FINAL RESULTS, CONCLUSIONS AND RECOMMENDATIONS

Content

Preface

This report is part of the EU Life project Hg-Rid-LIFE with the LIFE project number LIFE15 ENV/SE/000465. The project was carried out between 01/09/2016 – 31/08/2019. The project was coordinated by the health and dental care company Praktikertjänst in partnership with Sweden Recycling and the IVL Swedish Environmental Research Institute.

The main purpose of the project was to minimise the emission of dental amalgam at dental clinics in Sweden, and in the longer term throughout the European Union (minimisation of emissions at source).

This was done by a demonstration project for improving awareness and knowledge of existing installation techniques and maintenance routines for reducing emissions of mercury from amalgam separators. Furthermore, the project lead to an increased knowledge and competence regarding handling of waste containing mercury, management and procedures of amalgam separators, sanitation of mercury, and more. The project objectives were the following:

- Reduce mercury leakage from examined dental clinics.
- Clinics participating in the demonstration project with mercury levels in sewage waste from suction systems above 1,000 µg/l, will have their mercury levels reduced by 50 %.
- Remove sewage waste containing contamination corresponding to 100 kg mercury contaminated sludge.
- Increased knowledge and know-how on how to mitigate mercury leakage from dental facilities.
- Support the development of national and international guidelines for management of dental mercury by providing a draft proposal of guidelines.

This report is part of the EU Life project Hg-Rid-LIFE with the LIFE project number LIFE15 ENV/SE/000465. The project was carried out between 01/09/2016 – 31/08/2019. The project was coordinated by the health and dental care company Praktikertjänst in partnership with Sweden Recycling and the IVL Swedish Environmental Research Institute.

The main purpose of the project was to minimise the emission of dental amalgam at dental clinics in Sweden, and in the longer term throughout the European Union (emissions at source).

The aim of the project:

- Increased awareness and knowledge how the environmental impact of mercury from dental amalgam can be minimised.

- Development of methods for environmental decontamination which is efficient, user-friendly and cost-effective.
- Support the development of national and international guidelines for management of dental mercury by providing a draft proposal of guidelines.

For more information, please see www.praktikertjanst.se/life and www.hg-rid.eu

Action C1 - Monitoring of the impact of the project actions

The objective of Action C1 is to monitor and evaluate the effects of the screening and decontamination efforts of the project. The evaluation will describe the effects on the local level in dental care facilities as well as overall effects of the whole project.

The aims with the action are:

- To present an overall effect evaluation, as well as a process evaluation.
- To identify important key drivers and barriers for implementation of better mercury decontamination.
- To evaluate usability of project results and suggested methods
- To verify that the project actions enforce achievement of goals of EU legislation on water quality (Water Framework Directive (2000/60/EC), Decision 2001/2455/EC and Directive 2006/11/EC on dangerous substances and Directive 2008/105/EC on priority substances) where mercury is identified as a priority hazardous substance and is in line with the Community Strategy Concerning Mercury.

Earlier in the project an evaluation plan (C1.1.1) was developed to ensure that the project partners share a mutual understanding of the data and information that are required for the project evaluation, and to ensure that once collected, this data is as useful as possible in to the results of the Hg-rid-LIFE project. The evaluation plan presents an evaluation framework and describes the key activities for monitoring the impact of the project actions.

This report is structured in different types of evaluations. It begins with evaluating the effects of the decontamination process (DC) and use of amalgam separator which is then followed by the environmental and technical evaluation with Life Cycle Assessment. Then the report goes on to present the assessment of socio-economic impacts of the mercury abatement measures adapted in the project on mercury decontamination of dental care facilities. These are overall summarized here but described in full in separate reports (C1.4.1 & C1.6.1). The activities aiming at increasing knowledge and know-how and the usability of these, including the project performance indicators are then presented. This is followed by the process evaluation and finally, conclusions and recommendations.

Evaluating Impacts in the dental care facilities

This chapter presents the evaluation used to assess the effects of the decontamination process (DC) and use of amalgam separator. The assessment was based on data collection of mercury concentrations in effluent water and outgoing air from the dental clinics. Data presented in this chapter were collected and evaluated by IVL Swedish Environmental Research Institute. Details are presented in [Stripple H. et al.].

IVL was invited to participate during several DCs performed by Sweden Recycling AB (SRAB). IVL did in total 15 study visits to 10 different dental clinics in Sweden and one visit to Medentex facilities in Bielefeld, Germany, where the Hg contaminated waste is processed. The data were used for the environmental and technical evaluation of decontamination (DC) activities of dental care facilities, using Life Cycle Assessment (LCA) (Subaction C1.6). The objective was to evaluate the DC process and the use of amalgam separators (AS) at dental care facilities from an environmental and technical point of view. The use of a system perspective, provided by using LCA, was important to bring the whole life cycle of mercury into account when evaluating the role of DC and use of ASs to reduce mercury emissions.

During the visits, IVL got acquainted with used methods of Hg removal and handling. By using a portable device for measuring gaseous mercury in air, IVL was able to monitor the release of Hg to air before, during and after the DC work. Hg in air was also measured in the premises of dental clinics during normal operation and at clinics after shutdown or in between hand-over to new owners. Complementing water samples were collected for comparisons and for speciation. Concentrations of gaseous elemental mercury (GEM) in air was measured at all clinics and water samples were retrieved from 8 clinics.

Measurements of gaseous elemental mercury (GEM) in air was performed using a Lumex RA-915+ instrument, which uses Zeeman atomic absorption spectroscopy (AAS) technique for detection. Concentrations of GEM in air varied widely between different clinics and rooms. When a DC was planned, IVL measured GEM in air before, during and after the cleaning process. Results are presented in Figure 1. For discretion, dental clinics are here referred to as clinic A-J.

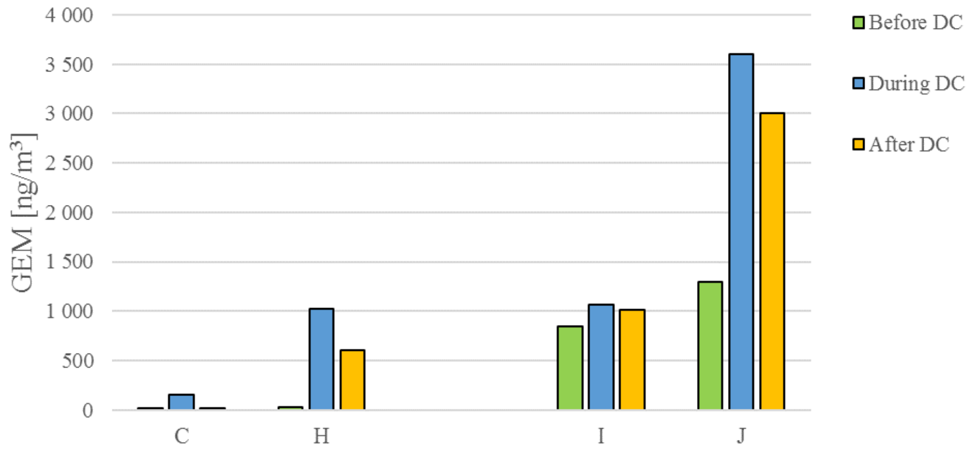

Figure 1. Average GEM (gaseous elemental mercury) concentrations in air measured at dental clinics A-J in different rooms of the premises before decontamination activities (DC). AS=Amalgam Separator.

A total of 29 water samples have been collected and analyzed for different forms of dissolved mercury in water. Water was sampled after the ASs either directly in the unit, if separator was installed in the chair, or at the outlet to the sewage system. What has been analyzed is dissolved gaseous elemental mercury (DGM, Hg(0)), oxidized forms of mercury (Hg(II)), total mercury (all forms of dissolved mercury in the sample, HgTot) and methylated mercury (MeHg, $HgCH_3^+$). The motivation for water sampling was to evaluate if all kinds of mercury is filtered by the ASs or if there are forms of dissolved Hg that pass the filter to the outgoing sewage water. The analysis methods used by IVL for Hg analysis are accredited by Swedac and are suitable for Hg speciation analysis. For comparison water samples for HgTot analysis were taken before, during and directly after DC at selected clinics, see Figure 2. Two clinics were revisited one month after the DC process and one clinic was visited four months after.

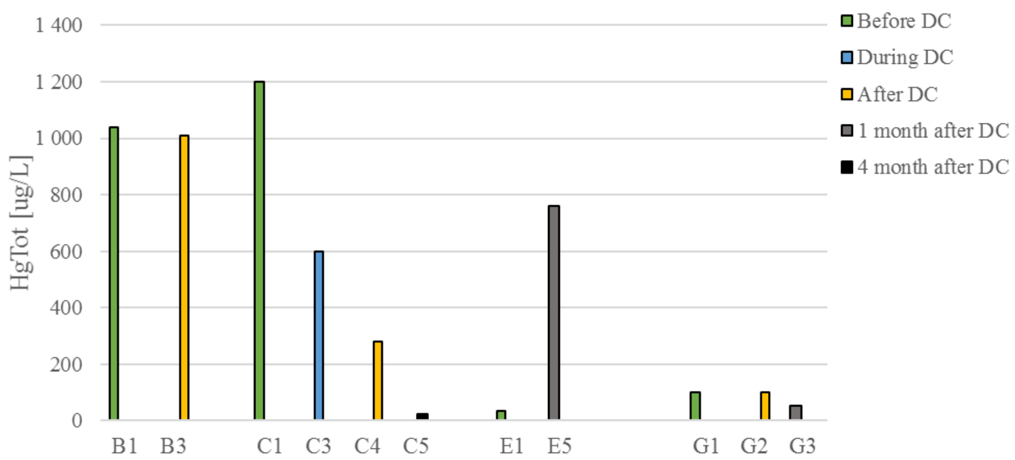

Figure 2. HgTot concentrations in IVL samples taken before, during and after the decontamination process (DC). Compared to Hg concentrations in water sampled one or four months after DC.

Sweden Recycling performed separate water sampling and analysis of outcoming water after the AS before and after DC at 16 dental clinics. The sampling and analysis techniques used by IVL and Sweden Recycling differs and are not directly comparable. Although, in average the reduction of HgTot concentrations in water sampled before and after DC showed similar results with an average decrease of 80-100% in concentration.

Assessment of the socio-economic impact of the project actions on the local economy and population

This chapter presents the assessment of socio-economic impacts of the mercury abatement measures adapted in the Hg-rid-LIFE project on mercury decontamination of dental care facilities. The two abatement measures are decontamination of pipes, and the use of amalgam separators. The aim of the measures is to reduce the mercury discharge to the environment through the facilities wastewater.

Based on decontamination of 68 facilities within Sweden, we have estimated the benefits and costs for an average decontamination as well for all the performed decontamination within the project. An average decontamination generates a net benefit for society of 5.8 thousand, with a benefit-to-cost ratio of 2.4 (however, with a wide range of -9.4 to 200 thousand Euro in net benefit/decontamination, depending on amount of mercury removed and valuation of effects). All 68 decontaminations performed within the project generated net benefit of 390 thousand Euro, with the benefit-to-cost ratio of 2.1 (with a range of -350 to 1 400 thousand Euro, depending on the monetary value set on mercury impacts). An average decontamination generates a net benefit for society of 5.8 thousand Euro. See Table 1 for an overview of the results.

Table 1. Results from the socio-economic analysis

Technology and time horizon	**Range**	**All 68 decontaminations**	**One decontamination of a clinic**	**All amalgam separators at a clinic**	**One amalgam separator**
		10 years	**10 years**	**10 years**	**1 year**
Costs of removed Hg, €$_{2018}$/kg	Min	1 700	1 700	13 300	13 800
	Mean	17 300	17 300	13 300	13 800
	Max	1 208 100	1 208 100	13 300	13 800
Net benefits, Euro	Min	-349 200	-9 400	-10 100	-400
	Mean	392 700	5 800	18 100	660
	Max	1 399 400	199 600	56 570	2080
Benefit-to-cost ratio	Min	0.0013	-0.00004	0.0015	0.0014
	Mean	2.1	2.4	2.8	2.7
	Max	5.0	51	6.5	6.3

Within the project, decontaminations have been performed for different types of suction systems, i.e. wet or dry. For wet systems two types of decontamination methods have been conducted. One in which they add a chemical (sodium hypochlorite) before and, one where no chemical in added before flushing the pipes (read more about the different techniques in the reports B 1.5.1 Decontamination of pipe systems with poor access, and B 1.4.1. Improved decontamination methods for sub-optimal pipe dimensions). Our analysis indicates that the highest benefit-to-cost ratio is for wet systems with chemicals, second dry systems and lowest ratio for wet systems, see Figure 3.

