Treatment of absorbent hygiene products for improved recycling of materials

In a nutshell

Summary overview							
It is best practice to treat separately collected absorbent hygiene products (AHP) waste for recycling. The core process is a thermal treatment in an autoclave, an horizontal cylindrical vessel where the AHP waste is sanitized and opened. The output solid stream is then shredded and separated through a mechanical process into the two AHP components: polypropylene and polyethylene plastics and cellulose fibres, which can be sent for recycling.							
Waste management area							
Cross-cutting	MSW - strategy	MSW - prevention	MSW - collection	MSW - EPR	**MSW - treatment**	CDW	HCW
Applicability							
This best practice is broadly applicable as no particular geographical or technical barriers exist. However, some specific conditions can influence the technical and economic viability of this treatment solution: • implementation of a selective collection scheme for AHP waste as a prerequisite; • minimum plant treatment capacity (based on treatment techniques and economics) of 8 000 t/year; • transport distance from collection areas to the plant and costs for landfilling and incineration; • population density in the collection area; • criteria and rules for recognising the end-of-waste and local market for recovered materials (plastic and cellulose).							
Specific environmental performance indicators							
• Plant sorting rate (weight %), calculated as the annual quantity of materials sent for recycling divided by the annual quantity of AHP waste processed. • Energy efficiency (kJ/t), calculated as the annual total energy consumption of the plant divided by the quantity of AHP waste processed. • GHG emissions (t CO_2e/t), calculated as the annual total CO_2 equivalent emissions (scope 1 and 2) of the plant divided by the quantity of AHP waste processed. • Water use (m^3/t), calculated as the annual total water used on site divided by the quantity of AHP waste processed.							

Benchmark of excellence
Facilities treating absorbent hygiene products waste have a plant sorting rate of at least 90 %.

Description

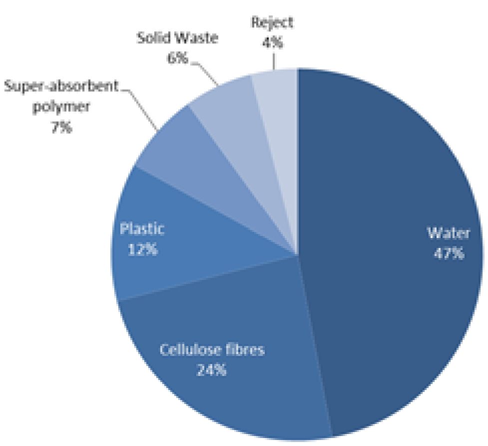
Absorbent hygiene products (AHPs) is the category name for baby nappies, sanitary protection pads, tampons, adult incontinence products and personal care wipes, and nowadays represents one of the most challenging types of post-consumer waste. Today post-consumer AHP waste represents about 2–3 % of total municipal solid waste. Currently, AHP waste is mainly not recycled and belongs to “unrecyclable” municipal solid waste. It is typically disposed of via either landfill or incineration, thus causing loss of valuable material resources and high economic and societal costs. As the EU moves towards its recycling targets, AHP waste has quickly risen to already represent up to 15–25 % of the residual waste in some facilities, where selective collection rates above 70 % are in place. As a consequence, and due to its potential for contamination and infection, consumers and stakeholders alike perceive AHP waste management as a growing environmental sustainability issue that needs to be addressed in an integrated way (Recall, 2015).

Public authorities and waste management companies are aware of this issue and are starting to take action to support the recycling of this waste stream. The best practice on this issue is thus focused on the treatment techniques available for the separation of the AHP waste into its different material components, which can be recycled into secondary raw materials (e.g. plastic, cellulose).

At present, there is still a lack of large-scale treatment facilities for such disposables in EU countries, but in recent years some innovative techniques have been developed and are now ready to market and the first plants are starting to operate in EU Member States.

Considering the treatment techniques available and the existing plants, a treatment process that allows the sanitisation of AHP waste and the recovery of cellulose and PE/PP plastics, which are the basic components of AHP, can be considered a best practice. The core process in the available techniques is represented by a thermal treatment in an autoclave, a horizontal cylindrical vessel where the AHP wastes, through the effect of steam at high temperature and pressure and continuous mixing by the rotation and alternative oscillation of the vessel, are sanitised and opened. The output streams from the autoclave are a water discharge, which is sent to a waste water treatment plant[1], and a solid stream that is then shredded and separated through a mechanical process into the two AHP components: plastics and cellulose fibres.

Based on available literature (Deloitte, 2011), the average composition of AHP waste can be considered to be as shown in the following figure.



