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METHOD AND EQUIPMENT FOR RECYCLING POST CONSUMER WASTE

Field of the invention

The present invention relates to the recycling of post-consumer waste, especially when comprising or essentially consisting of used hygiene products, such as baby diapers, adult incontinence products and the like. In particular, the present invention aims at recovering of components thereof, especially plastic materials, like polyethylene, polypropylene, natural fibrous materials, such as cellulose or pulp fibers, and superabsorbent polymers, such as cross-linked polyacrylates, most efficiently.

Background

Absorbent hygiene products, such as disposable nappies and adult incontinence products, are typically constructed from a liquid-impermeable back sheet, an absorbent core, and a liquid-permeable top sheet. There are also typically liquid-impermeable elements attached to the top sheet as leak guards, to prevent liquid being lost from a used absorbent hygiene product.

The liquid-impermeable and liquid permeable outer sheets of the absorbent hygiene product are typically polyethylene and/or polypropylene films or non-woven. The absorbent core of an absorbent hygiene product typically includes superabsorbent polymer (SAP), and currently still significant amounts of organic materials such as wood pulp and cellulose. SAP is also known as super absorbent material (SAM), sometimes as absorbent gelling material (AGM), and an example of such a material is cross-linked polyacrylic acid / sodium polyacrylate. SAPs may absorb many times their own weight in liquid, in tap water often up to hundreds of times their own weight. When the liquid is absorbed, the SAP forms a gel-like material. This is advantageous when being used for their primary purpose of absorbing liquid exudates, such as urine, menstrual fluids, liquid components of faeces, but can cause difficulties when trying to deal with used absorbent hygiene products.

Additionally, elastic materials such as polyurethane, polyester foam or fibrous webs, synthetic rubber and Lycra/Spandex elastics may be used in the construction of absorbent hygiene products. Conventionally, adhesives, such as hot melt adhesives, are used to join the materials together. Absorbent hygiene products can also include other fabrics and wicking materials in their construction. As can be seen, an absorbent hygiene product may be a complex composite product.

Disposing of used absorbent hygiene products to landfill has a negative environmental effect, as the plastic components can take a long time to break down. There is therefore a need to recycle used absorbent hygiene products.

Also, within the industry, recovery of the valuable ingredients has been considered since long. To date, the recycling efforts for separating the various materials which make up an absorbent hygiene product use processes that are expensive and complex, thus they appear to be not commercially

attractive.

Within the hygiene industry, a first approach has aimed at reducing “clean” factory scrap by better machine efficiency with lower scrap rates. Further along this path, the factory scrap has been collected and separated into its compounds, such as plastic, cellulosic fibers, such as pulp fibers, and superabsorbent, each of which may be recycled the more easily the purer they are. A particular approach has been described in WO2022/055422 (DRT).

Another approach aimed at the “post-use” or “post-consumer” waste, be it in connection with other municipal waste or “pure” used hygienic articles. Municipal waste has been the subject of many recovery methods to replace landfilling by other methods, such as composting, sorting and recycling of extracted components, but also “thermal recycling” or incineration under environmentally compatible conditions.

An overall life cycle assessments specific for used hygiene articles has been published by Itsubo et al, (“*Life Cycle Assessment of the Closed-Loop Recycling of Used Disposable Diapers”*: Resources 2020, 9, 34; doi:10.3390/resources9030034; MDPI resources), whilst a multitude of patent art focuses on particular aspects, such as WO2016/204697 (DRT), EP3417954A1 (Unicharm); WO2018/119970 (Wu); EP3626881A1 (Unicharm); WO2016/047294 (Unicharm); US4990244; US5322225; EP3712325; US6238516.

However, in spite of such disclosures, there is no broad penetration of such technologies in the markets, primarily due to inefficiencies of the approaches with regard to resource usages, such as water usage or energy requirements (e.g. for hot sanitization) or purity of resulting materials.

Thus, there is still the need for more efficient processes to be operated on simple equipment, that

- do not require high temperatures for sterilization or at least no non-renewable energy,
- allow efficient recovery of ingredients,
- allow operation of small (decentralized) units.

Summary

In a first aspect, the present invention is a recycling equipment for recovering materials by recycling products comprising plastic materials, superabsorbent polymers (SAP), and optionally cellulosic fibers, which are loaded with waste materials including human or animal exudates.

The equipment comprises a product receiving unit, optionally a pre-washing unit, a product shredding unit, a plastic separation unit, optionally a SAP / fiber separation and fiber recovery unit, and a SAP recovery unit. An overall fluid handling system is adapted to minimize or even eliminate ingoing and outgoing fluid streams, whereby the ingoing and outgoing fluid streams are preferably aqueous fluids. The fluid handling system further comprises elements for adjusting salt concentrations of liquids (including solidifying the particulates therein to dryness) for being selectively supplied to and received from the equipment units. Further, the equipment comprises an overall energy management system so as to minimize, if not eliminate, energy input other than from

a renewable energy unit, e.g., solar thermal energy collection unit.