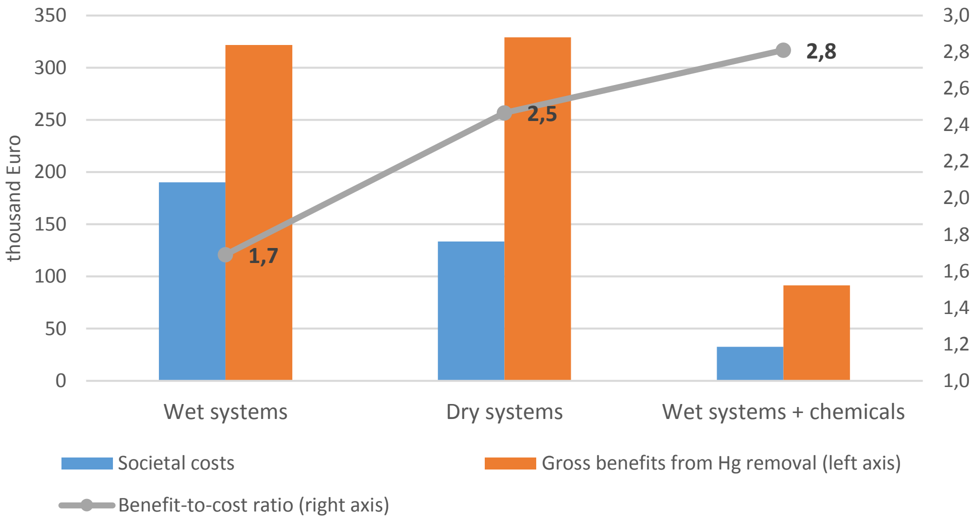

Figure 3. Total costs and benefits of clinics with different suction systems (wet and dry) and clinics with wet suction systems without use of chemicals.

For amalgam separators the analysis has been conducted per separator, indicating a benefit-to-cost ratio of 2.7 and a net benefit to society of 660 Euro (a range of -400 to 2080 Euro, depending on the monetary value of mercury).

A comparison between these two abatement measures, i.e. decontamination and amalgam separators, indicates that amalgam separator results in a higher benefit-to-cost ratio of 2.8 compared to 2.4 for an average decontamination. Decontamination can be considered as an important complimentary measure to remove mercury from dental facilities that cannot be captured by amalgam separators – a mandatory abatement measure in the EU from January 1st, 2019.

Due to the high variation in the results, depending on both the amounts of removed mercury and the uncertainty of the monetary valuation of mercury, we see a need for more studies, especially on decontamination that seems to be an under-researched area compared to amalgam separators. This to verify the main findings from our study. More in-depth description of the assessment of the socio-economic impacts are described in report C 1.4.1 Assessment of the socio-economic impact of the project actions on the local economy and population.

Assessment of the technical system for Hg reduction

The objective of the sub-action C1.6.1 *Environmental and technical evaluation with Life Cycle Assessment*, is to evaluate the decontamination (DC) process and the use of amalgam separators (AS) at dental care facilities from an environmental and technical point of view. The use of a system perspective, provided by using Life Cycle Assessment (LCA), was important to bring the whole life cycle of mercury into account when evaluating the role of DC and use of ASs to reduce mercury emissions. Details are presented in [Stripple H. et al.].

To perform an LCA, an understanding of the system, along with input data of emissions to and from different receptors, is needed. Therefore, a close cooperation between IVL, SRAB, PTJ and Medentex was essential to share information, share experiences, make study visits and access sampling points for data collection.

In this part of the project, an LCA model has been developed over the entire system of a dental clinic, the mercury cleaning process, and the final storage of collected mercury. A schematic picture of the technical system is shown below in Figure 4.

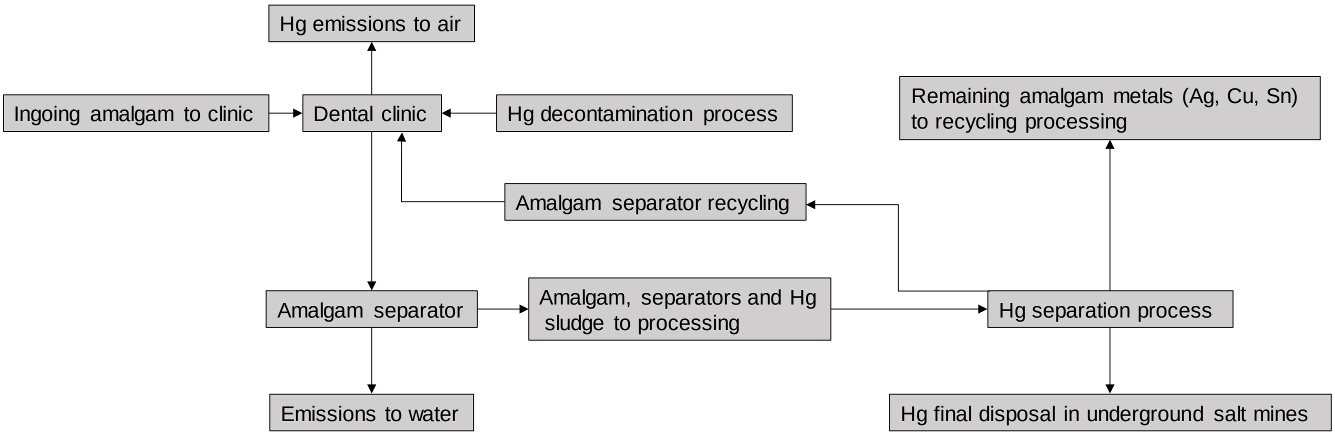

Figure 4. Schematic picture over the technical system for Hg separation at dental clinics in Sweden.

In addition, different forms of mercury have been analyzed in water samples at several dental clinics during the DC process. This information together with other process information has been used in the LCA model. Nine environmental impact categories have been evaluated in the study. The results are divided into the dental clinic, the Hg decontamination process, and the Hg sludge and final storage of Hg in closed underground salt mines. Three different scenarios have been evaluated:

- **Scenario 1:** Mercury handling with Hg decontamination, Hg processing and final Hg storage, representing the main handling system of today in Sweden.
- **Scenario 2:** Mercury handling with only amalgam separation and final storage of amalgam in Sweden.

- **Scenario 3:** Reference case with no mercury or amalgam handling. The amalgam from the dental clinics will go directly to the recipient.

All results are presented per functional unit.

The functional unit (FU) reflects the function that it intends to analyze. In order to make it possible to draw more general conclusions, and also to be able to transfer the result to corresponding activities in other countries, we have chosen to define the functional unit to: **one dental chair for one year of operation (226 working days)**.

In Figure 5 to Figure 7, three different results from the LCA models are shown, namely Total Hg emissions, Global warming potential, and Terrestrial ecotoxicity. As shown in the figures, the Hg decontamination process is efficient and removes a large share of the mercury entering the clinic, see Figure B. However, the separation efficiency for the amalgam separator is about 98.6 % (laboratory tests) so some of the amalgam/Hg can spread further to the surrounding recipient. Global warming potential (GWP) can be an indication of other emissions than Hg from other processes, see Figure C. Only a moderate increase in GWP can be found for the Hg decontamination process. The elevated values for scenario 3, without Hg cleaning and separation, are due to the electrical energy consumption used at the dental clinics during normal operation. However, the reduction in Terrestrial ecotoxicity is significant when having any kind of Hg cleaning in scenario 1 and 2 compared to the uncleaned case in scenario 3, see Figure 7.

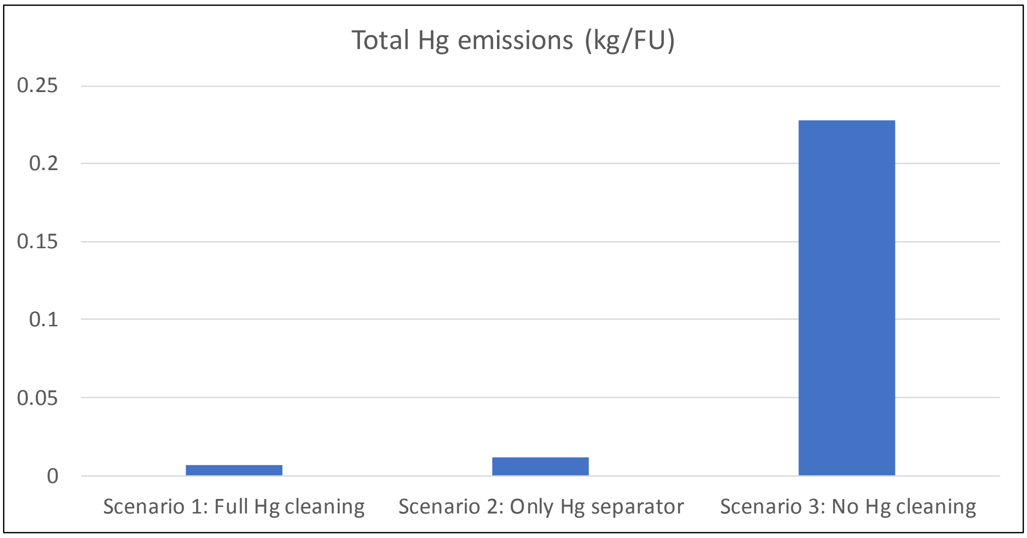

Figure 5. Scenario comparison of the total Hg emissions from the entire LCA model systems.

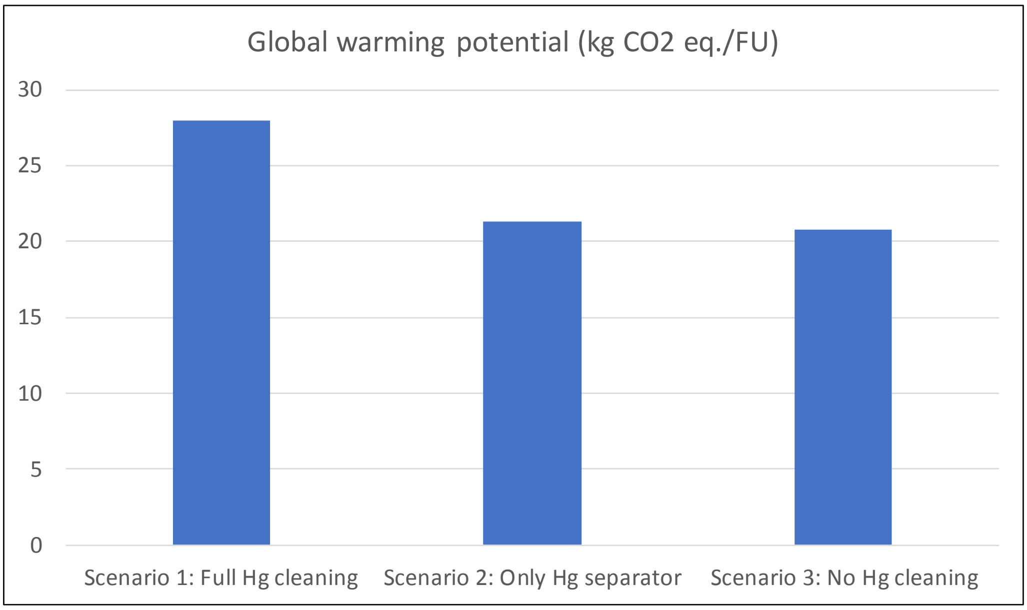

Figure 6. Scenario comparison of the Global warming potential (GWP100) for the entire LCA model systems.

