced at international conferences and seminars, which the representatives of the beneficiary have been attending in the course of the project (Biomass Conferences, International Poplar Commission meetings, seminars organised by European Biomass Association etc.). In the first place, all these events have given a possibility to introduce the project (for introductions of various presentations see Annex 5; the majority of the Powerpoint presentations are also available on our homepage www.zbi.ee/life). On the other hand numerous discussions during the breaks, dinners etc. have resulted with the new valuable contacts and information change, which significance is considerable. With the most interesting and promising of them the info exchange have continued later on through the internet, material exchange etc. These actions have been also very useful for after-LIFE planning.
- Dissemination of project results to other concerned specialists of the world. This group of actions is separated from the previous one for one main reason – the

current project has developed its team substantially and a new quality of work has been achieved. Before the current project we were mainly in the role of beginners ourselves, by now the project team has gained practical skills that are important also at international level among the top-specialists on this area around the world. This new situation has given us new challenges and tasks with we are going to achieve in our after-LIFE plans. During the project the most significant actions of this group were the visits of various top-specialists (Dr. Robert. Kadlec, Dr. Chris Paterman etc.), the international workshop of the three sections of International Poplar Commission that included also a visit to Kambja prototype and presenting the Estonian case in an international handbook for specialists of short rotation forestry.

All the dissemination presentations were carried out with clear indication to LIFE Environment financial support. In all dissemination materials that were made with the help of these finances also the LIFE logo was presented. In the cases where the other funding have been prevailing (for example, lecture courses for students at the universities) or in the cases where using LIFE finances was not allowed but the results of the project were disseminated (for example, presentation in Chile) oral mentions to the LIFE support to the knowledge and results development was made.

As the conclusion, all activities planned in our proposal were conduced with only minor changes in their content. This statement is supported also with the table of activities and their status, which is in analogous with those we sent in every half a year in our progress reports (Table 4).

Table 4. Summary of the tasks planned in our project proposal and reported in progress reports.

Task No in Gantt Chart	Tasks according to Gantt Chart	REAL SITUATION
1	Vegetation filter planning	Completed.
1.1.	Land lease	Completed.
2	Land preparation	Completed.

Task No in Gantt Chart	Tasks according to Gantt Chart	REAL SITUATION
3	Planning of sludge treatment plant	Completed.
4	Construction of treatment plant	Completed.
5	Weed control in plantations	Completed.
6	Planting of willows to the plantation	Completed.
7	Purification of sewage with sludge process	Completed. Will be continued with partners` own financial resources and skills.
8	Establishment of pumps and pipes network.	Completed earlier than proposed.
9	Purification of wastewater in the plantations	Achieved. Will be continued with partners` own financial resources and skills.
10	Monitoring of purification efficiency	Completed. Will be continued in frames of after-LIFE projects.
11	Monitoring of plantation state	Completed. Will be continued in frames of after-LIFE projects.
12	Dissemination	Completed. Will be continued with the aid and in frames of after-LIFE projects.

4 Analyse of lessons learned

The problems encountered and the solutions found were already reported in the detailed overview of activities. The conclusion of that part of the report was that all the main tasks of the project were achieved despite of various minor problems. Although, every project is useless if the team members do not learn something useful during its running. These lessons should also be disseminated in order to avoid such critical details in the future. Therefore we analyse here both details of management and technical layout that should be improved during the after-LIFE activities.

4.1 Overall project management

Throughout the current project from the proposal writing up to the final report composing the project responsible manager has been one person, Katrin Heinsoo, from EAU. This has ensured the consistent development of the project principles and enabled a deep analyse of the project management that is useful for following projects' implementation. The following statements are the basic essence of this analyse:

- The current project was the first international applied research project managed by Katrin Heinsoo. Moreover, such partly and stepwise-financed project was also new to both of the project partners. This caused serious work of every participant in the early stage of the project in order to improve their knowledge about the project management methods and network formulation (for general scheme of the management system look Fig. 1). It was particularly difficult for project partners, as all the documentation was available in English at the beginning. Therefore intensive work was done by the beneficiary in order to translate and explain all the necessary materials to the representatives of the partners. The most serious issue was the bookkeeping system arrangement. As in LIFE projects the beneficiary is responsible for all funding usage also by the partners, a special system of dealing with the bookkeeping documents was needed. During the proposal formulation the inexperienced project manager had not predicted such large amount of work by bookkeeping office and therefore the bookkeeping expenditures of the project were significantly underestimated. Fortunately the beneficiary authorities understood the difficult situation and found other financial sources in order to ensure the implementation of this essential project. Therefore the strong suggestion of the project team to the future is to pay much more attention and to plan much larger financial resources of the budget for the bookkeeping service. The other supporting idea is to create a local, regional or general "round-table" of the project managers and representatives of partners. This could be extremely important especially during the first stage of the project to diminish the possible smaller mistakes of project management that are difficult to correct later on. This kind of co-operation would also improve the quality of each project. At the same time the project team is very thankful to Mrs. Eili Erg and Mr. Toomas Pallo from External Monitoring Team of Astrale GEIE who have been very supportive and ready to answer our questions operatively also during their holidays and weekends.

- The issue that had a serious influence to the project management was the long interval between the proposal preparation and the end. In quickly changing world the detailed planning was difficult to follow quite many times, as the existing situation in 2005 was not predictable in 2000. On one hand this was crucial for team creation. In the project-based society, it is impossible to predict what kind of equipment, technology and which scientists are available in 4…5 years. In the case of current project the smaller failure can be mentioned in the monitoring task. Our prognoses were to involve to the vegetation filter monitoring also young scientists who were studying the methods of greenhouse gas analyses in order to monitor this emission. However, during the project it was clear that this method could not be used in such scale. Despite oral agreements during the first stage of the project the mentioned scientists were not improving their methods but preferred to join some other projects. Even more serious than the above-mentioned problem with planning the scientists team was the insufficient information about the conferences, workshops and international seminars during the proposal writing as non of them was declared in advance to take place in next 4…5 years. We are grateful that EC accepted most of our requests for approval to travel outside the EC (to the Ukraine and India). Unfortunately our request to allow the project manager Katrin Heinsoo to present to project results to the wide-scalest conference of Short Rotation plantation specialists in Chile was not accepted. We are very thankful that this situation was understood by the beneficiary authorities, who found the money for this conference from other sources. The retrospect to the conference participation shows that it was extremely useful for both dissemination of the current project – the seminar in Santiago resulted with the international colloquium with the best specialists of the world in this field in Tartu (in details in 3.12.) and for the after-LIFE projects and communication plans (in details in Chapter 6). There is also a list of events and contact outside EC, which have been not so successful because of the short notice of the holders. That has not given us enough time to ask for travel request from the Commission. We understand the requirement of control over the financial issues of projects. However, the countries from which the calls to give some advice or disseminate the knowledge have been in such economic-social level that additional help to their environmental issues is badly needed (Indonesia, Belarus). Therefore we would have appreciated highly the larger flexibility of travel possibilities also to third countries without planning them in the proposal in the future.

- During the current project Estonia has developed rapidly. Beside many positive and pleasant issues this has also caused a number of things that were unpredictable at the time of proposal writing. The most serious issues were concerned with the changes in Estonian legislation. For the project team it was impossible to foresee the demand of state procurement for the prototype establishment or the changes in VAT recovery system. We have reported about both of these changes and their influence to the project implementation already in our Progress Reports. However, this is a serious topic and caused large changes in our plans. We are very thankful for the representative of the construction company "Hüdroehitus" who understood our problem with different budget categories and agreed to write their invoices for materials and equipment in detailed way. However, as soon the company was involved, we were not able to pay to the constructors from the "Direct personal costs" category. As we did not got the permission to the budget shift, we had to keep the finances of "External Assistance" category down and were not able to do all the planned works on the optimal ways therefore. The change of VAT recovery system between the signing of the current project contract with EC and project start date caused automatically the increase of the costs of all materials, prototypes, and equipment by 18%. This had a strong impact to our project and dealing with it was beyond the skills of the beneficiary. The issue must be solved on the governmental level in the nearest future, as it has a strong influence to the applied research as a whole. The other considerable influence of the social development is the enlarged brain-drain from our country. This has had an impact to the project as about half of the scientists that were partly planned to involve in the current project (including both PhD students mentioned in the proposal) are now working abroad. In the future such situation should be avoided by keeping their salaries at least on the average level of this category in EC to ensure the interest of specialists with high quality.

Furthermore, different social benefits should be initiated to guarantee the sustainable education and research infrastructure in smaller countries.