In a second aspect, the present invention is a process for recovering materials by recycling products comprising plastic materials, superabsorbent polymers (SAP), and optionally cellulosic fibers, which are loaded with waste materials including human exudates. The process comprising the products recycling steps of receiving used products in a product receiving unit, optionally pre-washing the products in a pre-washing unit, shredding the used products in a product shredding unit, separating plastic materials in a plastic separation unit, optionally recovering cellulosic fibers in a SAP / fiber separation and fiber recovery unit, and recovering SAP in a SAP recovery unit. The process further comprises the step of operating an overall fluid handling system comprising the steps of receiving incoming fluid(s), preferably aqueous liquid(s), preparing at least one salt solution from the incoming fluid(s) comprising predetermined salt concentration and composition, distributing the salt solution(s) to the recycling steps, discharging spent salt solutions from the recycling steps, whereby the spent salt solutions exhibit differing degree of waste loads, separating the spent salt solutions into two or more fractions, whereby one fraction comprising a high waste load may be discharged to a waste water treatment, but preferably is submitted to a biogas generation unit or a composting unit, optionally and often preferably in an essentially dry state, and at least one further fraction is recycled to the product recycling steps.

In yet a further aspect, the present invention is a fluid handling system for providing and receiving fluids to and from processing steps for recovering materials from recycled products, whereby the products comprise plastic, superabsorbent polymers (SAP) and optionally cellulosic fibers. The fluid handling system comprises at least one incoming fluid tank, at least one spent process fluid tank, at least one separation unit for separating spent process fluids into a clean fluid fraction, adapted to be reused in the processing steps, optionally fed into the incoming fluid tank, a loaded fluid fraction for being discharged to a waste water treatment preferably a biogas generation unit or a composting unit, optionally further concentrating the solids therein to dryness.

In an even further aspect, the present invention is an energy management system for providing and receiving energy to and from processing steps for recovering materials from recycled products, whereby such products comprise plastic, superabsorbent polymers (SAP) and optionally cellulosic fibers. The energy management system comprises at least one solar thermal energy collector, at least one thermal energy storage element, distribution and control elements for delivering and receiving energy to and from the processing steps.

Also, the present invention is a process control system for controlling processing steps for recovering materials from recycled products, whereby the products comprise plastic superabsorbent polymers (SAP) and optionally cellulosic fibers. The process control system comprises process parameter monitoring elements, process parameter change element that allow change of parameters of the processing steps, process parameter input elements that allow process parameters to be set to

predetermined parameter, process parameter optimization elements that allow calculation of optimal combination of various process parameter according to predetermined optimization targets.

Brief description of the Figures

Fig. 1A depicts an overview of the processing and process sections according to the present invention.

Fig. 1B to G depict details of the processing sections and steps according to the present invention.

Fig. 2A depicts an overview of the overall equipment set up and equipment sections according to the present invention.

Fig. 2B to G depict more details of equipment sections of the overall equipment set-up as in Fig. 2A.

Fig. 3 depicts the main fluid handling system according to the present invention.

Fig. 4 depicts key elements of the thermal energy system according to the present invention.

Figures are schematic only and not to scale. Same numerals in different figures refer to same or equivalent executions or features. Hyphen (‘, “, ‘”) relate to multiplicities of elements or features.

Detailed description

Disposable absorbent articles including baby diapers, adult incontinence articles, feminine hygiene articles and the like, but also bed pads or other absorbent hygiene articles generally consist of lining, absorbent transport layer, absorbent material, waterproof film, leg and waist bands, and the like. In addition to diapers, diaper pants, training pants, youth pants, incontinence articles, feminine care products, and other disposable absorbent articles like bed pads or absorbent pet pads for animals can include similar structures. In many of these, the absorbent material includes superabsorbent polymer material and cellulose pulp. More recently, absorbent articles have been described that are essentially free of cellulose and/or adhesives, see e.g., WO2015/036561 (C4S).

Equipment set up and Processing operation

The different aspects of the present invention are now further explained jointly by referring to the figures.

Fig. 1A depicts an overview of overall process elements according to the present invention, and Fig. 1B to G depict more details of the process sections as in Fig. 1A.

Fig. 2A depicts an overview of the overall equipment set up according to the present invention and Fig. 2B to G depict equipment sections in more details.