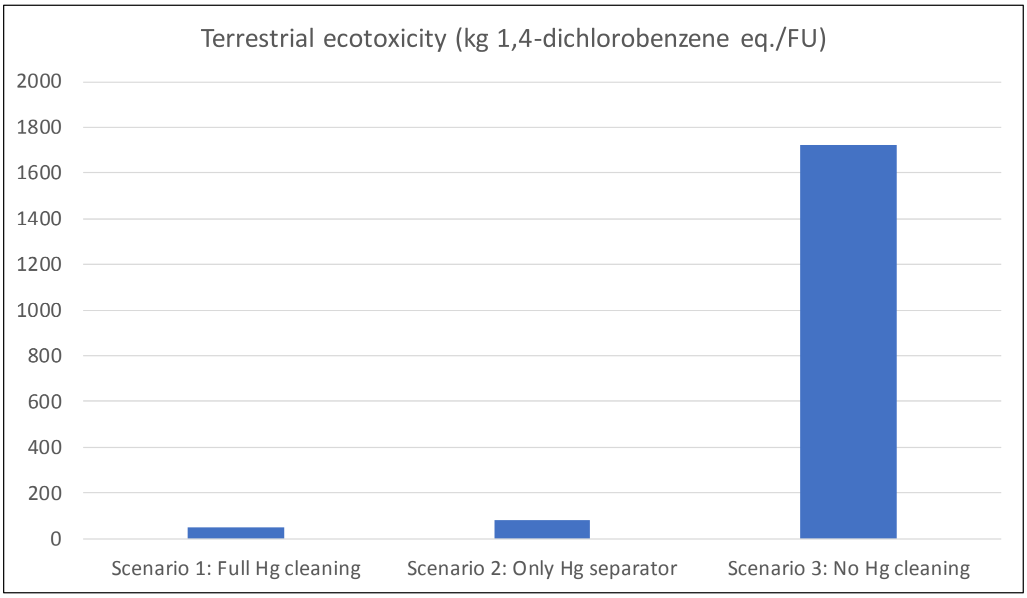

Figure 7. Scenario comparison of the Terrestrial ecotoxicity for the entire LCA model systems.

Most of the amalgam is separated by the amalgam separator, which is placed either directly in the dentist's chair (dry system) or at the end of the sewage-pipe system in the building, usually in the basement (wet system). However, the separation of amalgam in the separator is not complete since very fine-grained amalgam from e.g. drilling and grinding as well as dissolved mercury in the aqueous phase follow the wastewater into the main sewage system, as the separator is based on sedimentation and lacks e.g. an absolute filter for removal of particles and carbon filters to separate dissolved Hg in the aqueous phase. In the LCA models, a purification rate of 98.6 % has been assumed for the separator. This condition and the fact that there is also an emission of Hg to air via the suction system's ventilation, means that the dental clinic itself contributes with the largest emission amounts of Hg to the recipient from the entire system. The Hg decontamination process itself or the disposal and final storage of Hg only contributes to a minor part of the total emissions of Hg. However, it should be noted that the project did not have access to direct emission data from the Hg sludge and separator processing but were estimated based on Hg concentrations in outgoing air and water.

The amount of amalgam that accumulates in the dental clinic's sewage pipe system depends on several different factors and can therefore vary greatly between different clinics. Aspects affecting the accumulation of amalgam in the pipelines can e.g. be; the slope of the pipe system, the water flow in the pipes, the material and surface structure of the conduits, biogenic growth in the conduits etc. This condition is also shown by the varying amounts of amalgam obtained from the various Hg decontaminations. The design of the clinics' sewage pipe systems is therefore an important aspect for the remediation, and in the long term it might be conceivable to design the pipe systems in such a way that recurring Hg remedies can be minimized and most of the amalgam can be captured in the separator.

The sludge from the decontamination and the amalgam separators goes to a process where the sludge is dewatered and distilled at high temperatures to separate Hg and finally deposit it for all time. The amalgam separators are emptied of amalgam and cleaned and then reused at the dental clinics. The residue from the high-temperature distillation is then taken care of by external companies to extract the remaining metals (Ag, Cu, Sn). These recycling processes are slightly outside this project and in addition, it has not been possible to access technical data from these processes. In general, however, it can be said that recycling these metals can be a positive side effect of the process of extracting and final storage of Hg from amalgam. This metal recycling should then be compared with other metal recycling of these metals as well as new recovery of the metals from ore. The total resource utilization of these metals must also be considered. This means that the recycling process should be energy wise and environmentally in parity or better than these processes.

In this study, we also compared today's Hg management system for dental clinics with some alternative methods. These are reference scenarios entirely without purification of amalgam (scenario 3) where this goes straight into the recipient and a scenario with only amalgam separation and subsequent storage of amalgam (scenario 2). The amalgam separators are emptied of amalgam and are locally cleaned and reused in the same way as in today's system. Figure 8 to Figure 17 shows a comparison of these scenarios for all environmental impact categories included in the study.

Fel! Hittar inte referenskälla.8 shows the metal balances for the metals included in the amalgam, for the different scenarios. As can be seen, most of the metals (Ag, Cu, Sn) are recovered except for mercury that is finally stored in today's Hg management system (scenario 1). In the management system with only amalgam separation, all metals in the amalgam are finally deposited, which is then lost and then entails a permanent resource use of these metals but remain in available form. In scenario 3, however, all metals disappear as emissions to the surrounding recipient.

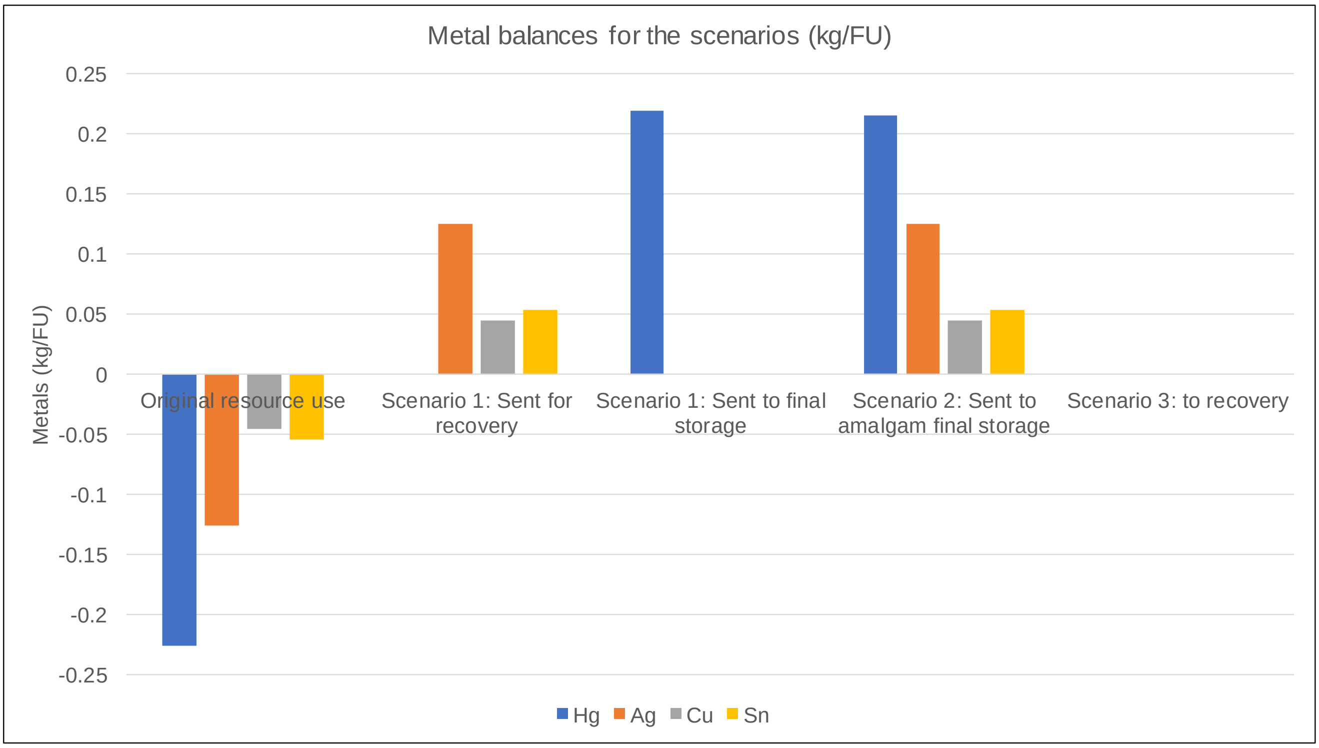

Figure 8. Scenario comparison of the metal balances showing also the resource use of the metals.

The total emissions of mercury from the different scenarios are shown in Figure . The figure clearly shows that the cleaning measures for Hg found in scenario 1 and scenario 2 have a good reducing effect compared to scenario 3 without separation and cleaning. The system with only Hg separator (scenario 2) also has a good reducing effect of emissions.

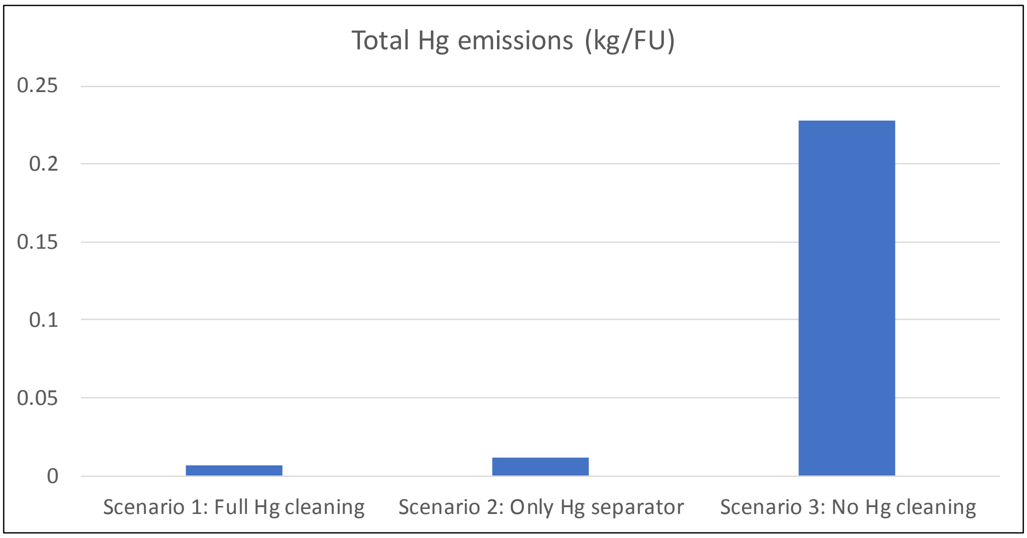

Figure 9. Scenario comparison of the total Hg emissions from the entire LCA model systems.

The use of energy resources is of course also higher when using a more complex cleaning method as shown in Figure 10. The fact that the system without purification has such high energy resource use is due to the fact that the suction system at the dental clinic is included as part of the cleaning technique.

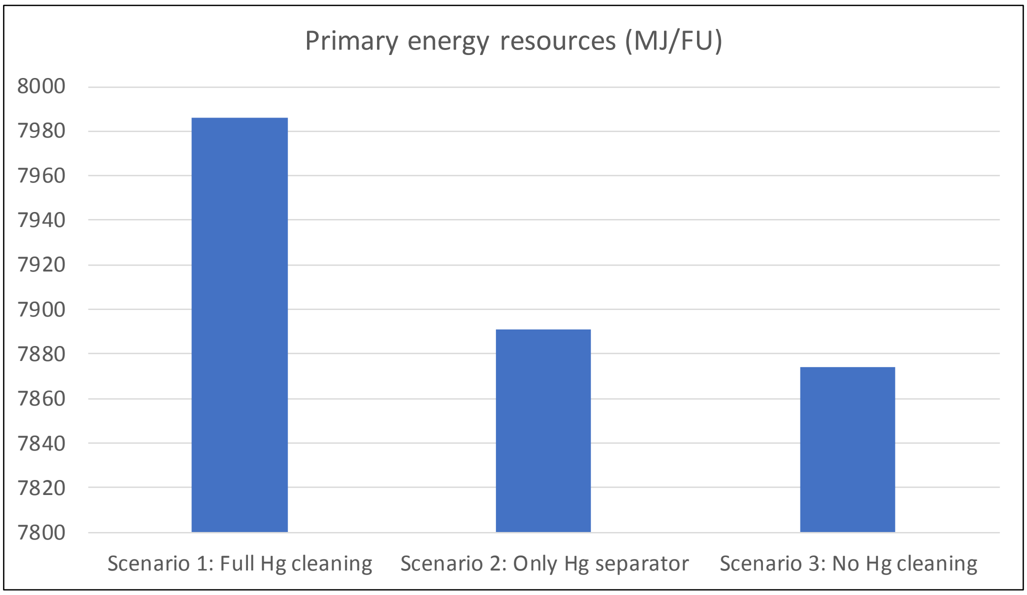

Figure 10. Scenario comparison of the use of primary energy resources for the entire LCA model systems.

The emissions of greenhouse gases that give rise to global warming will then also be lower for a purification system that uses less energy and is less complex or for a case without purification, as shown in Figure 11.