Source: Deloitte, 2011

Figure 1. Average breakdown of AHP waste (% weight)

Available treatment technologies are able to recover 100 % of the original products of disposable nappies, i.e. 100 % of the plastics and 100 % of the cellulose fibres plus the super absorbent polymers (SAP) that are present in the AHP waste flow, considering the output of the nappy's recycling process but not considering the residues resulting from the further sorting and industrial processing of these recovered materials. As cellulose and plastics used as raw materials for the production of AHP are high-quality materials, their recovery through treatment technologies provides the market with valuable secondary raw materials with multiple potential uses. The plastic is granulated and can be reused in several production cycles to make high-quality plastic goods or as an ingredient in composite materials replacing concrete and steel. The cellulose fibres can be used for the production of pet litter, pet care absorbent products, concrete and tarmac additives, brick manufacture, paper and cardboard, insulation materials and agricultural nutrients (Recall, 2015; Knowaste, 2016).

[1] The water discharge can be treated in a municipal wastewater treatment plant

Environmental benefits

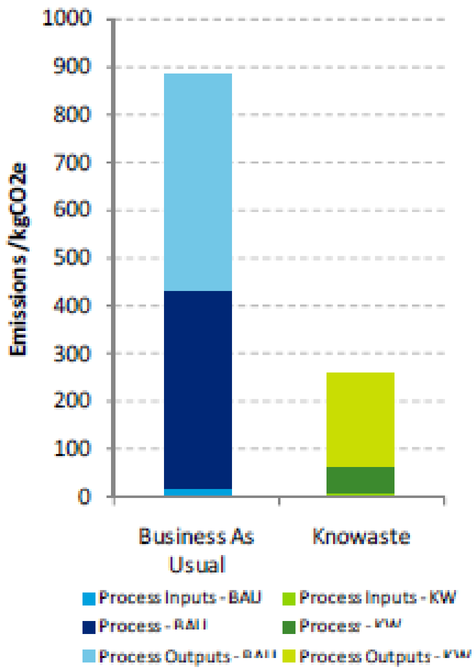
The main environmental benefit of AHP waste recycling consists of the recovery of valuable materials (plastic, cellulose fibres) to make other products, thus reducing the need for virgin materials to be extracted and reducing greenhouse gas emissions and energy use.

As for the greenhouse gas emissions and energy implications of recycling AHP waste, reference studies, related to two of the available technologies identified (Deloitte, 2011; RECALL, 2015), analysed the environmental benefit based on a life-cycle assessment (LCA) approach, consistent with the ISO 14040 international standard. The system boundaries assumed in the two studies are different, so a direct comparison of their results is not possible, but both studies point out that nappy recycling, compared to a "business-as-usual" scenario (BAU) based on landfilling and incineration of this waste flow, allows the achievement of relevant CO_2 savings.

The study carried out by Deloitte (2011), related to the nappy recycling technology developed by Knowaste Ltd as described in Operational data, compares the performance of the recycling process to standard UK disposal practice, as outlined below:

- BAU consists of a standard UK waste scenario based on waste collection, landfill (81 %) and incineration (19 %), including useful energy recovery from landfill (as a result of methane capture) and incineration processes. Finally, since no recyclate materials (such as plastic) are recovered from this process, the extraction and manufacture of additional virgin materials are included.
- The "Knowaste" scenario covers the collection and processing of AHP waste, using a "two-stream" process that generates its own energy from gasification of organic fibres produced by the process and produces useful recyclates for the UK market (mainly plastics, but also some metals and other process rejects). Since the AHP waste is not landfilled or incinerated, this scenario includes the extraction and combustion of additional fuels for energy that would have been produced in a BAU situation.

Based on these assumptions, compared to landfill and incineration, the Knowaste recycling process emits up to 71 % less carbon emissions, which based on an annual capacity of 36 000 tonnes of AHP waste, means 22 536 tonnes of greenhouse gas emissions saved per year (equivalent to the annual carbon emissions of 2 064 UK citizens). Figure 2 shows the global warming results per tonne of AHP waste, highlighting that the largest carbon impact for BAU and Knowaste is from the "outputs stage". For BAU, the outputs stage refers mainly to carbon emissions from the manufacture of virgin plastics, as all material that could potentially be reclaimed or recycled via Knowaste processing is effectively lost under BAU. For BAU, the outputs stage also refers to the generation of grid electricity from landfill gas and energy from waste incineration which is effectively lost under Knowaste. A number of alternative scenarios were created to analyse the sensitivity of the results, and, even in the worst case (the Knowaste process using grid electricity rather than generating its own electricity from gasification), the carbon emissions are reduced by 50 % with respect to the BAU scenario.