4.2 Prototype technical layout

Due to the short period of the project we had to establish all three prototypes in one year and therefore were not able to learn from the smaller mistakes that occurred in practice after running the first one. Therefore the first stage of the project was crucial for the overall success. Even if all the project tasks were achieved there are some issues we want to point out that are important for further development of experiments on this topic:

- The land preparation (and history) for vegetation filter establishment is extremely important. One of the aims of our project was to find a new reasonable usage for abandoned farmlands of Estonia. Therefore most of the vegetation filters were planned on the areas, where no ordinary agriculture was carried out before the project for some years. As re-usage of former agricultural land was not very usual in Estonia in 2002 we underestimated the effort we had to put on the weed control during the first vegetation period. Even then the survival of plants was lower than expected. The best example for the importance of this issue is the Vohnja vegetation filter. One third of it was used regularly by a local farmer before the project. In the situation where all the procedures throughout the vegetation filter running (ploughing, weed control, planting time, irrigation load) were the same everywhere in the prototype, we saw even in autumn 2005, that the plants in the pre-used part of the vegetation filter were much larger and their survival significantly better than in the other part of the vegetation filter where the land was out of use before the vegetation filter establishment. Therefore we suggest establishment of vegetation filters to an area, which is used for ordinary agricultural crops during previous years. If abandoned agricultural land would be used, it should be ploughed and kept like a fallow for at least one year before the establishment.
- Efficient purification systems need stable central canalisation systems and should be designed according to the local conditions. In all of our prototypes we have met some problems with leaking or not-hermetic central canalisation systems in settlements. This has caused damages or clogging of the mechanical filter

equipment. At the same time the actual water amounts that are significantly smaller than those expected by the number of households connected to the canalisation have made management of the prototype (Kihlevere) more complicated.

- Kambja prototype is a bit larger than strictly necessary. The only data about vegetation filter purification efficiency were gathered previously from our experimental site of 200 m^2, where the wastewater flows to the vegetation filter directly from the septic. No information about the role of passive bioponds (both evaporation and changes in content of pollutants) was available in Estonia prior to the project. In order not to fail in our experiments and to meet all the necessary environmental needs we underestimated the purification efficiency of the bioponds and the pre-purification system as a whole. After the implementation of the project and having additional knowledge our statement is that hereafter smaller areas for vegetation filter per person equivalent can be established while using the same pre-purification method than in Kambja prototype.
- More information is needed about the subsurface filters. Subsurface filters for wastewater purification is not a new topic in Estonia and there are examples available which work efficiently. The reasons of poor purification efficiency at Kihlevere are unclear yet. Besides of the unpractical septic tank that should be re-built in the future there are also some other issues that should be analysed. It is possible, that some mistakes by constructors were made during the establishment (poor isolation of gravel from the upper soil cover for example) and which were impossible to figure out during the project. On the other hand it can be possible that such high concentration of chemical compounds (especially biological) in the used wastewater have clogged the water movement paths in filter. There have been negotiations with various specialists to study these issues during the after-LIFE activities with the help of some tracers.
- Not all the planted tree species are reasonable to use in vegetation filters. Purification efficiency of a vegetation filter depends on the production potential of trees. Especially important is the growth of root systems in order to form a rhizosphere needed by microbes. Both alders and aspens used in our project showed significantly lower growth during their young age than willows. At the same time their density in the field was lower as the cost of planting material is

higher and their growth period longer with additional needs for more available space. Moreover, these plants should be replaced after their harvesting, as they do not re-sprout from their roots like willows do. Therefore we do not suggest their usage in vegetation filters in the future.

- Applied environmental research studies need more time than that of the current project. Beside the project team itself the studies in prototypes were also carried out by the scientists of different universities. In most cases the quality of a scientist in Estonia is evaluated by his international publications with high quality. Therefore the scientists were mostly interested not in the salary we were able to pay them during their fieldwork but in the opportunity to use the collected data for their publications in the future. However, it was difficult to achieve their plans during fieldwork that they were able to perform only in 1…2 years under the changing circumstances (both weather conditions and developments during prototype running). Therefore we assume that it is not useful to plan both establishment of such prototypes, which need a long period for stabilising, and applied research in large scale into one project. Although, the current project had gave a good starting point and most of those who agreed to start working in this project had found themselves in after-LIFE activities in which they can continue their activities.