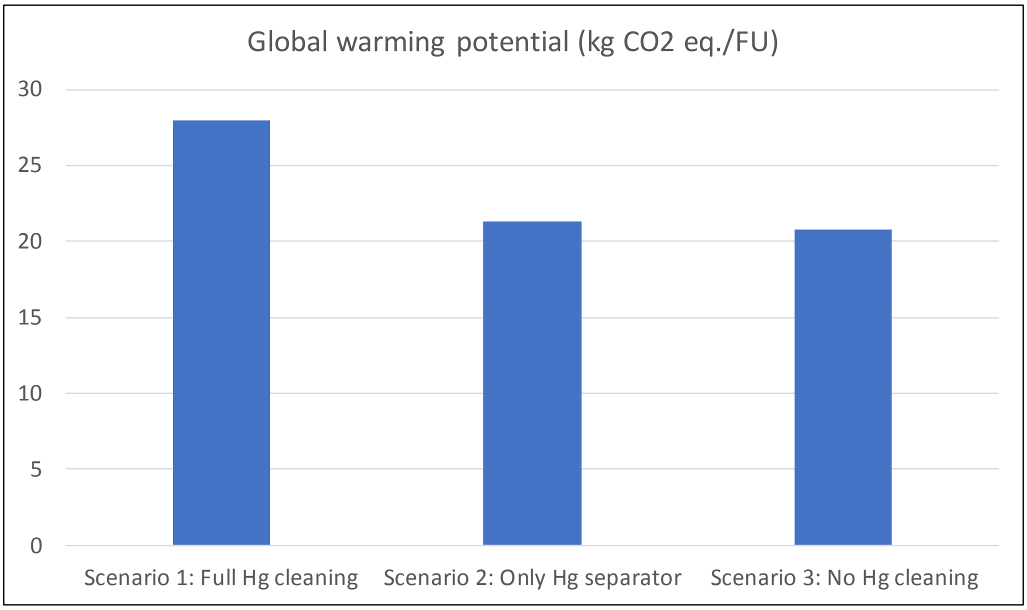

Figure 11. Scenario comparison of the Global warming potential (GWP100) for the entire LCA model systems.

The eutrophication and acidification potential also become lower for a less complex system or a system without Hg purification, as shown in Figure 12.

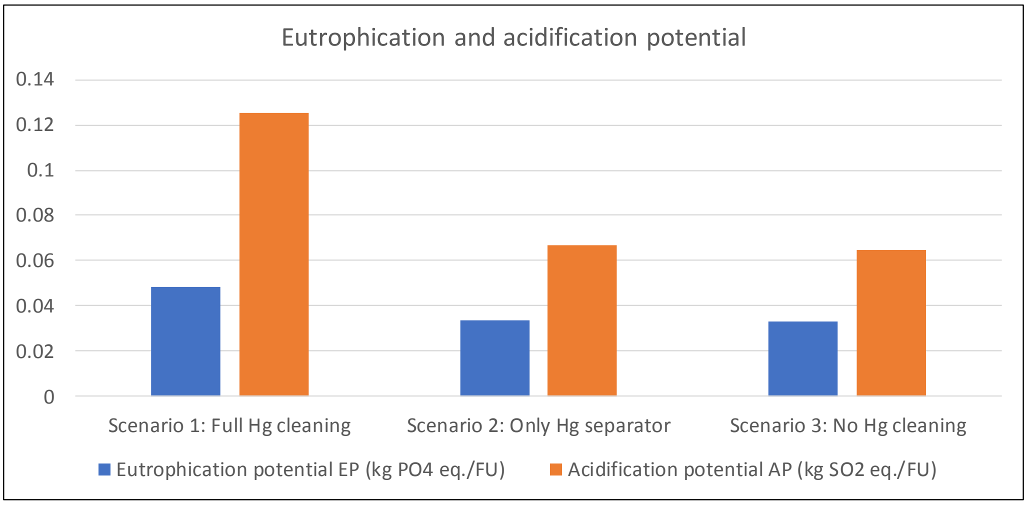

Figure 12. Scenario comparison of the eutrophication and acidification potential for the entire LCA model systems.

The formation of ground-level ozone is mainly due to the availability of hydrocarbons and the NO_X environment where the emission occurs, as well as the availability of sunlight. The formation of POCP is thus calculated based on an assumed situation for the method and is assumed to be the same in the three scenarios. The values shown in Figure 13 are thus formation potentials that are best used as a comparison between the different scenarios. As shown in the figure, this also shows an increased emission level for a more complex cleaning method.

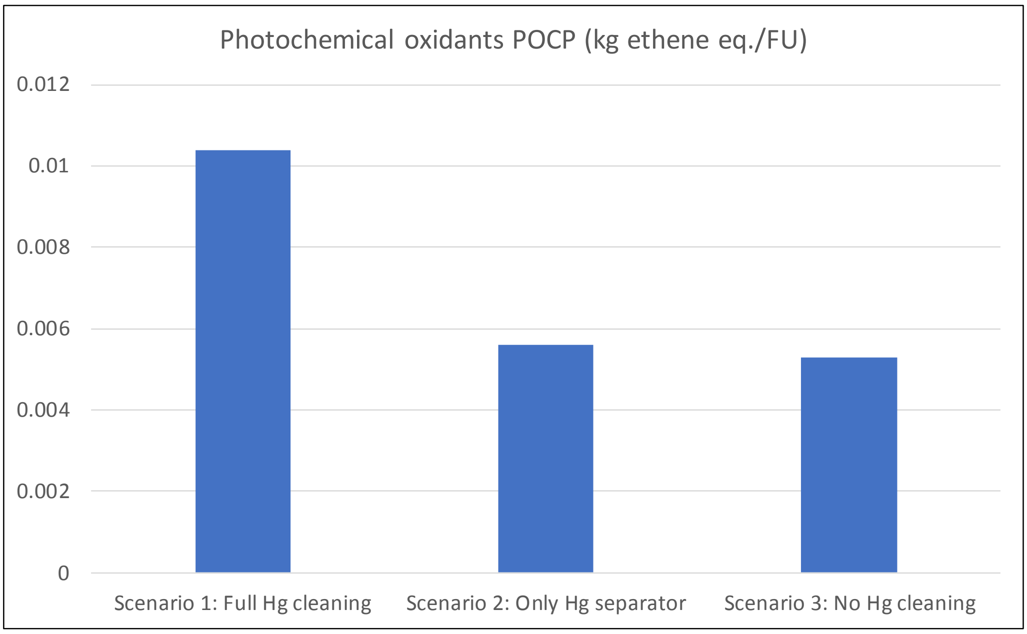

Figure 13. Scenario comparison of the photochemical ozone creation potential (POCP) for the entire LCA model systems.

Figure 14 to Figure 17 shows a comparison of four different toxicity values for the three different scenarios. The values are shown in kg 1,4-dichlorobenzene equivalents per functional unit. The results show Human toxicity, Terrestrial ecotoxicity, Marine aquatic ecotoxicity and Freshwater aquatic ecotoxicity. As clearly shown in the figures, all toxicity values indicate major improvements when mercury cleaning methods are used. Even the use of only an amalgam separator provides major improvements. We have also noted that high values are obtained for Marine aquatic ecotoxicity where the toxicity factors for this method are also high. However, we have not really been able to find a good explanation for these high values compared to the other toxicity values.

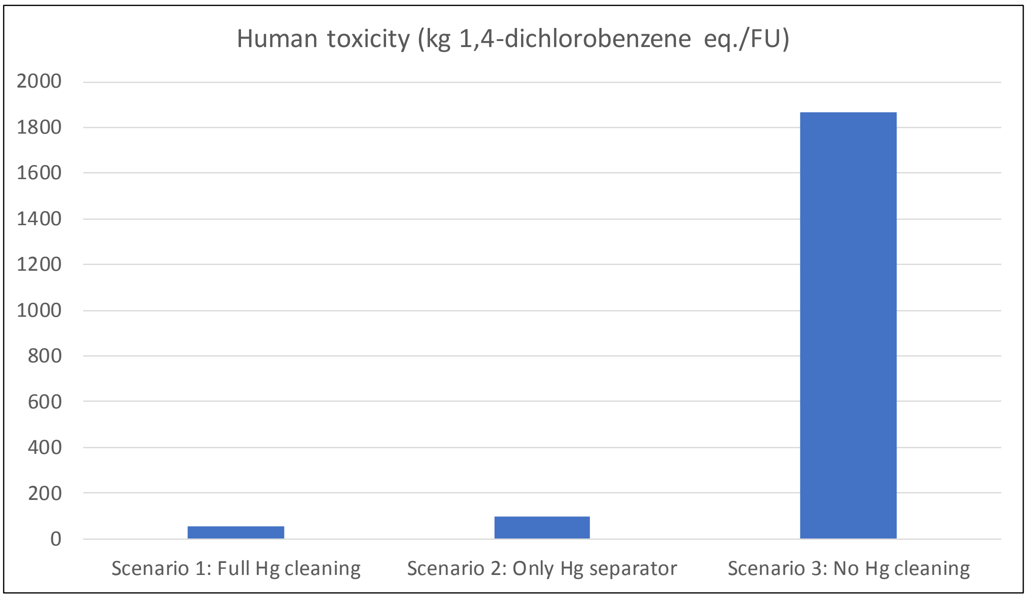

Figure 14. Scenario comparison of the Human toxicity for the entire LCA model systems.

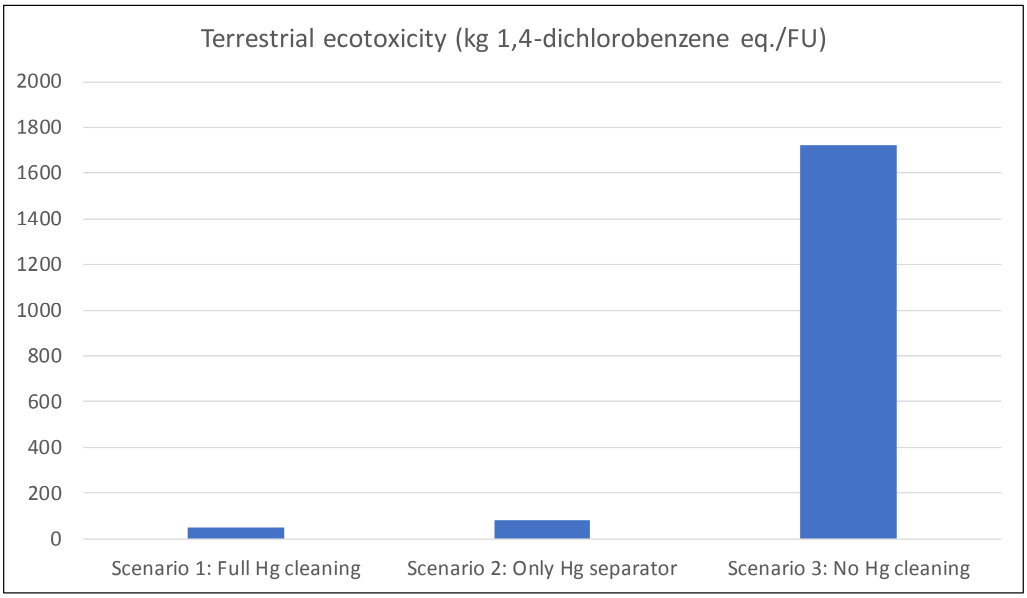

Figure 15. Scenario comparison of the Terrestrial ecotoxicity for the entire LCA model systems.

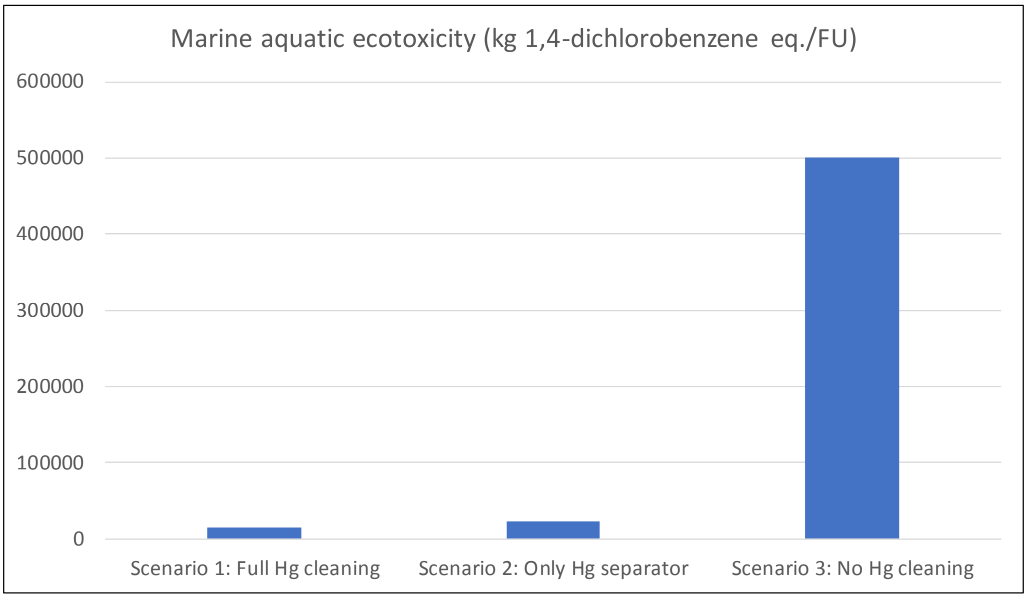

Figure 16. Scenario comparison of the Marine aquatic ecotoxicity for the entire LCA model systems.