Fig. 3 is building on Fig. 2A and indicates typical fluid handling systems according to the present invention.

Fig. 4 is building on Fig. 2A and indicated typical energy transfer systems according to the present invention.

Generally, process sections or step are indicated by four digit numbers, equipment sections or apparatuses by five digit numbers, and products or materials by three digit numbers.

In the following explanation of the present invention, reference is made in parallel to the overall recycling process 1000, as depicted in Fig. 1A and the process steps, as per Fig. 1B to G, to the overall equipment set-up 10000, as depicted in Fig. 2A and equipment elements, as in Fig. 2B to 2G, as well as particular fluid handling aspects as shown in Fig. 3, and particular thermal energy transfer aspects as depicted in Fig. 4.

Delivery and preparation – Fig. 1B, 2B

Used hygiene products 100, 100', … are delivered to and received 1100 at a delivery and receiving unit 11000. The products may be dumped in bulk 1200 in a bulk dumping station 11200, and/or in bags 1300 / 11300, which may be removed 1400 at bag removal station 11400, such that the products are now in the bulk container 11210. Coarse solid contaminants 510 such as metals may be removed 1500 at removal station 11500 to be separated 1510 into a coarse solid contaminants container 11510. Preferably, the products are individualized 1600 at an individualization station 11600 for further conveying. A preferred method may be the use of a vacuum gripper, e.g. an automated robot with a vacuum nozzle which collects one product at a time and places it e.g. on a conveying belt. Instead of or in addition to removing contaminants before the individualization, contaminants 520 may accumulate in the bulk container 11210 and be removed 1520 and be disposed in a container 11520.

Pre-washing – Fig. 1C, 2C

In order to reduce the load of dirt for subsequent steps, it may be preferred to remove body exudates, especially faeces, from the general undamaged products in a separate pre-washing step 2000 in a pre-washing equipment 12000.

As used products 100, 100',… are often in a rolled up configuration and closed by adhesive or mechanically engaging closure means, it may be preferred to open these in a tab opening step 2100 in a tab opening unit 12100. Such a unit may comprise heating, optionally applied only to the outside of the products, so as to soften the adhesive of the tabs. Preferably, the heat is applied only superficially, in order to not overly raise the temperature of the total product, even more preferably specifically directed towards the tapes, as may be detected by optical sensors, optionally with a device for slowly turning the products. The heat applied may be any suitable heat source, preferably it is hot water or steam as may be supplied by nozzles or fluid curtains. As will be discussed in more detail herein below, and referring to Fig. 4, wherein an overall main thermal energy flow chart is depicted, the heat may be collected from a solar thermal collector system 18000, as may further be connected to a thermal energy storage 18100, so as to also allow heating during nights.

In addition or alternatively, mechanical impact or agitation can be employed to open the mechanical fastener, e.g. in a rotating drum, optionally inclined versus the horizontal, where the products are submitted to physical impact, such as by an avalanching effect in the drum, and/or further intensified

by tapping aids, such as rubber balls of appropriate large size and weight so as to remain in the opening unit when the products are transferred to the next treatment equipment for the next processing step.

The opened products may then be transferred to a pre-washing unit 12200, where they are pre-washed 2200, i.e. especially solid excrements are removed. To this end, a pre-washing fluid 210 is prepared in a washing fluid preparation unit 12210.

It should be noted that closed products, like training pants or incontinence pants, will not open like the “taped” products but remain typically in the closed pant configuration. However, such products are less often – if at all – loaded with difficult to remove exudates, especially faeces, and thus do not require to be opened and/or prewashed.

As will be explained in more detail herein below, and now also referring to Fig. 3, wherein the main fluid handling system 17000 is further detailed, the fluids like the pre-washing fluid 210 are most preferably water based, preferably exhibiting a high salinity so as to avoid excessive swelling of the SAP, such as with broadly available inorganic salts, such as sodium chloride 791, or calcium chloride 792 or magnesium chloride 793.

Further additives may be added 2220 from a pre-washing additive supply 12220 to the pre-washing fluid in the pre-washing unit 12200 or before the pre-washing step 2200, as may fat removal aids, or other density adjustment means beyond salinity.

The pre-washing fluid may further be operated at an increased temperature, so as to ease dissolving or suspension of the excrements, as may preferably be achieved and controlled 9220 by pre-washing control system 19220, such as by being connected to the overall energy management system 8000 (see Fig. 4) by using the solar thermal collector system.

The pre-washing may be executed in a tank with products floating therein and thereby releasing the excrements to the pre-washing fluid, where the excrements are either dissolved or suspended as small particles. The pre-washing may be executed in a drum type container with apertures in the outer walls, as known in principle from household washing machines. The products in the pre-washing may be moved, such as by stirring, rotating of the drum, or fluid movement.