Source: Deloitte, 2011

Figure 2. Comparison of CO_2 emissions per tonne of AHP waste for the BAU and Knowaste scenario

The study realised within the RECALL project (2015), related to the nappy recycling technology developed by FATER SpA as described in Operational data, compares the performances of the recycling process to standard Italian disposal practice, as outlined below:

- BAU consists of a standard Italian waste scenario consisting of waste collection, landfill (65 %) and incineration (35 %), including useful energy recovery from incineration processes and emission offsets due to the storage of carbon in landfill processes (carbon sink)
- The RECALL scenario covers the collection and processing of AHP waste, with the recovery of two flows of materials (plastics and cellulose), the sorting and grinding of plastics which replace propylene production from virgin materials, the sorting and refining of the cellulose fraction for the production of pulp which replaces pulp production from virgin fibres.

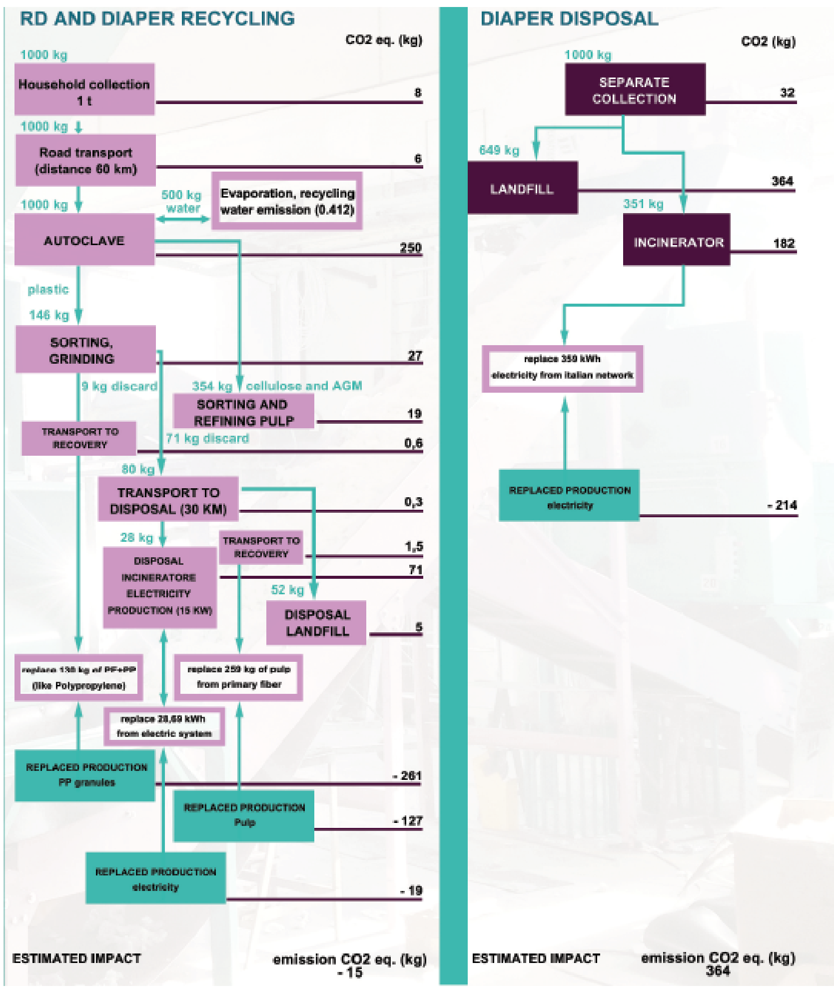
Figure 3 shows in detail the results of the comparison, considering the different process steps, with reference to one tonne of AHP waste. The main results are also summarised in Table 1, which shows how the end-of-life of nappies in the RECALL scenario becomes carbon negative, i.e. the recycling process recovers all greenhouse gas emissions generated by the collection and processing of AHP waste and even saves 14.8 kg of CO_2e per tonne, thanks to the replaced production of polypropylene and pulp for cardboard production from virgin raw materials.

Table 1. Main results of the comparison of CO_2 emissions per tonne of AHP waste for the BAU and RECALL scenarios

	RECALL scenario	BAU scenario
kg of CO_2e generated/t	375.4	577.6

	RECALL scenario	BAU scenario
kg of CO_2e avoided/t	-390.2	-213.7
CO_2e balance	**-14.8**	**363.9**

Source: Recall, 2015



Source: Recall, 2015

Figure 3. Detailed results of the comparison of CO_2 emissions per tonne of AHP waste for the BAU and RECALL scenarios

Both studies also allow the provision of some reference figures related to other environmental benefits.

With reference to the Knowaste process, the study by Deloitte also compared the process performance to that of the BAU scenario considering also, besides global warming, the other environmental indicators defined in LCA methodology. The results show that the Knowaste process has reduced impacts for all other environmental impacts assessed in the study, namely: toxicity impacts for humans reduced by up to 97 %, toxicity impacts for animals and plants reduced by up to 99 %; acid rain impacts reduced by up to 48 %, resource depletion reduced by up to 54 %, eutrophication reduced by up to 93 %.