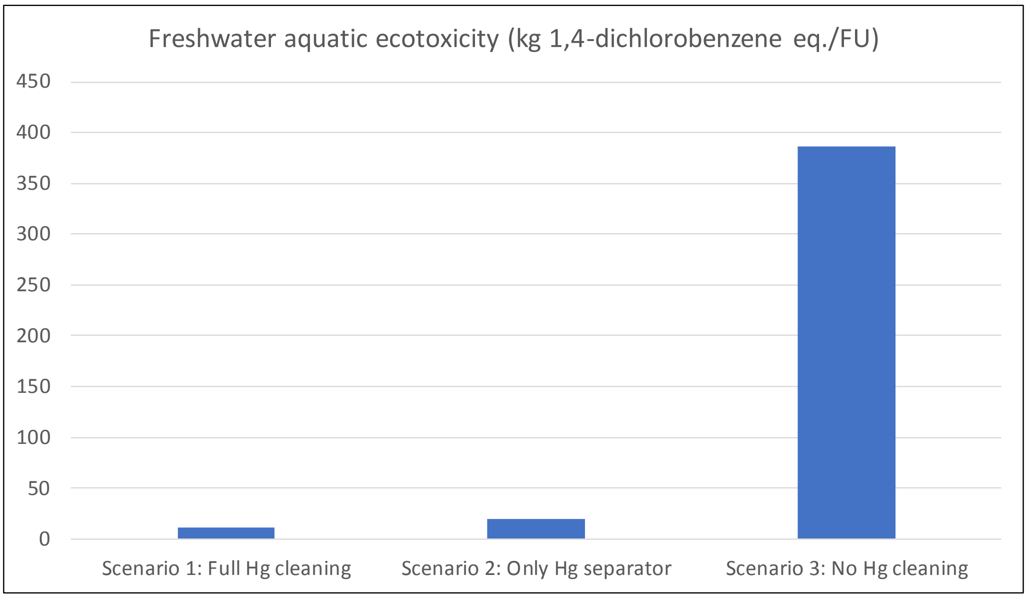

Figure 17. Scenario comparison of the Freshwater aquatic ecotoxicity for the entire LCA model systems.

Project effects and usability of results

This chapter and the next are covering the evaluation of project effects and usability of results and process evaluation. The process evaluation is complementary to the effect and usability evaluation. Whilst the former finds out if and to what extent certain results have been achieved, the latter allows understanding of how and why those results have (or have not) been achieved.

To evaluate the effects and usability of the project results the project performance indicators functions as the core. A full table of the indicators can be found in Annex 1. We present selected indicators below.

The evaluation on usability of results are studying the following:

- The relevance, effectiveness and usability of training material
- Accessibility and relevance of information
- Usability and relevance of online training and workshops

The analysis has been done mainly through a qualitative analysis of different project activities, mainly through questionnaires, monitoring of dissemination activities and surveys with relevant stakeholders, such as dental teams, students in the dental sector, environmental inspectors etc.

The general conclusion is that the project results have been distributed and used by a wide range of stakeholders. Awareness seems to have increased but an indication of increased knowledge base among the participants is hard to interpret. Most respondents seem to think that the information and training material has been useful, is easy to access, easy to use and a good way to access knowledge.

Table 2. Monitoring and measuring selected project performance indicators

Performance indicator	Result	Evaluative comment
Number of persons engaged in survey regarding awareness*	1066	The project has reached a significant number with information through different activities and the conclusion is that it has resulted in increased knowledge and awareness. The response rate is not enough for statistical representation. The results should not be seen representative for the stake holder groups but instead an indication (more in chapter “increased knowledge and know how”).

Number of training seminars	12 (15 booked, 3 cancelled)	12 seminars held with students or environmental inspectors. A total of 260 people participating and increasing awareness. According to the survey in connection to the seminars, 61 percent estimated their knowledge as good or very good before the seminar, and about 94 percent at the end of the seminar. The results also show a large increase from perceiving the knowledge as good before and then very good after the seminar (from about 8 % to 44 %).
Number of individuals taking part in training seminars*	260	-
% of participants that perceived the training as usable/relevant and state that their knowledge has increased	95% (estimate their knowledge as very good or good after training)	The students participating in the seminars were asked if they thought the web-based tools would help them increase awareness and knowledge to reduce emissions from mercury in the future. 115 students answered and the majority think that it will help to great, or some, extent (see figure 21).
Number of users of web-based training tool*	Total 3244 / 5785 unique (2019/08/31)	-
% of participants that perceived the web-based tool as usable/relevant and state that their knowledge has increased	Too few respondents to be statistically relevant.	5 visitors of the web-based tool answered the follow up questions on usability. Although the general interest and opinion among people the project team have talked to during meetings, seminars and convents the web-based tools is perceived as relevant, a god way to reach more knowledge and easy to use.
Number of clinics/dental services committed to or applying the new tools/methods*	-	It takes time to implement new methods, therefore it cannot be evaluated at this point.

Number of individuals reached by international webinar*	99 (2019/08/14)	Live at the webinar it was 80 participants (dental students). The webinar is still available on Youtube and at the moment 99 people have seen it, the number expect to increase as long it is online.
% of participants that perceived the webinar as usable/relevant and state that their knowledge has increased	-	No questionnaire made for the international students taking part in the webinar.
Continued transfer of technology and know-how across the EU (% of European dental care facilities applying technology or corresponding in 5 yrs) *	-	Information not available. (Results available in 5 years).
Number of visitors on the project website*	Total 8 945 / 6 463 unique (2019/08/31)	-
Number of dental care facilities with project notice boards	154	-
Number of general public reached with information on project notice boards*	4.400.000	The information has had a wide spread both to stakeholders and general public. Notice boards have been an effective way of spreading information and it can be assumed it has resulted in increased awareness.
% of stakeholder that perceived the information as usable/relevant	-	Only qualitative results, in dialogue with stakeholders, that they perceive the information as relevant and usable, for example the proposal to guidelines and the information about mercury's effect on the environment.
Number of national and EU conferences/fairs visited by the project partners	16 (11 national and 5 EU-conferences/fairs)	-
Number of articles in trade and other relevant magazines	8	The information has had a wide spread both to stakeholders and general public. The project has appeared in different articles, both

		in daily local newspapers and in sector specific media.
Number of stakeholders reached by project materials	More than 6 stakeholder groups	• Dentist, other dental professionals • Environmental Inspectors • Technician (service technician, environmental service technician) • Students • Representatives from government, industry, NGOs • Others (participants at trade fairs from companies and authorities in other countries, for example).

What can be stated in the evaluation of relevance and usability of project activities and results are that the activities have created awareness and, in some cases, increased knowledge about safe management on mercury waste and mercury's effect on the environment.

In the different surveys, the respondents have self-assessed their own ability, their knowledge and their awareness, this of course affect the results in our study. The results cannot be stated as statistically significant or representative of these stakeholder groups.

The results do not show a large increase in assessed knowledge among dental staff and environmental inspectors. Although, among the students taking part in the seminars the ones assessing their knowledge as very good increased significantly after the seminar compared to before (see figure 20).

The number of people reached by the information and the response from people taking part in the different activities indicates that the project most likely has resulted in higher awareness. The project team are of the opinion that, most people they have interacted with, within the project, have expressed that they learned something they didn't know before and have gained larger understanding on the issue, which is one of the main objectives with the project.

The web-based tool was essential for the project objectives and helped the project to reach out. The tool made the information more accessible and enabled people from all over the world to educate themselves on this issue in an effective and user-friendly way.

The main activities to increase knowledge and awareness, and a selection of results from these are described in the following sections.

Usability and relevance of training material

In order to contribute to increased knowledge and know how. The project developed and launched a web training tool on safe mercury management. It is primarily targeting dental care, environmental inspectors and service technicians. The web-based training tool was developed to reach out with information about the project and spread knowledge about mercury management in dental facilities to a wider audience. It provides information and examples from the project as well as information about mercury in dental facilities and mercury management.

The user can read information, listen to it and watch informative videos on mercury, on how a decontamination is done etc. The users can also do a quiz to test their knowledge.

Those who answered the questions regarding their experience of the tool believed it had increased their awareness and knowledge and will help them in their future work to reduce mercury emissions from dental care. They also thought the web-tool helped them increase their knowledge about environmental impact from mercury.

The web tool itself has to a large extent been perceived as user-friendly and easy to assimilate, but one person answered that it was not easy to find the right information on the site. The movie-clips on the website were considered informative when asked about them specifically. Regarding accessibility the training tool has been translated from Swedish and therefore enables users in English, French, Spanish and German to access the information. The visitors have so far mainly been from Sweden, but also from Poland, Norway, Italy and Germany. The web site has an average of 2.5 minutes per visit.

Training seminars

During spring 2019, 12 lectures were held on dental nursing educations in ten cities in Sweden, two as webinar. An international webinar was also held for circa 80 students in different countries.

The purpose of the seminars was to educate and inform as well as to spread the web-based tool, which could be used to further increase knowledge. 67.8 percent of the students who responded to the surveys in connection to the seminars believed it to be a helpful tool to gain awareness and knowledge in their future work to reduce mercury emissions.

The students were asked some questions before and after the seminar. Most estimated their knowledge level concerning impact from mercury on the environment higher after the lecture. 61 percent estimated their knowledge as good or very good before the seminar, and about 94 percent at the end of the seminar. Further, the knowledge about how amalgam waste should be handled in dental care also seem to have increased. From 83 percent answering that it was good or very good before the lecture and 96 percent after (figure 20). This indicates a high increase in knowledge and that the seminars were a good way of reaching out with information and creating awareness.

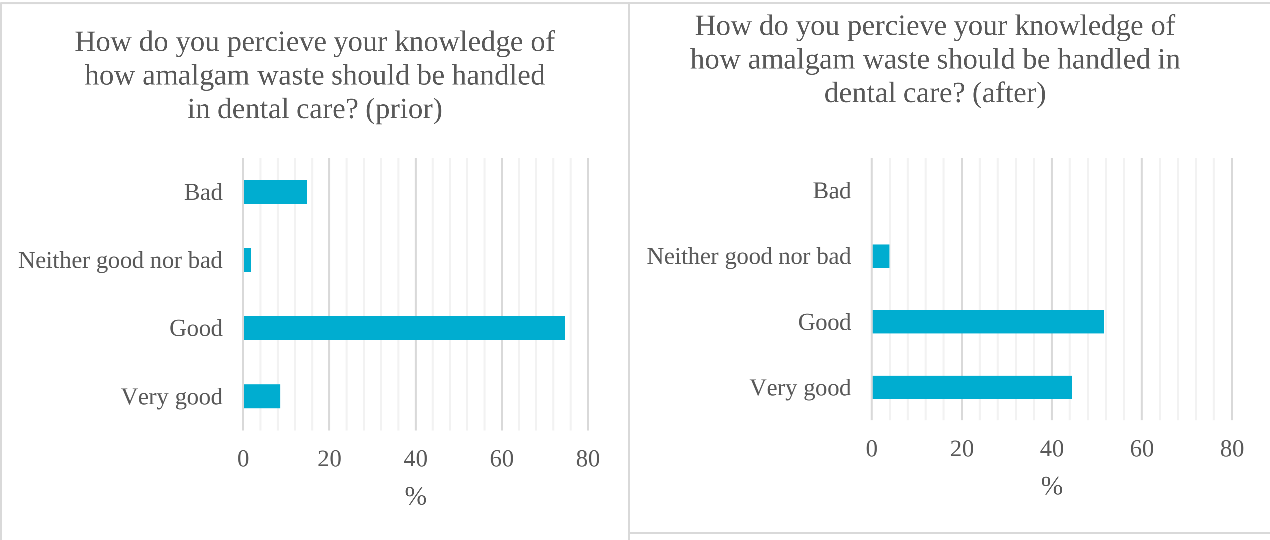

Figure 20. Results from question to students in training seminars (%)

The students participating in the seminars were asked if they thought the web-based tools would help them increase awareness and knowledge to reduce emissions from mercury in the future. 115 students answered and the majority think that it will help to great, large or some, extent.