In a particular execution, the pre-washing may be executed in a vessel comprising a rotating drum and further comprising product movement elements, such as rotating paddles, or a helical screw. The rotating drum may be arranged with a rotational axis inclined by an angle to the horizontal, e.g. at an angle of more than 5° or more than 15° or more than 25°or even more than 45°, but less than 90°, or less than 80°, or less than 60°.

Additionally or alternatively, especially in the case that the products are readily opened and are in an overall flat position, the pre-washing may be achieved by spraying the pre-washing fluid onto the soiled surface, thereby removing the excrements at a lower fluid amount relative to the amount of products. Here, the products may be placed on a liquid permeable support, such as a mesh belt, such

that the loaded pre-wash fluid can penetrate through. The pre-washing fluid may be applied from the top or from any side of the products and/or the products may be turned in the process.

The dirt-loaded pre-washing fluid 250 coming from the tank or the spray cleaning unit can be collected 7250 and be transferred to a “black” water tank 17800 (see Fig. 3), from where it can be further treated such as to be submitted to a biogas treatment unit 17820 or a composting unit 17830, optionally after the solids being dried, or just be delivered to a sewer and a wastewater treatment unit.

Optionally, the pre-washing may be supported by applying vibrations 2400, such as by an ultrasonic unit 12400, or by an ozone treatment step 2300 with an ozone delivery unit 12400, as may further apply a sanitization effect.

The pre-washing process may comprise a controlling step 9220 by a process control unit 19220, as may measure and /or control one or more selected from the group consisting of temperature, density of the pre-washing fluid, mechanical movement (stirring, fluid movement, rotating, vibrations, esp. ultrasonic vibrations, etc.), salinity, time sanitization aid, e.g. ozone, addition and distribution, other additive level, pH, and turbidity.

The pre-washing may be executed in a batch processing mode, such when a batch of products is dumped into the equipment and processed until sufficiently cleaning occurred to be removed before or after the loaded pre-washing fluid is removed.

The pre-washing may also be executed in a continuous operation, such as for the spraying process for the flat products, or in a vessel, for which products are continuously fed in and removed 2500, e.g. by a conveyor screw or similar equipment 12500. ´The loaded prewashing fluid 250 may also be continuously removed 7250 for further transfer 17250 to the black water tank 17800.

It should be noted that at this processing stage, the products are still generally intact and the SAP is only moderately swollen due to the at least moderate salinity of about 3.5 % to about 10 % salt content of the pre-washing fluid. The skilled person will also realize that the pre-washing fluid may exhibit a high salinity of more than about 10% of salt, such that the SAP will swell even less.

Upon sufficient removal of the excrements, the products are removed 2500 by a removal equipment 12500 and may further be submitted to a dewatering step 2600 in a dewatering unit 12600, as may be a mechanical dewatering unit, such as a press or a centrifuge. The expelled fluid 260 may also be transferred 7260 via a transfer unit 17260 to the black water tank 17800.

Optionally, further dewatering chemicals, such as salts, e.g., different ones or at a higher concentration, may be applied.

Also, the skilled person will readily realize that the pre-washing step may be executed at an acidic or alkaline pH level, such as below a pH of about 2.5, or above a pH of about 10. The pH adjustment may be made as a specific solid or liquid further additive at step 2220 via an additive feeding unit 12220. Optionally, but not necessarily, the pH may be brought to neutral conditions of pH of about

7 at the end of the pre-washing.

At the end of the pre-washing step the products may be conveyed in step 2900 by a conveying unit 12900 to the next processing step.

Coarse shredding – Fig. 1D, 2D

In order to be able to separate the materials plastic, pulp (if present), and superabsorbent of the products from each other, the products 100, 100', … may be disintegrated in a coarse shredding step 3000 in the coarse shredding unit 13000.

The shredding may be performed by conventional tools, such as cutter, shredder and the like. However, often, such tools generate small cutting pieces of the plastic material, which are difficult to separate from pulp and SAP. Henceforth, it is preferred that the shredding is executed by a tearing operation, such as described in WO2016/204697 (DRT) or WO2022/055422 (DRT), to which express reference is made here as far as the shredding is concerned.

This step can be applied to products as coming from the pre-washing step, alternatively the pre-washing step may be skipped, and soiled products may be submitted to the coarse shredding step 3000 essentially as delivered.

During the coarse shredding, drip water 310 may be released that can be recycled 7310 via coarse shredding drip water removal system 17310 to a grey (17850) or to a black (17800) water tank, depending on the soil load.

The coarse shredding creates stream of shredded products 200 of a pasty consistency or a slurry, which may be transferred 3900 by a transfer unit 13900 to further processing.