With reference to the RECALL process, the studies carried out within the Ecoinnovation project show that, for a plant with an annual capacity of 8 000 t/year of AHP waste, the following environmental benefits can be expected:

- recovery of raw materials: 4 000 t/year;
- air quality: 27 kg/year less particulate, 432 MJ/year less nitrogen oxides and 368 kg/year less carbon monoxide (compared with incineration);
- primary energy consumption savings: 18 574 MJ/year (equivalent to the annual electricity consumption of more than 800 families).

Side effects

The operation of AHP waste treatment plants is associated with energy consumption (both electricity and natural gas). Emissions of odour and water discharges are also significant environmental effects. Precise figures about these impacts are not available because of confidentiality issues of the operating plants.

Another cross-media effect associated to the implementation of this best practice may be the increase in GHG and air emissions due to the need to introduce additional collection routes for this specific waste flow. The relevance of such emissions largely depends on the collection schemes adopted, with a very low potential impact where AHP waste is collected at waste collection centres or via door-to-door collections combined with other waste flows, while it can be more significant in the case of collection schemes specifically for AHP waste. In any case, the analysis of GHG emissions reported in the Achieved environmental benefits section, which includes the waste collection phase in the impact assessment, shows that the potential additional impacts due to such collection are largely offset by the environmental benefits offered by the recycling of the recovered materials.

Applicability

This best practice is broadly applicable as no particular geographical or technical barriers exist and the implementation of the best practice is perfectly in line with the EU waste legal framework.

However, some specific framework conditions can influence the technical and economic viability of this treatment option (Recall, 2015):

- The plant operation requires the implementation of a selective collection scheme for AHP waste, from households or other relevant producers of this waste fraction (retirement homes, hospitals, kindergartens), in order to secure a stable input flow to the plant. Such schemes are already in place in only a limited number of municipalities across the EU, in particular in areas with door-to-door waste collection schemes, especially if accompanied by PAYT charging systems[1].
- The plant treatment capacity, based on the available treatment techniques and considering the economics of the treatment process, cannot be lower than 8 000 t/year.
- The transport distance from collection areas to the plant, AHP waste collection schemes as well as local costs for landfilling and incineration must be carefully taken into account when planning an AHP waste recycling facility, as they can significantly influence its economic feasibility.
- Population density in the collection area is also an important parameter to be considered, as it can significantly influence the maximum AHP input flow to the plant and consequently its economic sustainability. From literature estimates (Recall, 2015), it can be cautiously assumed that territorial areas of about 1 million inhabitants can

generate at least 10 000 t/year of AHP post-consumer waste. If these inhabitants are spread over a large territory (low population density), transport costs from collection areas to the treatment plant can become too high for the plant to be economically sustainable. This aspect then needs careful evaluation during the planning phase.

- All the aforementioned factors affect the AHP waste plant capacity.
- Clear criteria and rules for recognising the end-of-waste and local market for recovered materials (plastic and cellulose) are needed. This condition guarantees the presence of a receptive market for the secondary raw materials produced by the recycling plant and consequently its environmental and economic sustainability.

[1] The collection of AHP waste is particularly developed in Italy, where a selective collection for this waste stream is already implemented in almost 600 municipalities covering a population of over 8 million inhabitants. In the UK the AHP collection systems in place are run mainly by private companies specialized in the healthcare waste sector (OCS/Cannon Hygiene, Initial, SRCL, PHS), but in the last years also some Local Authorities are implementing separate collection of AHP waste produced by households (e.g. Cardiff and Monmouthshire, in south east Wastes, or some local authorities in Scotland) (Recall, 2015).

Economics

In the absence of reference literature on the economics of AHP waste treatment or actual economic data from operating plants, some evaluations have been produced considering different scenarios and applying specific estimations, based on information provided by experts.

The economic viability of an AHP waste treatment process has been evaluated estimating the potential expenditures and income sources, considering treatment plants operating at different throughputs and under different framework conditions. The estimations have been based on the following assumptions:

- three different case studies have been considered, corresponding to treatment facilities with treatment capacities respectively of 10 000 t/year, 25 000 t/year and 40 000 t/year;
- gate fees for the incoming AHP waste range from a minimum value of EUR 90 per tonne, and a medium value of EUR 110 per tonne, to a maximum value of EUR 130 per tonne;
- revenues from the two recovered materials also range from minimum to maximum unitary values, and are calculated assuming a recovery rate of 100 % of the original AHP components (estimated as 40 % of the AHP waste input flow), with the following percentage breakdown for the materials: 28 % cellulose fibres and 12 % plastics.

These assumptions are summarised in Tables 2 and 5.