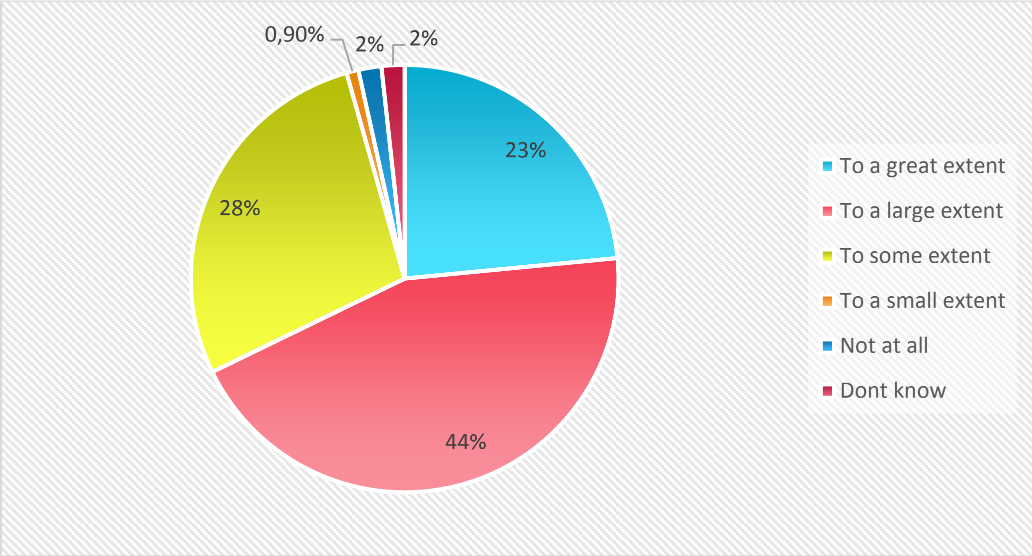

Figure 21: Based on answers from 115 students participating in the training seminars on the question, "Do you think the web-based tool will help you increase your awareness and knowledge in your future work with reducing emissions from mercury?"

Proposal of guidelines

The proposal of guidelines has been developed within the project for the purpose to establish a consensus among dental care players and environmental authorities concerning the regulation of mercury. The hope is that the proposal in the future may initiate the formulation of national guidelines and through that minimize the emission of dental amalgam from dental clinics in Sweden.

Praktikertjänst together with SRAB developed a draft on guidelines, which was then discussed and revised after dialogue meetings with dental teams, service technicians and inspectors from local authorities. The draft has then been discussed in various dialogue meetings with relevant stakeholders in order to get support and reach a common understanding.

This process has been successful in the sense that the actors have moved towards a common understanding in regards of how to handle mercury waste in dental facilities, regarding supervision and on how minimize emission of dental amalgam from dental clinics. But also created awareness and increased knowledge through the process of going in depth on routines and how to reduce emissions as effective as possible. The fact that different stakeholders have been involved and been able to have a say on the draft on guidelines have made knowledge and awareness accessible as well as usable for a wide range within the dental sector.

Increased knowledge and awareness

A survey was carried out at two different times, the first one during May in 2017 and the second one two years later, in May 2019. The survey was an activity for identifying the current knowledge and competence situation in Swedish dental facilities on how to mitigate mercury leakages from dental facilities. The purpose of sending out the survey on two different occasions is because it enables us to see if there has been an increase in knowledge etc.

The respondents of the survey were asked to answer how they estimate their own knowledge regarding what effect mercury has on the environment. In general, both target groups (dental staff and environmental inspectors) estimate their knowledge on mercury's effect on the environment and their knowledge on safe handling of mercury waste as *good*.

The general difference between the two occasions were not that significant but in overall, they estimated their knowledge higher in 2017 than in 2019. For environmental inspectors about 18 percent estimated their knowledge as *very good* in 2017 but only 13 percent in 2019. About 61 percent estimated their knowledge as *good* year 2017, in year 2019 this increased to 67 percent. The same trend can be seen regarding the dental staff; 35 percent in 2017 estimated their knowledge as *very good* compared to 32 percent in 2019. The comments from the survey in 2017 shows that many know that mercury is harmful to the environment but not in what way.

The results on how they estimate their knowledge about safe managing of mercury at dental facilities showed that the knowledge seem to have somewhat deteriorated among environmental inspectors, fewer consider themselves to have *very good* knowledge in 2019 while more considered themselves to have *good* knowledge in 2019. Further, more answered that their knowledge is *very bad* in 2019 than 2017.

The first survey in 2017 was sent out to all Praktikertjänst 994 dental practices, 413 responded. Of these, 96 percent were dentists and 4 percent dental nurses. This means an answering frequency of 41 percent. A survey was also sent out to environmental inspectors in all 290 municipalities, 140 inspectors replied (some inspectors work in several municipalities). The survey was sent out by email to all dental facilities part of Praktikertjänst and to the environmental inspectors in the municipalities. The second one in 2019 was sent out to the same contacts, 242 of dental practices responded and 89 of the environmental inspectors. There is a significant decrease in answer frequency in 2019 than 2017 but the result of the survey can still be an indication on the state of the knowledge.

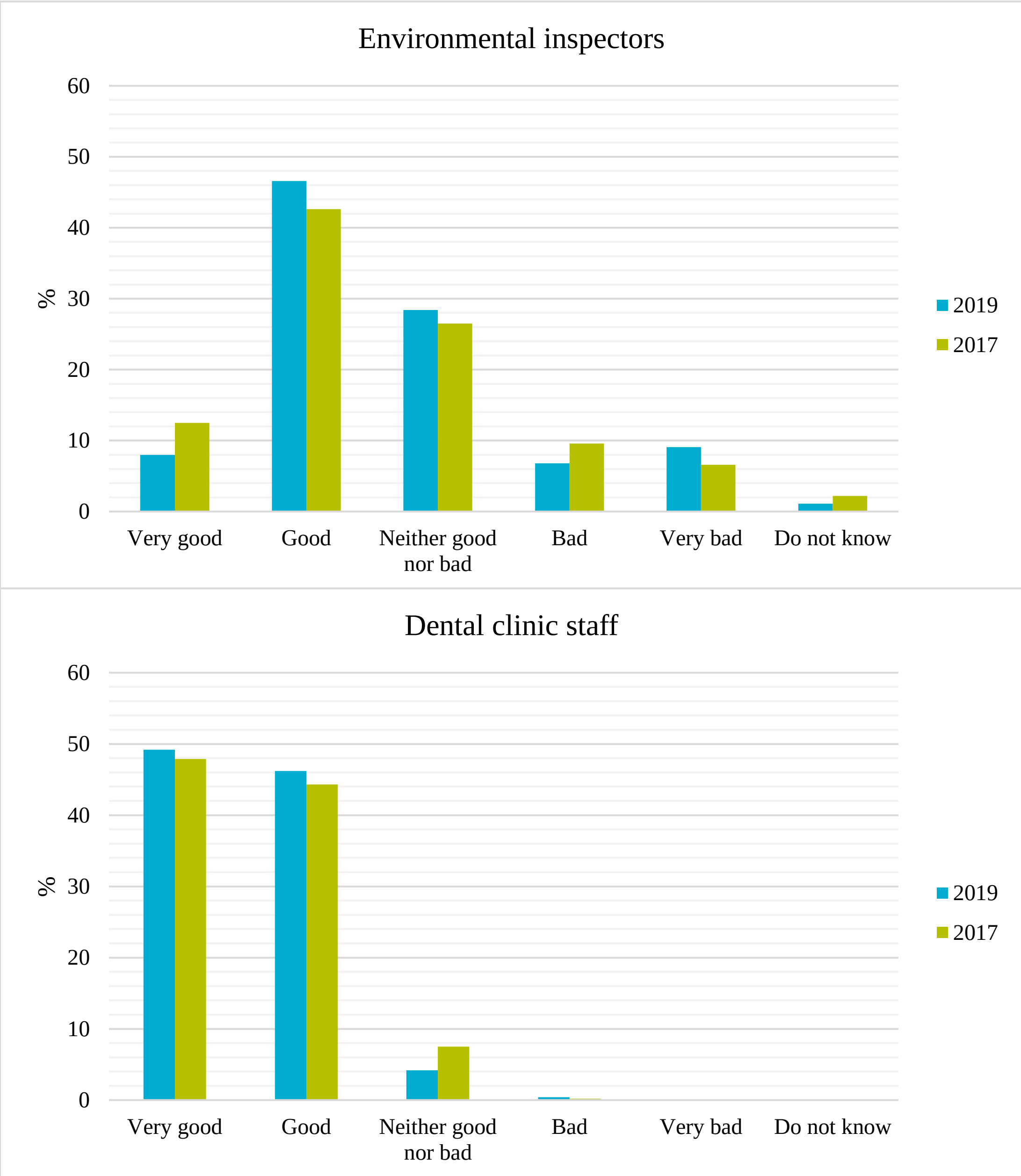

Figure 18. How do you estimate your knowledge about safe managing of mercury at dental facilities? Answers from Environmental inspectors and Dental clinic staff 2017 and 2019 (%).

Regarding training in safe handling on mercury waste, there is a significant difference between the two target groups but not between the occasions. Among environmental inspectors most (ca 85 percent) said that they haven’t received any education on the subject. Whereas among dental staff, over 70 percent answered they have received education. The difference between 2017 and 2019 is minor, among environmental inspectors there is a smaller proportion who says they received training in safe handling of mercury in 2019 (about 14 percent) than in 2017 (about 19 percent).

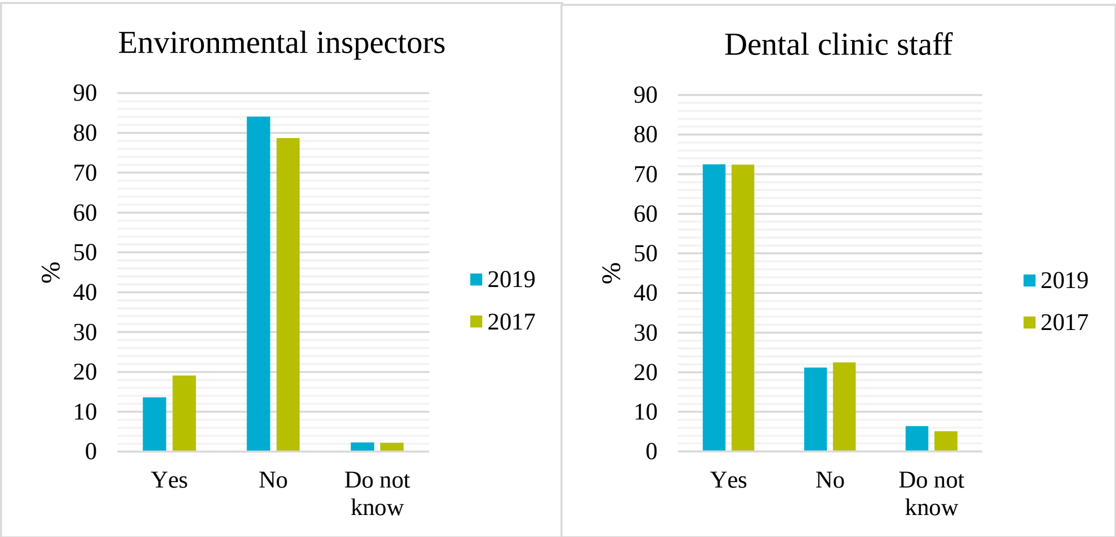

Figure 19. Have you received any education about safe handling on mercury waste? Answers from Environmental inspectors and Dental clinic staff 2017 and 2019 (%).

The free text responses show that many inspectors feel that they do not have updated knowledge. Here some example:

" – We have had good knowledge, but it has been a long time since it was updated, so there may have been a lot of new developments"

" – We currently perform no inspections in dental practices. Last inspection was 2008."

Among those who answered that they did not had received education or training, they obtained it through inspections, from colleagues and read material themselves. Among dental staff they answered that knowledge and training has been obtained through for example Praktikertjänst website, own research and contact with suppliers. The decrease may be due to other people answering the survey the second time, or that they are more aware of the problem and answer differently or more truthfully.