(Wet) Plastic Separation – Fig. 1E, 2E

The shredded products 200 are fed to a plastic separation step 4000 in a plastic separator 14000. In the preferred execution, the separation 4100 takes place in separation tank 14100 with a separation fluid 4210 as may be prepared and supplied via plastic separation fluid supply 14210 in analogy to the pre-washing step, whereby the properties, especially fluid densities, e.g. via salinity, are adjusted 9410 by a plastic separation control unit 19410 such that the plastic parts float and can be readily removed. Optionally, the plastic separation fluid may exhibit a high salinity so as to minimize SAP swelling, and /or further additives may be added 4220 by an additive feeding unit 14220.

Optionally, the wet plastic separation fluid may be taken from the grey water tank 17850, which refers to process water stemming from other process steps, but being not highly loaded with contaminants or excrements.

Optionally, vibration, (1)4400 such as ultrasonic vibration may be applied. Optionally, ozone (1)4300 may be added for sanitization purposes. Optionally air bubbles (1)4350 may be introduced to aid flotation of the plastic materials. Optionally stirring can be applied.

Optionally, the SAP may be submitted a de-swelling step, such as by electro-de-swelling step 4450 via electrodes 14450, e.g., at a voltage of more than about 50 V or more than about 100V for more

than about 1 min of exposure time.

The plastic separation step may be controlled 9410 by a plastic separation measurement and control unit 19410 in analogy to the above.

The plastic material 300 may be removed in a plastic material removal step 4500 by a plastic removal unit 14500, such as a scraper or a feeder screw.

The plastic material may then be further purified 4600 in a plastic purifying unit 14600, preferably by providing a cleaning fluid 4620 in a cleaning fluid feed 14620. The cleaning may be washing in a tank, or spraying with the cleaning fluid, e.g. on a liquid permeable support, like wire mesh.

The cleaned plastic material may then be dewatered in a dewatering step 4700 in a plastic dewatering unit 14700, and the expelled water may be transferred 7470 by a fluid transfer unit 17470 e.g. to the grey water tank 17850.

Further, the plastic material may be dried 4800 in a drying unit 14800, preferably by using energy 8780 by thermal energy supply unit 18780 as connected to the solar thermal collector system 18000 (see Fig. 4).

If the plastic material is dried at sufficiently high temperatures so as to accomplish sanitization, the sanitization step in the separation step may be omitted. Additionally or alternatively, the plastic material may also be sanitized during plastic material purification step 4700, e.g. by adding a ozone treatment there.

Subsequently, the plastic material may be pelletized 4900 to plastic pellets 350 in a pelletizer 14900 for further uses, whereby required thermal energy may come from the overall thermal collector system 18000.

The separation fluid 400 devoid of plastic material will the comprise primarily SAP, at a degree of swelling that may be adjusted by the separation fluid comprising de-swelling agents, such as without limitation, salts, like sodium, calcium, or magnesium chlorides. Further pulp fibers, if present, will be floating in the separation fluid.

SAP / fiber removal, separation Fig. 1F, 2F

In the preferred execution, the separation 5100 of the separation fluids 400 with suspended fibers and SAP takes place in fiber / SAP separation tank 15100 with a fiber / SAP separation fluid 5210 as may be prepared in analogy to the pre-washing step, whereby the properties, especially fluid densities, e.g. via salinity, are adjusted 9510 by a fiber / SAP separation control unit 19510 such that the fibers remain suspended, but the SAP concentrates on the bottom, such as by adjusting high salinity of the SAP/fiber separation fluid 5210 so as to maximize SAP de-swelling and SAP gel density. Further additives may be added 5220 by an additive feeding unit 15220. Optionally, fiber / SAP separation fluid may be removed (1)7510 and e.g. recycled to the overall fluid handling system, preferably without carrying fibers and/or SAP.

Also, the optional processing steps as sanitization 5300, e.g. by ozone, addition of air blowing to

enhance fiber flotation or frothing, by fiber / SAP sanitization unit 15300 may be applied analogously.

It should be noted that it is within the present scope that the fiber/SAP removal step may be executed concurrently with the plastic separation step, if the processing can be adjusted accordingly, especially the fluid properties.

The SAP may be removed 5400 from the separation tank such as in the form of a high SAP concentration sludge 600 by SAP removal units 15400, such as mechanical separators like screw conveyor, bucket conveyors, optionally with sieve buckets so as to enhance draining, centrifugal separators, and the like, but also fluid handling separators like cyclones, cascade separators and the like.

Obviously, in case that the articles are essentially free of pulp, the fiber / SAP separation step may be skipped as well as the following further fiber treatment.