Table 2. Assumptions for the basis of the economic viability evaluation of AHP waste treatment processes

Treatment capacity			
Type of plant	**Low capacity**	**Medium capacity**	**High capacity**
Plant capacity (t/year)	10 000	25 000	40 000
Range for gate fees - unitary values			

	Min.	Med.	Max.
Gate fee (EUR/t)	90.00	110.00	130.00
Range for revenues from recovered materials - unitary values			
	Min.	**Med.**	**Max.**
Revenues for plastic (EUR/t)	200.00	250.00	300.00
Revenues for cellulose fibres (EUR/t)	100.00	200.00	300.00
Recovery rates for the different materials (% weight with respect to input flow)			
Recovery rate for plastic (%)	12		
Recovery rate for cellulose fibres (%)	28		

Source: own elaboration

The gate fees and revenues have been defined from information gathered during this study by interviews with plant operators. As for the gate fees, the unitary values have been set considering also the need to keep them of the same order, or at least not much higher, than landfilling[1] or incineration fees. As for the potential income from recovered materials, the range of values assumed is affected by many uncertainties, as the market value of recyclates is very volatile and highly dependent on their quality, and at present – given the innovative nature of nappy recycling processes – reliable data related to actual case studies are not yet available. The market value for recycled plastic can be defined based on current reference values for high-quality plastics recovered from packaging/plastic sorting, but the market value of the cellulose fibres is more difficult to determine given the different potential uses and the lack of reference data for similar secondary raw materials. The results of the estimates provided must therefore be considered a general reference, affected by substantial uncertainties.

Based on the assumptions described above, the profit and loss accounts for the three different case studies have been simulated, calculating the expected annual revenues and expenditures, assuming investment costs ranging between EUR 4.5 million for the low-capacity facility, EUR 9 million for the medium-capacity facility and EUR 13 million for the high-capacity facility, with amortisation periods of 10 years. The results of the simulation are shown in Table 3.

Table 3. Estimation of incomes and expenditures for the three case studies

Type of plant	Low capacity	Medium capacity	High capacity
Plant capacity (t/year)	10 000	25 000	40 000
Revenues from gate fees - Annual values (EUR/year)			
Min. gate fee	900 000.00	2 250 000.00	3 600 000.00

Type of plant	Low capacity	Medium capacity	High capacity
Med. gate fee	1 100 000.00	2 750 000.00	4 400 000.00
Max. gate fee	1 300 000.00	3 250 000.00	5 200 000.00
Revenues from recovered materials - Annual values (EUR/year)			
Min. revenue values	520 000.00	1 300 000.00	2 080 000.00
Med. revenue values	860 000.00	2 150 000.00	3 440 000.00
Max. revenue values	1 200 000.00	3 000 000.00	4 800 000.00
Investment and operating costs			
Investment costs (EUR)	4 500 000.00	9 000 000.00	13 000 000.00
Annual amortisation (%)	10	10	10
Total annual amortisation (EUR/year)	450 000.00	900 000.00	1 300 000.00
Annual operating expenditures (EUR/year)	850 000.00	2 125 000.00	3 400 000.00
Annual labour costs (EUR/year)	374 400.00	561 600.00	748 800.00
Other annual general costs (EUR/year)	167 440.00	358 660.00	544 880.00
Total annual expenditure (EUR/year)	**1 841 840.00**	**3 945 260.00**	**5 993 680.00**

Source: own elaboration

As can be observed, the majority of income arises from the gate fee, but the revenues are also relevant, in particular in the scenario with the maximum values. As for the expenditures, major costs are mainly determined by the plant operation (raw materials, energy, waste water treatment, maintenance, etc.), as the process is not labour-intensive. Investment costs are also significant, in particular in the case of the high-capacity facility.

Based on the incomes and expenditures estimated, the net cash flow before taxes has been calculated for the three case studies, considering all possible combinations of the framework conditions. The results are shown in Table 4.

Table 4. Net cash flow before taxes estimated for the three case studies

LOW-CAPACITY TREATMENT PLANT

Net cash flow before taxes		Gate fee revenues		
		Min.	Med.	Max.
Material revenues	Min.	-EUR 421 840.00	-EUR 221 840.00	-EUR 21 840.00
	Med.	-EUR 81 840.00	EUR 118 160.00	EUR 318 160.00
	Max.	EUR 258 160.00	EUR 458 160.00	EUR 658 160.00
MEDIUM-CAPACITY TREATMENT PLANT				
Net cash flow before taxes		Gate fee revenues		
		Min.	Med.	Max.
Material revenues	Min.	-EUR 395 260.00	EUR 104 740.00	EUR 604 740.00
	Med.	EUR 454 740.00	EUR 954 740.00	EUR 1 454 740.00
	Max.	EUR 1 304 740.00	EUR 1 804 740.00	EUR 2 304 740.00
HIGH-CAPACITY TREATMENT PLANT				
Net cash flow before taxes		Gate fee revenues		
		Min.	Med.	Max.
Material revenues	Min.	-EUR 313 680.00	EUR 486 320.00	EUR 1 286 320.00
	Med.	EUR 1 046 320.00	EUR 1 846 320.00	EUR 2 646 320.00
	Max.	EUR 2 406 320.00	EUR 3 206 320.00	EUR 4 006 320.00