Most of the environmental inspectors who answered the survey think they need more knowledge in this area. They state that they need knowledge about:

- Assessment on how to evaluate new regulations for decontamination.
- Sampling of the wastewater from different systems to obtain a representative sample.
- Information on amalgam separators.
- Proficiency for the operator.
- How supervision should be conducted (specific requirements to be set).
- How the mercury accumulates in pipes.
- Methods on decontamination and purification technique
- Environmental and health aspects of mercury.
- Needed measures for high levels of mercury in outgoing water.

For dental staff its about 67 percent answered that they *do not need* more knowledge. But they wish more knowledge on:

- New findings and research
- Decontaminations
- Equipment and how to handle it.
- What happens to the mercury if you swallow it?
- Routines for drilling / amalgam replacement.

One main activity within the project has been to formulate a proposal to national guidelines for safe handling of mercury waste at dental facilities. In the survey, we asked how the situation is today (2019).

In most cases, the municipalities have not had an information meeting regarding mercury handling for dental clinics. Only 2 out of 69 respondents replied that it has taken place. Whether the municipality has sent out guidelines on safe handling of mercury at dental clinics, over 60 percent answered *No*, and around 28 percent state that they don't know.

Supervision campaigns however, are in some cases included in the regular supervision of dental clinics. In the municipalities where the supervisory campaign has been carried out, it has sent out information about inventory of all dental clinics, then follow-up of waste management at dental clinics, supervision of self-monitoring, chemical handling, waste management, including hazardous waste and re-control on procedures regarding amalgam separators. Almost half of the environmental inspectors stated that the municipality has had a supervisory campaign aimed at dental clinics about mercury handling (2019).

Process evaluation

The process evaluation assesses the implementation of mercury mitigation solutions and addresses the project operations regarding allocation of resources (time, personnel and money). As well as significant factors, which have sustained or hindered the project.

The project process has been affected by a number of factors. The main factor which seems to have affected all activities through a snowball effect has been the initial marketing of this project. That is, to anchor the project, the screenings and decontamination process with the dental facilities and reach an understanding on what was supposed to happen. On the positive side, there have been a large commitment within the project management group and also among the different actors when they fully understand the purpose of the project.

Implementation of actions and use of resources

In general, the activities within the project have been implemented with good results and according to ambition and plan. However, some activities have been altered after circumstances. The administration has been heavy at times as there are many parties involved in the project. The views are that the planning initially could have been more thorough and that there could have been more time and resources allocated for administration throughout the project, as well as for carry out the screenings and decontaminations. The project did not include a first planning phase when it began, this could have been the reason for the view that it was lacking and caused unanticipated administration. More details on each activity are to be find in Mid-term report and final report (also see PPI:s in Annex 1).

It can be stated that it is of high importance to prepare and to reach understanding among project members as well as participating actors to be able to implement every action according to plan. Since many of the project members worked with a project of this scale for the first time, with different organizations working together, the planning of project activities required more effort than expected initially. To forestall potential consequences this might have the project included GIA Sweden as an external support with these questions. However, it was still perceived as difficult to estimate time effort etc. and the startup phase thus lasted longer than first assumed.

One significant barrier for implementation of the initial activities were the delays in screening the clinics (B1.1). This was due to various reasons regarding logistics (planning and organizational aspects). With a longer establishment period and through more effort to reach understanding for both the screening and decontamination process the project could have worked smoother and many of the issues would not have arisen.

600 clinics were to be screened for the purpose of collecting data and information on which to undergo decontamination. 530 clinics have been screened by the end of the project. Why the project didn't reach the goal of 600 were due to different aspects: there were some resistance from the dental clinics, the screenings required more resources than planned because of e.g. longer driving distance than assumed which made the planning occasionally difficult. This resulted in further delays in the next phase, selection of clinics to decontaminate. For SRAB, the activities also resulted in a high workload in total since ordinary work still needed to be carried out simultaneously.

There have been changes with project members when they have ended their ordinary employment. This has affected the work regarding time and efficiency. One example is the CBA and LCA assessments which were changed to be finished at the same time (end of project) but when new people came in to the project and started to plan these activities it became that the socioeconomic analyze should have been planned to take place before the LCA, and the LCA as a following step, in order to use the results from the CBA as input.

Regarding the reference group in the project, they have been used as support and as experts during the process but not overly involved or active themselves. They have met three times during the project and most work have been done during the meetings, as for example discussing the proposal for national guidelines. The group could advantageously be involved more in the project process in regards of their expertise and connections. For example, as said in the evaluation plan, the representatives from both the reference group and the steering group could have been of help earlier in the project to help foresee some barriers which could have facilitated more effective activities or different results. The majority within the reference group although think that their knowledge and expertise has come to good use and that the combination of different fields of expertise has enabled fruitful discussions and perspectives to the issues need resolving.

The project team believe the project has succeeded with the goal and what was considered important from the beginning: mercury sludge has been reduced from dental clinics and the awareness of mercury waste has increased (also see project effects and usability of results).

> *"The increased knowledge could result in better waste management and new clinics establishing equipped with right facilitates to handle amalgam waste correctly. Further when action plans are to be*

developed for phasing out mercury use, long term, the hope is that the project will benefit the whole EU".

Barriers and enablers

Process barriers are events or conditions that prevent the process from achieving its goals and results. In contrary, process opportunities are events or conditions that enables a successful process to achieve its goals and results. In Hg-rid-LIFE, a template with success factors and barriers were developed early on and been working as a base through the project process and used when identifying barriers and success factors (or enablers) during interviews with employees, project meetings concerning planning, implementation and operation of the various actions undertaken during the project.

Key factors affecting the project process

The main factors affecting the project results and outcome can be concluded to communication and commitment.

The commitment has been crucial for how the project has worked and for reaching the project objectives. All involved have been committed to the subject and the success of the project. Furthermore, the team has been very capable, which has strengthened the project, for example during the decontamination when the technicians at SRAB was able to answer questions not always within their ordinary activities. The high number of dental clinics within PTJ further helped the project to reach its goals.

The main barriers have been to reach out with information to both members of the project and participating dental clinics. Furthermore, despite several attempts to contact the dental clinics, the information was not as efficient as wanted and it was difficult in the beginning to get the dental clinics interested and participating in the project and to get their approval to go through a decontamination.

Barriers

Some factors that have hindered or complicated the project process has been identified. These are mainly regarding areas of organization, planning and communication.

Barriers	***Examples***
Politics, strategy	Resistance or conflict due to different norms or values.

Institutional factors	Administration, routines, laws or hierarchical structures that make work difficult.
Culture	Cultural conditions that inhibit the project process.
Problem-related	Complex problems.
Commitment, communication	Low participation, awareness and involvement. Bad conflict management.
Positioning	Poor exchange with other relevant initiatives.
Planning	Insufficient technical and financial planning. Poor understanding of user requirements.
Organization	Lack of leadership, poor partner arrangements.
Finance	Obstacles to good finance.
Technology	Technical requirements, insufficient technology, technical problems.

Institutional barriers and insufficient planning

The variety in how municipalities handle questions regarding waste, different requirements on how to decontaminate mercury, appeals about the extent of decontaminations and different requirements on mercury levels in water, have also at occasions obstructed the project process. In some municipalities the inspectors set stricter demands on decontamination of dental clinics than considered necessary by the technicians and project team. This resulted in a number of cancelled planned decontaminations. Also, in some cases dental clinics cancelled with short notice. This affected the whole process.

The absence of national common guideline has sometime made the communication difficult because there are many different practices and different guidelines and routines which sometimes contradict each other. The large variation regarding routines for mercury management among dental clinics, as well as divided opinions are factors hindering better output from some activities. The development of the proposal of input to national guidelines has thus also been a challenge to compose.

The unforeseen amount of administration was a burden to several involved in the decontamination process. The administrative forms that were to be used were hard to understand how to complete as well as time consuming. Further, the methods that were planned for in the project have been used to great extent but the ambition on develop and using an automatic sampling machine failed due to hinders in e.g. legislation. The optimism might have been to high beforehand and did not match real possibilities.

Insufficient **planning** in periods of the project has been identified as a major barrier which have hindered the flexibility of the process and obstructed some activities moving forward. The visits at the clinics has taken longer time than anticipated and for the technicians it has sometimes been difficult to combine the project activities and ordinary work. The screenings were also postponed sometimes as it took longer time, because of logistics problems. The planning problem occurs when a booking for a decontamination change with short notice. Driving the distance to and communicating with different clinics, took more time than planned. In addition, the results from the screening showed that not so many clinics corresponded to the selection criteria according to the application form (high mercury levels in sewage waste and suboptimal pipe dimensions). The number of clinics with suboptimal pipe dimensions was very small. The selection criteria in sub-action B1.4 was therefore changed and it delayed performing the decontaminations.

Communication and organization

Barriers regarding communication and commitment are mainly due to general uncertainties and/or because of the communication paths which were not always clear, within the organizations as well as between project activities and ordinary activities. Within the project management group, the information flow is perceived to have worked well but further out in the periphery and those affected by the project activities the information and communication does not seem to always have been enough. Communication between and to everyone involved in the project, should have high priority.

One of the most important aspects affecting the project process has been the ability to reach out to the dental facilities. The request to dental clinics to participate in the project did not go as easy as first thought. There was a low response on the information that was first sent out inviting clinics. Further measurements were then taken by Praktikertjänst to improve the response rate and to increase the engagement. Additional information was sent out and put out on Praktikertjänst internal website.

It was not until then clinics started to understand that they could decontaminate their pipes to a lower cost within the project more started signing up for participation. The response towards the technicians carrying out the decontaminations were because of the obscurity not always experienced as positive. It was however perceived as quite easy to change once the technicians, face to face, could inform the dental staff about the project and what they were doing.

The fact that dental staff has been somewhat resistant to the project and the decontamination process initially, to then turn around and be quite positive to it when being visited by staff carrying out the decontamination and getting the information straight from them instead is an indication of failure in the communication. This demonstrate the importance of information, how it is communicated and its focus. Also, how important it is to create right prerequisites for the project to be successful. To reach a common understanding and to make sure everyone can see the use of the project in advance might be crucial to reach a wide acceptance.

The main **organizational** barrier is when employees within the organizations have been replaced. This have sometimes caused inconsistencies and to introduce new people to the project is demanding considerable resources. It slows down the process but also the fact that new people might have feelings of not being involved in the project and therefore not motivated. The commitment within the project has sometimes been low due to changes in the workforce.

Other barriers

- A few issues have been identified as **technical** barriers. When decontaminate the pipes (from mercury sludge), non-removable pipes and old pipes have made it difficult. Some were too short or had narrow dimensions, which made it hard to flush the sludge out. Furthermore, filming inside the pipes have at those occasions not been possible (see benefits with filming below in enablers section) The tablet used in screening had some faults as well. It was not fully developed at the start, which meant that information intake did not work as intended and the application could not handle the amount of data that needed to be registered.
- A barrier for reaching out with project results beyond Sweden to international connections is that there is no natural platform that enables communication regarding these questions on an EU level. It is therefore difficult to reach out to other actors operating in European countries.

Enablers

Enabling factors for the project process are conditions that enables a successful process to achieve the projects goals and results.

The most important thing in the project has been the common goal to reduce mercury emission from dental facilities. Everyone in the project team and stakeholders connected to it have believed in the positive effects of the project and have supported the work to reduce mercury in the environment.

This fact has enabled successful activities and successful cooperation. The common view on the importance of safe mercury management has thus contributed to an effective cooperation during the whole project. This have also enabled the proposal of national guidelines where different stakeholders have been involved.

Success factors	***Examples***

Politics, strategy	Commitment or cooperation due to the same norms or values.
Institutional factors	Administration, routines, laws or hierarchical structures that facilitate work.
Culture	Facilitating cultural conditions.
Problem-related	High priority of problems.
Commitment, communication	High participation, awareness and involvement. Good conflict management.
Positioning	Good exchange with other relevant initiatives.
Planning	Accurate technical and financial planning. Good understanding of user requirements.
Organization	Good leadership, good partner arrangements.
Finance	facilitating good finance.
Technology	Potentials offered by technology. New technique.

Communication and commitment

The developed web training tool have been a success factor in the project. It has been perceived as user friendly by the ones that tried it. It helps the project reaching out in as easy way, not only in Sweden, but other countries in Europe as well.

The **commitment** to, and in, the project has in general been good. The dentists have been positive about the project when they have understood and accepted the information. The people carrying out screenings and decontamination have had great knowledge and experience with the process and their knowledge has therefore strengthened the project. The project partners have also been very committed, within the PMG there have been high energy and activity during meetings, and everyone are agreeing on that the commitment and energy has been one of the main success factors in the project.