Further fiber treatment Fig. 1G, 2G

The fiber suspension 500, which is essentially free of SAP, may be further treated such as by purification 5100 with a fiber purification fluid 5510 from a fiber purification fluid supply 15510, in a fiber purification unit 15500, optionally with further fiber purification aids 5520, or sanitization aids like ozone 5530, as may be provided by respective supply units 15520, 15530, respectively.

The fiber suspension will typically exhibit a low consistency, and may be submitted to further treatment such a dewatering 5600, whereby the removed fiber free water may be introduced 7560 into the water recycle process, drying 5700, whereby the energy may be provided by the solar thermal collector system 8570, and be finished in conventional steps 5800, such as baling or sheeting to the final fiber material. These steps may be executed by respective treatment units 15600, 17560, 15700, 18570, and 15800.

SAP reworking Fig 1H, 2H

The SAP sludge 600 from the fiber /SAP separation step may be transferred to the SAP reworking process step 6000 in the respective SAP reworking unit 16000.

Depending on the purity and sanitization in the previous processing, the SAP reworking may include a further SAP purification step 6100 in a SAP purification unit 16100. A SAP purification fluid may be provided 6210 by a SAP purification fluid supply 16210, as may be connected to the overall fluid handling system 17000. Preferably, the SAP purification fluid will not allow the SAP to swell significantly, such as may be achieved by appropriate selection of fluid densities and salinity as well as may be enhanced by adding 6220 further SAP purification additives from an additive supply 16220. Also, further sanitization may be applied, such as by an ozone treatment 6300 with an ozone supply unit 16300.

However, in particular in this step, but also in any of the previous step, care should be taken to avoid decomposition of the SAP by the ozone, as the latter, upon sufficient treatment time and under other

conditions, especially temperature, may react with the crosslinking of the SAP, and cleavage of the crosslinking may deteriorate absorbency properties of the resulting SAP, which actually may lead to complete deactivation of the crosslinking, thusly making the residual acrylic acid / acrylate polymer water soluble. Whilst this may be appropriate for other reworking approaches for the SAP, in the present case it is preferred to maintain the water absorbency properties of the SAP material.

Thus the SAP may be transferred 6400 by a suitable transfer unit 16400 from the SAP purification step 6100 in the SAP purification unit 16100 to a SAP de-swelling step 6500 in a de-swelling unit 16500, as may be an electro-de-swelling unit, e.g., at a voltage of more than about 50 V or more than about 100V for more than about 1 min of exposure time.

Under appropriate conditions as may be controlled 9610 in the SAP processing control unit 19610, the de-swelling 6500 may actually be accomplished concurrently with the SAP purification 6100, or subsequently thereto, but in the same purification unit 16100.

The fluids as resulting from the SAP purification as well as from the SAP de-swelling may appropriately be recycled 7640, 7650, respectively, to the main fluid handling system via fluid transfer units 17640, 17650, respectively.

The purified and de-swollen SAP 620 may then be transferred to a SAP drying unit 16600, where by connection to the solar thermal energy unit 18000 via a heat transfer unit 18660 the SAP may be dried 6600 to a residual moisture of less than 15%, or less than 10% or even less than 5%. The drying of the gel may be accomplished in drying equipment as well known to a skilled person, with fluidized bed dryer being a preferred equipment. Thereafter, the SAP may be submitted to a finishing step 6700 in a finishing unit 167600, wherein SAP finishing additives 6750 from a SAP finishing additive supply 16750 may be applied, such as so called particulate material flow enhancer, such as without limitation silica.

Also, it should be noted, that in particular multivalent salt ions, such as calcium or magnesium ions are very efficient in de-swelling of the SAP, but may deteriorate absorbency properties of the SAP after recycling. Henceforth, in case of employing such salts at any of the processing steps, specific multivalent ion removal may be included in the SAP purification step.

Overall fluid management – Fig. 3

In a further aspect, the present invention relates to a system 17000 and its operation 7000 for effective fluid handling for the various process steps of recycling used hygiene products.

The objective of smart fluid management system is to minimize the effect of the overall recycling process on the environment as well as to minimize, if not eliminate, clean water resource usage and waste water occurrence, which also enables a more cost effective operation of the recycling process.

The present invention aims at using mainly aqueous, i.e., water based, fluids, as well as additives that are not harmful to the environment and humans, and which are also available in sufficient volumes at low costs.

When explaining the principles of the present fluid management system reference is made to Fig. 3, schematically depicting the elements for such a fluid management system and the connection to the various process steps and respective equipment units.

In a first execution for this aspect, generally available tap 710 water may be used, additionally or alternatively sea water 740 may be used, where readily available. These fluids may be stored in feedstock tanks 17110 and/or 17745, respectively.