5 Cost-benefit analysis, impact assessment

While analysing the cost-benefit of the prototypes several factors should be taken into account. Most of these are influenced by general issues of environmental politics as a whole. Therefore the project team continues working on these seriously during their after-LIFE activities and only some patterns will be stressed out in the current report. The first-stage simple model designed during the current project is added in Annex 6.

The overall cost benefit ratio of wastewater purification plants is depending on various options which general issues are explained in the current list:

- Definition of agricultural land. According to the Estonian Statistic Office the area of agricultural land has decreased 611 thousand ha during the last twelve years in Estonia. At the same time Estonian Agricultural Registers and Information Board reports only about of 270 thousand ha of agricultural land that was not used in

2004. The difference of these two numbers is 341 thousand ha that means more than 7.8 % of Estonian mainland area. That is mainly the land without agricultural use at the moment and reforestation of it is usual activity right now. On the other hand that is a large change in Estonian landscape and decreases the employment rate in the rural areas. Cultivation of short rotation forests (SRF) in these areas and usage of them for different environmental purposes could be one option to decrease the influence of the changes. Larger development of short rotation forestry in Estonia in order to provide our energy sector with renewable energy sources can be possible only by increasing the area of agricultural land. The small area of today's agricultural land in this Register is necessary to assure the strategic food and feed reserves for Estonia and therefore we are not able to foresee larger development of SRF in these lands. However, according to the legislation no governmental support for reusing this abandoned land for agricultural crops, like SRF, is available, as it does not belong to the Agricultural Register created in 2004. Another issue is the differences in support policy of different crops. Today no financial support for SRF management is available in Estonia. At the same time such support is usual for other agricultural crops or even for grasslands management. Therefore it is not reasonable to make very detailed economical comparisons of different crops before the changes in support mechanisms in Estonia have been carried out.

- Experimental versus common costs. The current project was a pilot one in terms of large-scale establishment of SRF. Therefore it is very difficult to generalise costs for different actions needed for SRF running. Various equipment for SRF management is available in the field and as always the average cost of one procedure decreases if it can be used in larger scale. In addition, our SRFs, established during the current project, are not gone through the stabilisation stage yet and therefore it is impossible to predict the management costs during the next years of the current rotation period or after that.
- Credits achieved from pollutant utilisation. These are difficult to include to a cost benefit model because of two reasons. At first, the penalties exploited for the pollutant disposal to natural water bodies have been increasing approximately twofold in Estonia during the project period. Moreover, we are not able to restore the situation of pre-project stage in order to find out how much pollutants over

limits would have been produced if not purified it in the prototypes. The data existing before the project period is not possible to use for comparison as the communities` structure involved in our project have changed a lot. Although, if the municipalities needed to pay penalties for the pollutants disposed from their canalisation system after mechanical pre-treatment their expenditures would be approximately 70 % larger (Table 5).

Table 5. Hypothetical monthly expenditures of municipalities if the wastewater was disposed after mechanical pre-treatment to the natural water-bodies in 2005.

Site	Pollutant compound	Average concentration after mechanical treatment	Total amount of pollutant (kg)	Amount of pollution over the limit (kg)	Pollution tax according to water use permission (EEK)	Penalties due to increased pollution (EEK)	Total sum of expenditures (EEK)	% of penalties
Kambja	BOD_7	64	319	244	1794	4118	5913	69,7
	total N	25	126	76	666	1203	1869	64,4
	total P	3	17	10	91	244	335	72,9
Kihlevere	BOD_7	233	350	328	1968	5524	7492	73,7
	total N	77	115	100	610	1591	2200	72,3
	total P	11	17	23	90	586	676	86,7
Vohnja	BOD_7	844	844	829	4745	13982	18727	74,7
	total N	96	96	86	506	1360	1866	72,9
	total P	16	16	15	87	378	465	81,3

- Credits achieved from producing CO_2 neutral biofuel. According to European Union strategy for incoming period the usage of renewable energy sources should increase during the next decade. In order to meet the needs of the target an open CO_2 market is actively searching different options. In autumn, 2005 in this market it was possible to sell a credit of CO_2 ton for 22 €. As a rule, annual shoot production of SRF is above 10 tons of dry biomass per hectare. In the case where the CO_2 subsides would be developed to promote smaller distant heating plants or producers as well, the benefit of a farmer from its SRF will increase significantly.