Source: own elaboration

The net cash flow before taxes is always positive in the event that the maximum or medium value for the gate fee is applied (with the only exception being for the low-capacity plant with minimum values of the revenues from recovered materials), while it is negative or very low in the event that the minimum value for the gate fee is applied with minimum or medium values of the material revenues or in any case when the minimum material revenues are assumed. In general, the financial performance of the high-capacity plant is better than that of the medium- or low-capacity plant, under each set of framework conditions.

Considering the best case for the three case studies (maximum gate fee and maximum material revenues) and assuming that the taxes would be about 30 % of the net cash flow, we can estimate the following payback periods for the treatment plants:

- low-capacity treatment plant: 10-year payback period, with earnings after taxes of about EUR 460 000 per year;
- medium-capacity treatment plant: 6-year payback period, with earnings after taxes of about EUR 1 600 000 per year;
- high-capacity treatment plant: 5-year payback period, with earnings after taxes of about EUR 2 800 000 per year.

These evaluations show that, in the best case scenario, all the types of facilities are financially viable. Sustainable economic performances are also achieved for the medium- and high-capacity facilities in three of the intermediate scenarios (maximum gate fee and medium material revenues; medium gate fee and maximum material revenues; minimum gate fee and maximum material revenues), with the most sustainable performance achieved in the case of the high-capacity plant, which can be also financially viable in the case of a medium gate fee and medium material revenue.

Based on this analysis, the following conclusion can be drawn: the financial viability of an AHP waste treatment plant can be considered more robust where a relevant flow of AHP waste and a good market value for the recovered materials can be assured. It must be noted that a treatment facility with a high or even medium capacity (> 20 000 t/year) could face feeding constraints, as it is estimated that to collect about 10 000 tonnes per year of AHP waste an area of about 1 million inhabitants is required (Recall, 2015).

Given these data, in the assessment of the economic viability of the treatment plant it is also important to consider the collection and transport costs of AHP waste, i.e. the economic viability of the best practice implementation from the point of view of local authorities or private waste collection operators, which would provide the necessary input flow to the treatment facilities. The costs of waste collection and transport have thus also been estimated, under different scenarios characterised by the following parameters:

- collection costs for four different collection schemes: door-to-door (specific and combined with other waste fractions), street bins (opened by key provided to households requiring the collection service), waste collection centre;
- distance from the plants ranging between 50 km and 100 km and 150 km.

The costs under the different scenarios are simulated considering a small town of about 10 000 inhabitants in a flat territory with a medium population density, where 10 % of the households need a nappy waste collection service.

Based on these assumptions and considering reference data regarding the productivity of the different collection systems, the following collection costs are estimated.

Table 5. AHP waste collection unitary costs under different collection systems

COSTS	Door-to-door collection (specific for AHP waste)	Door-to-door collection (combined with another waste flow)	Street bin collection	Waste collection centre
Collection cost per tonne of AHP waste (EUR/t)	119.00	63.00	55.00	14.00

Source: own elaboration

Transport costs are estimated considering that most of the territories that send their AHP waste to the recycling plant need to collect them in a transfer station in order to optimise the transport costs, and that weekly transfers are realised from each transfer station to the recycling plant, by using a dump track. Transport costs in the simulated case study are then estimated considering the following unitary costs:

- transfer with average distance to the plant of about 50 km: EUR 200/container;
- transfer with average distance to the plant of about 100 km: EUR 350/container;
- transfer with average distance to the plant of about 150 km: EUR 425/container.

Based on these assumptions, the following transport costs are estimated.

Table 6. AHP waste transport costs considering different average distances from the transfer station to the recycling plant

Average distance between transfer station and recycling plant	Cost per trip (EUR)	Number of trips per year	Annual cost (EUR)	Unitary cost (EUR/t)
50 km	200.00	52	10,400.00	45.22
100 km	350.00	52	18,200.00	79.13
150 km	425.00	52	22,100.00	96.09

Source: own elaboration

To complete the analysis of the economic viability of the best practice implementation from the point of view of local authorities, the treatment costs for sending AHP waste to the treatment plants must be also considered, based on the gate fees applied by the plants. Three different scenarios have been thus assumed (considering gate fee ranges as defined in Table 2):

- best scenario: average transport distance = 50 km; gate fee = EUR 90/t;
- medium scenario: average transport distance = 100 km; gate fee = EUR 110/t;
- worst scenario: average transport distance = 150 km; gate fee = EUR 130/t.