The communication activities about safe mercury waste management and the risks of mercury waste has been a factor enabling awareness. There is no actor in Sweden really questioning the negative environmental effects mercury have and therefore it is an issue rather easy to talk about. One of those situations was the yearly conference in Sweden called Swedental, a platform for the dental community where the project could spread information and raise awareness. This conference together with others have contributed to creating awareness of the project as well as the environmental problem mercury waste can be. A goal with the project.

On a more local scale, information has also been available through the monitors in many of the waiting rooms at dental clinics. There are 154 dental clinics within Praktikertjänst, which have shown this information on their monitors.

Further, the project has had a rich cooperation with the University of Umeå which have enabled spreading information about this matter as well as creating awareness and knowledge to students becoming environmental inspectors. The effect of this can be significant. To reach students is a step towards reaching common routines in how to practice more common supervision and promote the same routines in the different municipalities. The other activities reaching out to students and relevant stakeholders can hopefully have the same effect.

Planning and organization

Regarding the planning, one main enabling factor have been identified. The high frequency of meetings within the project group have produced good results. Information to the SRAB organization outside the project management group has been carried out on several occasions. Although the planning aspects was not perceived to work optimally, the project has done what was intended from the beginning. An organizational enabler is the composition of the reference group where the members have a wide spectrum of background and knowledge, which is a valuable source. The composition of the project group is interdisciplinary as well which enables sharing experiences and knowledge. Further, through their contacts and networks the information, knowledge and results can reach good exposure. Moreover, the width of competence and different premises in the project group, has been a strength in the project.

Other enablers

Technical enablers which helped the project were also the filming of pipes which have been a way of developing the decontamination method. The result show that filming can be a useful way to find clinics with more mercury sludge and therefore in need of decontaminations. It is also a way to control efficiency of the carried-out decontamination.

Further, the new nozzles the technicians used with the high-pressure water and more powerful units as well as preparing the pipes with chemicals. The learning process regarding the decontaminations resulted in high-pressure water only from above and from one direction (read more on technical details in final report).

Conclusions and recommendations (C1.5)

Final conclusions and recommendations from the evaluations are presented below.

Objectives and results

Even though there have been some obstacles during the project, the main goals are reached. Initially the project planned for 600 screenings and decontaminations in 125 clinics. In the end, 530 clinics were screened, and 76 dental facilities decontaminated (132 dental clinics). Some changes have been made, for example that the automatic sampling machine was not developed and some shifts in the timetable. The project has collected mercury from dental clinics and reduced emissions from clinics, but foremost developed methods for more effective decontaminations and increased knowledge and awareness of the issue.

The communication towards dental clinics has not worked as efficient as hoped. This resulted in difficulties getting clinics to participate in the project and carry out decontaminations. This show the importance of clear information and to communicate the use for the receiving part. However, the commitment within the project group has been great and the web training tool has worked as a platform about information concerning mercury in the environment and mercury waste management in dental care. The project has further helped involved actors to get a common view on mercury waste management.

The results show no clear result of increased knowledge among dental staff and environmental inspectors but could indicate an increase in awareness. The survey shows that their perception is that they already have a good knowledge about the safe handling of mercury waste and its effects on the environment. However, the perception is that they want more knowledge in the subject. Among environmental inspectors, education in safe handling on mercury waste had been given to them in rare cases. However, most dental staff had received education about the subject.

During seminars for environmental inspectors and students, the surveys show that knowledge increased about mercury waste handling in dental care. They further thought the web training tool could be a useful tool in their upcoming career. The training of dental teams, environmental officers, service technicians and other stakeholders, can be seen as relevant and given in an efficient way since their own opinions are that their knowledge has increased.

Users of the web training tool thought it was easy to use and increased their knowledge about the subject. and the movie clips was informative. Thus, training material is of relevance, given in an efficient way and have a high usability.

Socioeconomic and environmental impact

A comparison between these two abatement measures indicates that the amalgam separator gives a higher benefit-to-cost ratio of 2.8 compared to 2.4 for an average decontamination (comparison over a period of 10 years). Decontamination can be considered as an important complimentary measure to remove mercury from dental facilities that cannot be captured by amalgam separators – a mandatory abatement measure in the EU from January 1st, 2019.

Since decontamination is most often a voluntarily performed procedure, it is interesting to discuss what are the main **driving forces and obstacles**, and what can be done to increase the number of decontaminations. A decontamination does not necessarily bring net benefits; when it does, the benefits concern society in general while the costs are paid by the individual clinics. This gap is in line with the polluter pays principle, there is clearly no financial incentive for dental facilities to perform decontaminations today. Besides, it can happen that environmental authorities do not approve the procedure. The experience from the project is that it was difficult to find a large enough number of facilities to be decontaminated, even despite a high subsidy of the costs (up to 80 %). A more common reason for facilities to voluntarily order decontaminations is in case the pipes are clogged and therefore need a cleaning. Otherwise, it could be a requirement by a supervising authority (in the case for Sweden, the municipality) on a final decontamination when a facility is being shut down. For the 68 decontaminations performed and analyzed within the project generated an estimated net benefit of 390 thousand Euro.

The measured concentrations of Hg at dental clinics depended on too many factors (such as; type of facility, age of facility, number of chairs, type of ventilation system etc.) to be able to generalize how much handling of dental amalgam contributes to the indoor Hg concentrations at dental clinics. During decontamination processes the concentrations could temporarily increase but dropped quickly after, probably thanks to good ventilation. No harmful indoor Hg concentrations were detected.

Analysis results of water samples showed that small amalgam particles and dissolved Hg species pass the AS filters and are discharged to wastewater. Of total Hg measured in water samples, 4 percent was in its oxidised form as Hg(II), which probably origins from the oxidation of amalgam particles in the water, 0.5 percent as dissolved gaseous mercury (DGM) and 0.05 % was as the bio accumulative form methylmercury (MeHg). DGM and MeHg is generally formed by certain bacteria. Although MeHg and DGM concentrations were low, the finding of MeHg and DGM in the samples indicates a potential in-situ formation in the enclosed pipe systems of dental clinics.

Built-up dental amalgam stuck in the pipe system of a dental clinic can dissolve and release small amounts of Hg into the passing water. Dissolved Hg species can pass the AS and are therefore leaking into the environment. The removal and cleaning of the pipes by DC could lower the risk of the formation of dissolved Hg species, and thus lower the environmental burden of Hg.

Results from samples taken and analyzed by IVL and SRAB show that actions such as collecting and treating waste amalgam by using amalgam containers, ASs and performing decontamination of pipes, reduce the concentration of Hg in the outgoing wastewater, and thus reduce Hg emissions. This verifies that the project actions enforce achievement of goals of EU legislation on water quality (Water Framework Directive (2000/60/EC), Decision 2001/2455/EC and Directive 2006/11/EC on dangerous substances and Directive 2008/105/EC on priority substances) where Hg is identified as a priority hazardous substance and is in line with the Community Strategy Concerning Mercury.

Recommendations

- It has been shown that small amalgam particles can pass the AS and be discharged to the waste water. Therefore, a development of more efficient AS filters is recommended. Also, dissolved mercury species in water can pass the AS filter. A development of a technique to capture dissolved mercury species in water is needed to supplement the AS, which with present technique mainly captures bigger particles.
- The emissions of Hg to air, through the vacuum system, can easily be reduced by using an active coal filter. Active coal absorbs and collects gaseous mercury and is thus cleaning the exhaust gases from Hg. The technique is cheap and reliable and is easy to install.
- A well-functioning ventilation system is important to ensure good air quality and low indoor Hg levels for staff and patients at dental clinics.
- Due to the high variation in the results of the CBA, depending on both the amounts of removed mercury and the uncertainty of the monetary valuation of mercury, we see a need for more studies, especially on decontamination that seems to be an under-researched area compared to amalgam separators. This to verify the results from our study.
- To increase the number of decontaminations, an important factor is municipalities' requirements on dental facilities– which today differs between municipalities due to different interpretation of environmental legislation, mainly, the Environmental code.
- Dental clinic staff consider their knowledge about safe handling of mercury as good or very good. However, some answered that they had not had any education about safe handling on mercury waste. A continued information

process should be carried out in order to assure safe handling of mercury at the clinics. The website developed during the project is a good tool to get knowledge about the subject.

- Environmental inspectors think they need more knowledge about safe managing of mercury at dental facilities and perceive their own knowledge as *good* in larger extent than *very good*. Considering that the majority have not receive education about safe handling on mercury waste, more information concerning the issue should be available and provided to environmental inspectors working with dental care facilities.

- Commitment to the project and high competence has been one of the main enabling factors for the project. There is therefore recommended that project team involves a range of competences, including communication expertise as well as people with experience in the matter and committed to solving the issue.

- It can further be recommended that the chain of information is assured both within the project group and for external participants and stakeholders. The planning of the communication actions is important in order to reach out with the message and in the right time.

References

Mellin, A. & Yaramenka, K. (2019) C 1.4.1 Assessment of the socio-economic impact of the project actions on the local economy and population, Technical Report within the project HG-rid LIFE Mercury Decontamination of Dental Care facilities.

Stripple H., Nerentorp M. and Wängberg I., (2019) C 1.6.1 Environmental and Technical Evaluation with Life Cycle Assessment, Technical Report within the project Hg-rid LIFE Mercury Decontamination of Dental Care facilities.

Annex 1

Monitoring and evaluation of expected effects (Project Performance Indicators)

Key to effect/usability evaluation is the identification and measurement of appropriate performance indicators, which are tools enabling a quantification of the project´s outputs and achievements. The key indicators, outlined and defined in the excel table LIFE project specific indicators call 2015, are marked with *

Action	Overall objectives	Specific objectives/Expected results	Performance indicators (impact units)	Sources of verification
B1	Reduce mercury leakage from dental clinics	Mercury levels reduced by 50% in clinics with initial mercury levels above 1 000 µg/l in sewage waste from suction systems Sewage waste removed that contain contamination corresponding to 100 kg of mercury sludge. Drains from 600 dental clinics screened for mercury 125 dental care facilities decontaminated from mercury with new and improved technology Costs for sampling of mercury concentration reduced from EUR 5000 to EUR 500	Mercury emissions [µg/l] in effluent from dental clinics before and after decontamination* Mercury sludge removed in kg* Number of clinics screened Number of clinics decontaminated Costs for old and new sampling methods in EUR Capital costs (cost of equipment for sampling mercury concentration, EUR)* Expected savings (staff costs for decontamination EUR/year)*	Sampling and analysis of mercury in waste water from dental clinics Technical evaluation of the Hg cleaning method Measured in the effluent from dental clinics at flow rate 20 l/day and chair Measurements and analysis of mercury content in sludge removed from dental clinics Protocols from SRAB technicians Accounting reports from SRAB

B2/D1	Increased knowledge and know-how on how to mitigate mercury leakage from dental facilities	15 training seminars across Sweden held to demonstration of best practice of mercury management Web-based training tool developed regarding mercury management in dental facilities Knowledge transfer to other European actors through international webinars	Number of persons engaged in survey regarding awareness* Number of training seminars No of individuals taking part in training seminars* % of participants that perceived that the training as usable/relevant and state that their knowledge has increased Number of users of web-based training tool* % of participants that perceived the web-based tool as usable/relevant and state that their knowledge has increased Number of clinics/dental services committed to or applying the new tools/methods* Number of individuals reached by international webinar* % of participants that perceived the webinar as usable/relevant and state that their knowledge has increased	Survey of knowledge situation through questionnaires and interviews User studies during tool development, survey questionnaires and interviews. Training attendance lists Data from PTJ Reports from PTJ

			Continued transfer of technology and know-how across the EU (% of European dental care facilities applying technology or corresponding in 5 yrs) *	
		Dissemination of information and project results to national and European stakeholders and the public	Number of visitors on the project website* Number of dental care facilities with project notice boards Number of general public reached with information on notice boards* % of stakeholder that perceived that the information as usable/relevant Number of national and EU conferences/fairs visited by the project partners Number of articles in trade and other relevant magazines Number of stakeholders reached by project materials (project video, brochures, newsletter etc.)	
B2/D2	Support the development of national and international	Draft proposal of improved guidelines provided	Number of draft proposal delivered Number of Business Strategy/Plan adopted	Reports from PTJ Meeting attendance lists

	guideline for management of dental mercury	1 Business strategy/plan developed and adopted 10 dialogue/networking meetings held with Swedish dental actors and responsible authorities	Number of dialogue/networking meetings held Number of supervisory/enforcement bodies involved* Number of NGO*	
E1	Economic growth and jobs		Number of full-time equivalents* Running costs/year (EUR)* Payback time*	Reports and data from SRAB Report and data from PTJ