All the mentioned issues are connected with the development of Estonia and European Union as a whole. Therefore solutions for these problems were not possible to find out during the current project and additional work will be needed. The members of the project team will continue their work on this topic after the end of the project. It is possible to carry out on Estonian level as the representatives of the beneficiary are today advising the Estonian Minister of Agriculture on the issues about promoting bioenergy production and very much attention is paid to the economical issues in this work. Moreover, participation in a new international project "Solutions for the safe application of wastewater and sludge for high efficient biomass production in short-rotation-plantations" includes special tasks on this topic. Beside the beneficiary the best specialist in this field all over the Europe, Dr. Håkan Rosenquist, is included to this study.

The achieved knowledge impact assessment of the current pilot project is in details described in the subchapter 3.12. Therefore we give here only a general overview of different aspects of the project impact on different levels. On local level both the beneficiary and the partners got a better overview about the sustainable wastewater purification method in which it is possible to produce also a significant amount of renewable energy. They also got a very useful experience on the EC funding system and skills of project management. The inhabitants of the partner municipalities live today in an environment that is less polluted with their own wastes. A very intensive dissemination and explanatory work among them improved also their attitude to the environment protection and to the more sustainable way of living. On national level the current project helped to find out different obstacles to be changed in order to meet better the targets of renewable energy production and the limits of pollutants disposed to the natural water-bodies. Also the Estonian specialists of environmental protection and water economy got better practice in the usage of the project technologies. On international level the members of the project team are now experts in this field. The demand of such specialists is high and the potential of the team members is already engaged in various projects with the aim to apply the current methods in different countries. Such kind of international co-operation would have been impossible without the experiences and knowledge attained during current project.

6 Reuse of results, transfer potential, scale and scope

The improved knowledge achieved during the current project will be used on different levels. The gathered material that is useful for the basic research studies is already included in two different basic research projects funded by Estonian Science foundation: ETF 5773 "The influence of the hydrophysical characters and irrigation system on the water balance and nutrient leakage in a vegetation filter" and ETF

5305 "The ontogenetic development of leaf water regime and photosynthetic structural and functional characteristics in a broad-leave tree plantation". In both of these projects the main part of the fieldwork is carried out in the Kambja prototype. The gathered data are also used in the "Development of Estonian state programme of bioenergy promoting" – the first stage finished in summer, 2005 will be continued after the adoption of this material by the authorities. Studies about changes of microbial activity will be continued inside EC COST 859 network "Integration and application of phytotechnologies". The new skills of the team members will be used also for teaching the students in next years.

The project team is and will be also involved in different international projects on this topic. In EC CRAFT project "Monitoring and Control System for Wastewater irrigated Energy Plantations" our role is to be an expert of vegetation filter establishment and scientific expertise of the demands of WWPS control system needs (www.wacosys.info). In this project the vegetation filters similar to those of the current project have been established in Spain and in another county of Estonia, Põlvamaa, at Põlgaste village. The nine partners of this project represent both EU10 and EU25 countries. Another EC 6th Framework project, where the beneficiary is a leader of different tasks, called "Solutions for the Safe Application of Wastewater and Sludge for High Efficient Biomass Production in Short-Rotation-Plantations" (BIOPROS) started in the last months of 2005 (www.biopros.info). This project, having 25 partners from different EU countries, focuses mainly on the analysis and evaluation of the sector's current situation and to co-ordination of applied research activities on this topic. Furthermore, this project enables to continue our previous task to disseminate the methods among biomass producers. During the BIOPROS project some new SRFs will be established and their capability of wastewater and sludge utilisation monitored. At the same time a part of Kambja prototype will be an object for fieldwork in this project. The third project of EC 6th Framework, where the beneficiary actively takes part in is "Integrated European Network of Biomass Co-firing" (www.netbiocof.net). Here we are the experts of biomass production in Nordic climate that can be used for co-firing and the number of partners both from EU and other East-European countries is 25.

There are also several projects, which are still in the stage of ideas or proposals not funded yet. The two main aims of these are: 1) creating a network of specialists of biomass production for energy purposes in colder countries involving here the different skills and knowledge of Scandinavian countries, Baltic states and Great Britain; 2) dissemination of the sustainable and comparatively cheap wastewater purification method to developing countries (both in former socialist countries and Asia). The scale, where this information is possible to be transferred, depends on the generalisation level.

Therefore we conclude that the transfer potential of the knowledge gathered during the current project is large and we are planning to use it according to our time and energy limits after the end of the current ESTWASTE project.