The final results of the cost analysis, under the three different scenarios, are reported in Table 7. The costs include AHP waste collection, transport to the treatment plant and treatment.

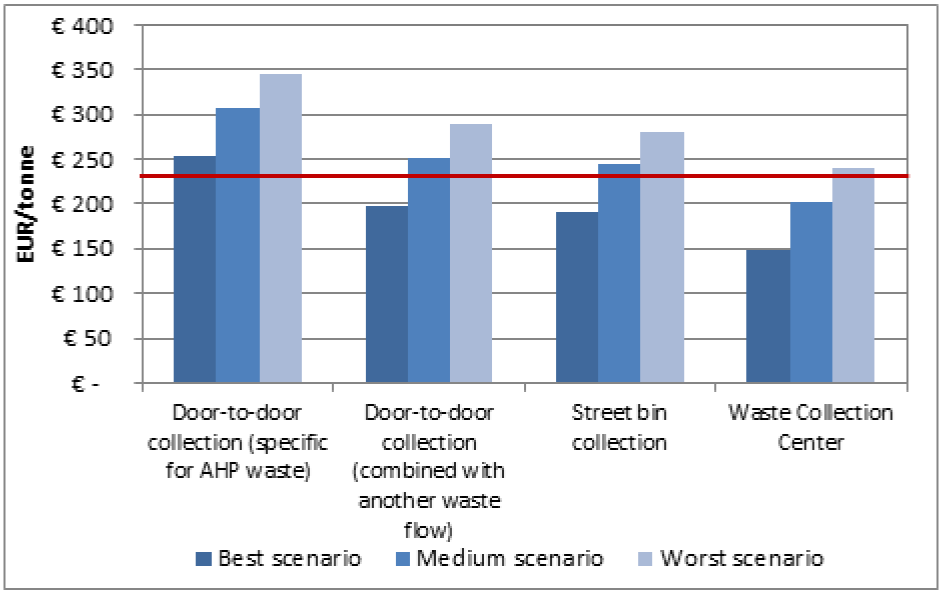
Table 7. Costs for AHP waste collection, transport and treatment under three different scenarios

EUR/tonne	Best scenario	Medium scenario	Worst scenario
Door-to-door collection (specific for AHP waste)	254	308	345
Door-to-door collection (combined with another waste flow)	198	252	289
Street bin collection	190	244	281
Waste collection centre	149	203	240

Source: own elaboration

The economic viability of the BEMP implementation, from the point of view of local authorities, is highly dependent on the costs of the municipal waste management services in each specific context, which largely depend on the costs of landfilling and/or incineration (gate fees and taxes).

Assuming a reference context where the average waste collection and transport costs are ~ EUR 130/t and landfilling/incineration costs are on average ~ EUR 110/t (which is the case, for example, of Italy, according to Utilitalia, 2016), the total cost for the municipal waste management service is ~ EUR 240/t. Under these conditions, the best scenario for separate collection and recycling of AHP waste appears convenient, except in the case where a door-to-door collection specifically for AHP waste is implemented. And it also appears convenient or at least comparable with the status quo in the medium scenario, except in the case where door-to-door collection services are implemented, as shown in Figure 4.



Source: own elaboration

Figure 4. Cost analysis of AHP waste collection, transport and treatment under different scenarios

[1] Indeed, landfilling fees are much lower in some EU Countries, as shown in Figure 3 reported in the best practice about mattresses treatment, but it is assumed that in future they should increase because of landfill phasing out policies

Driving forces for implementation

The main driver for the implementation of this BEMP in Europe is the EU waste legal framework, and in more detail:

- the binding targets for municipal waste recycling (> 50 % by 2020 according to the Waste Framework Directive, 60 % by 2030 according to the proposal for the revision of the Waste Framework Directive introduced by the Circular Economy Package);
- the binding targets for reducing waste landfilling (targets for reducing the amount of biodegradable municipal waste landfilled introduced by the EU Landfill Directive (1999/31/EC); proposal for a binding target to reduce landfill to maximum of 10 % of municipal waste by 2030 introduced by the Circular Economy Package).

Since the introduction of these targets, in many EU countries a lot of effort has been devoted to achieving higher recycling rates and in some regions ambitious targets have already been achieved (recycling > 70 % and residual waste sent to landfill almost zero). Under these conditions, the AHP waste can represent up to 15–20 % of the residual waste, and its diversion from landfills or incinerators can be the best option for further reducing the residual waste.