The system also comprises tanks for capturing fluids coming from the various processing steps, such as spent fluids or exudate loaded fluids. Depending on the degree of soil loading, these fluids can be classified as heavily loaded “black water”, as may be captured in a black water tank 17800, and which is unsuitable to be directly fed into other processing steps, or moderately loaded “grey water” as may be captured in a grey water tank 17850, which can be used in other processing step. Most preferably, the fluid handling system according to the present invention also comprises fluid treatment units that separate fluids into a clean and a high load fraction. Such a separation can be achieved thermally, whereby water is evaporated and the clean vapour may be condensed for re-use, as may be readily and cost effectively be achieved by the connection with the overall energy management system described herein below in more detail. Such a separation may also be achieved by membrane system, based on the reverse osmosis principle, and may employ micro metal sieves and / or ceramic membranes. With these basic components, the fluids may be appropriately adapted for each of the processing steps, whilst the exudates and other soil may be removed as a highly concentrated fluid for further treatment, such as in a sewage treatment plant 17810, or in a bio-gas generation unit 17820, or be dried, e.g. for being fed towards a composting unit 17830.

For applications where the fluids come into contact with SAP, such as in the pre-washing, the fluids like the pre-washing fluid 210 may comprise a predetermined amount of salts in order to avoid excessive swelling of the SAP. Where there is intense contact, the salt concentration should be higher, Such salts are preferably broadly available inorganic salts, such as sodium chloride 791, or calcium chloride 792 or magnesium chloride 793.

The pre-washing fluid may be prepared from tap water 710, as may be provided in a tap water tank 17710 and to which the salts are added in a low salinity tank 17730, with less than about 3.5 % salts. In addition or alternatively in particular in regions close to the sea, the pre-washing fluid may be obtained from sea water 740, typically exhibiting a moderate content of between 3.5 and about 4% of salts, predominantly sodium chlorine. The sea water may be further treated and be split in a sea water splitter 17745 into a low salinity fraction 720, as may be used as in the above, and a high salinity fraction 730, as may have more than about 10 % of salts, via a high salinity tank 17730, the use of which will be explained in more detail herein below.

The sea water splitter 17745 may be operated by reverse osmosis systems or it may be operated by using the solar thermal energy system18000.

It is now a particular feature of the present invention that varying processing steps are provided with processing fluids with adjusted properties, but in an overall almost closed system with minimized inflow of fresh fluid and removal of exudate, and optionally salt, loaded fluid. The skilled person will realize that due to the fluid load in the used articles, as may readily amount to a multiple of the dry weight of the articles, there may be a positive liquid balance, i.e. there may be more liquid coming from the recycling than being fed as tap water or saline, preferably in the form of “blue”, i.e. essentially clean water, or steam, useful for other purposes.

In a particularly preferred set-up, the overall system comprises a lower salinity tank 17730 with a fluid exhibiting a lower salinity than the high salinity fluid in a high salinity tank 17740. The difference in salinity may be achieved by differing concentrations of salts, such as without implying a limitation, of sodium, calcium, or magnesium.

With the process control systems of the processing steps the fluid properties for the respective processing step are adjusted according to predetermined properties, optionally adjusted by input from measurements from the processing steps. Optionally, for each processing step further additives may be dosed. The process control systems also monitor the properties of the outgoing fluid flows from the processing steps.

Overall energy management system 18000

In yet another aspect the present invention is an overall energy management system 18000 for providing and receiving energy to and from processing steps for recovering materials from recycled products, whereby said products comprise plastic, superabsorbent polymers (SAP) and optionally cellulosic fibers.

In particular, the energy management system 18000 comprises at least one solar thermal energy collector 18100, preferably at least one thermal energy storage element 18200, and distribution 18300 and control elements 19850 for delivering and receiving energy to and from said processing steps.

Whilst various process steps are preferably operated at elevated temperatures, in particular the drying of recaptured fibres and SAP require not only large amount of energy, but also at a relatively elevated temperature level of over 100°C.

Thus it is a particular aspect of the present invention to operate the overall recycling system with minimal additional energy that would need to be bought from the general energy providers, be this electricity, or fuel or other energy sources.

To this end, the present system comprises a solar energy collection system 18100, preferably comprising a collector, as may be a flat thermal solar energy collector, but preferably comprises a mirror system, such a parabolic mirror that focuses the solar energy on a heat exchanger, thus allowing to achieve temperatures of well over 100°C, often more than 300°C, or even up to 400°C, whilst higher temperatures e.g. of 500°C should not be exceeded due to increase in material requirements. This primary heat exchanger loop is connected to an energy distribution system 18300

that is connected to one or more heat exchangers 18410, 18420, 18430, … that transfer the energy, optionally via multi-stage cascading heat exchangers, into secondary loops, typically at a lower temperature level in order to distribute the energy as described below.