Another driving force that is being observed in the territories with door-to-door (or kerbside) waste collection schemes, especially if accompanied by PAYT charging systems, is the operative and social problem encountered by households producing AHP waste. In these contexts, considering that the residual waste is usually collected no more than once a week, many municipalities are forced to introduce the selective collection of AHP waste, independently from the existence of recycling solutions, because households producing AHP waste need a more frequent service for this waste stream. Moreover, this household category produces a higher amount of residual waste, which is generally the only waste fraction that is charged when PAYT schemes are in place. It is therefore the case that these households pay high fees for the waste collection service, for a waste fraction that they can hardly reduce. The introduction of selective collection systems for AHP waste, which would remove this waste fraction from residual waste, also becomes the solution to this social problem.

These factors create favourable conditions for the implementation of this best practice. Indeed, the construction and operation of AHP waste treatment plants becomes the solution by providing the opportunity to recover materials from this waste stream that otherwise would be sent to final disposal, even if separately collected.

Reference organisations

The reference organisations identified for this best practice are the following:

- Contarina SpA: a public waste management company that operates the first recycling plant based on the RECALL recycling technology developed by FATER SpA. More details can be found at: http://www.contarina.it/chi-siamo/impianti/riciclo-prodotti-assorbenti
- Fater SpA: an Italian company, and an industrial leader in the production of absorbent hygiene products, that has developed the RECALL Recycling technology in the framework of the CIP Ecoinnovation RECALL project (Recall, 2015). More details can be found at: http://www.fatergroup.com/it/news/progetti/progetto-riciclo
- Knowaste Ltd: a UK company that has developed, since the 1990s, a nappy recycling technology and has built the first operating plants in Europe. More details can be found at: http://www.knowaste.com/

Besides these reference organisations that are already implementing AHP waste treatment techniques for material recycling, it is worth also mentioning Diaper Recycling Technology Pte. Ltd, a Singapore-based company that has developed a treatment technology that currently converts absorbent hygiene factory scraps back into the original raw material streams (including cellulose pulp, SAP and PE/PP). Research and development efforts are under way to expand the applicability of this newly developed technology to post-consumer AHP waste (Nonwovens Industry, 2016). More details can be found at: http://www.diaperrecycling.technology/.

Literature

Arena U. et al. (2016), Technological, environmental and social aspects of a recycling process of post-consumer absorbent hygiene products, Journal of Cleaner Production 127 (2016) 289-301.

Colón J. et al. (2013), Performance of compostable baby used diapers in the composting process with the organic fraction of municipal solid waste, Waste Management 33 (2013) 1097–1103.

Deloitte (2011), Absorbent Hygiene Products comparative Life Cycle Assessment, prepared for Knowaste Ltd, April 2011.

Ent-Environment and Management (2009), Viabilidad de la recogida y el tratamiento de pañales de un solo uso en Cataluña.

Knowaste (2016), information available on the Company website: http://www.knowaste.com.

Nonwovens Industry (2016), article in the news section of Nonwovens Industry website: http://www.nonwovens-industry.com/issues/2016-05-15/view_breaking-news/diaper-recycling-technology-launches-generation-6-in-line-recycling-technology; Last access September 2017.

OVAM (2009), Conclusie evaluatie afvalluiers, 2009.

Recall (2015), deliverables of the CIP Ecoinnovation RECALL project "*REcycling of Complex AHP waste through a first time appLication of patented treatment process and demonstration of sustainable business model*", Layman Report; information available also on the project website: http://www. http://recall-ecoinnovation.eu/; Last access September 2017.

Rowtech (2013), Absorbent Hygiene Products Waste – Review of South Australia, Report commissioned by Government of South Australia, January 2013.

RWS Rijkswaterstaat (2015), Ministerie van Infrastructuur en Milieu, Diaper cycle project - Inventory of opportunities and obstacles, Date:15th April 2015.

UK Environment Agency (2008), An updated life cycle assessment study for disposable and reusable nappies.

Utilitalia (2016), Green Book – *I dati sulla gestione dei rifiuti urbani in Italia*, Realized by Utilitatis with the scientific support of CdP SpA, January 2016.

Veneto Region (2016), Bur n. 88, 13/09/2016, Regional Decree n. 1319 - 16 August 2016, *Contarina Spa - richiesta di modifica ed autorizzazione all'esercizio dell'impianto sperimentale per il trattamento ed il recupero di rifiuti urbani e assimilabili costituiti da prodotti assorbenti (pannolini, pannoloni ed assorbenti igienici), presso lo stabilimento di Lovadina di Spresiano (TV). Art. 211 del D. Lgs. n. 152 del 2006 e s.m.i. e art. 30 della L. R. n. 3 del 2000.*

World Resources Institute and World Business Council for Sustainable Development (2004), The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, Revised edition, March 2004.

Zero Waste Scotland (2013), Evaluation of the Absorbent Hygiene Products Collection Trials in Scotland, June 2013.