A further loop may be connected to a thermal energy storage system, such as hot water tanks or – at higher temperature level – phase change storage systems, wherein materials such a salts undergo a phase change from solid to fluid, for which energy is required, or conversely from fluid to solid, whereby energy is released. Such systems can be operated at temperatures of up to 300°C.

Yet a further loop may be connected to a system for generating electricity from surplus energy via a steam generator, for use within the recycling system under consideration, or for being fed into the general power grid.

The secondary loops may transfer the energy to indirect heat exchangers that may form the walls of tanks or pipes, thus heating the temperature of the fluids therein. The secondary loops may be connected, optionally via multi-stage cascading heat exchangers, to open systems, such as when liquids or gases are heated, which are then in direct contact with the heated medium, such as when hot air is used to dry materials.

Without wishing to be bound by the examples, the following exemplifies particularly suitable applications for connecting processing steps and the overall thermal energy management system.

For the pre-washing section 2000, high temperature energy, such as steam from a steam generator 18430 may be provided to heat rolled-up products so as to allow softening of adhesive tapes and thereby ease opening of the products. Such energy may be directed towards the surface of the products.

Further energy, optionally at a lower temperature from a heat exchanger 18420 may be delivered to the pre-washing fluid or to the pre-washing tank 12200, such that soil may be more readily removed at elevated temperatures.

For the plastic separation and purification section unit 14000, the plastic separation fluid and/or a washing fluid may be heated so as to ease separation and/or washing of the plastic. Also, drying of the plastic material and/or preheating for the pelletizing may be achieved.

For the SAP fiber separation section 15000, the SAP/fiber separation unit 15100 may be heated so as to ease the separation.

For the fiber purification section unit 15500, the fiber cleaning fluid may be heated so as to ease cleaning of the fibers. In particular, the fiber drying 5700 may be executed by using such energy for removing residual moisture from the fibers, preferably at temperatures of more than about 100 °C, or more than 120°C, or more than about 140°C but preferably less than about 200°C, or less than about 170°C, or less than about 150°C.

For the SAP purification section 6000, the SAP cleaning fluid may be heated so as to ease separation of the SAP. In particular, the SAP drying unit 16600 may use such energy for removing residual

moisture from the SAP gel, preferably at temperatures of more than about 100 °C, or more than 120°C, or more than about 140°C but preferably less than about 200°C, or less than about 170°C, or less than about 150°C.

Preferably, the system includes heat exchange elements for transferring the thermal energy after exiting processing steps, which is still at a relatively high temperature level, such after fiber or SAP drying, to other processing steps requiring elevated temperature, but at a lower temperature level.

Process control system 9000

Preferably, the various executions of the present invention are combined with a process control system for controlling processing steps for recovering materials from recycled products, whereby said products comprise plastic superabsorbent polymers (SAP) and optionally cellulosic fibers.

The process control system comprises

- process parameter monitoring elements;
- process parameter change elements that allow change of parameters of said processing steps;
- process parameter input elements that allow process parameters to be set to predetermined parameter;
- process parameter optimization elements that allow calculation of optimal combination of various
- process parameter according to predetermined optimization targets.

Each of the respective processing units may comprise a process unit control device that is connected to the overall system control device that may also serve as an overall parameter input device, e.g. by a human interface.

A particular area for the overall processing control relates to the thermal energy management system, whereby the distribution of the energy as delivered by the primary loop or from the energy storage system is controlled according to the specific processing sections, in particular during start-up of the overall system.

General features

Within the overall description, the term “fluid” encompasses liquids or gases. Liquids may exhibit a low viscosity and “fluidity”, or which may be highly viscous, which may be essentially pure liquids, like tap water or salt solutions, or which comprise solids, such as when fibers or particles are suspended, or – at higher solid contents, sometimes also referred to as consistencies – which exhibit a sludge or pasty appearance. Preferably, in the present invention water based liquids are employed, though certain additives may be added on a solvent basis, which may be miscible or immiscible with water.

Gases may be added at certain processing steps as an essentially inert gas, such as air, as may aid in suspending or separating certain solids as may be suspended. Especially in combination with surface tension modifications, be this due to inherently included components, e.g. of faeces, or due surface tension active agents, addition of air may generate foam bubbles, which also may aid in suspending

or separating certain solids. Gases may also comprise reactive agents, especially ozone may be used at one or more processing steps. When applying ozone to remove bio-active ingredients, such as bacteria, or smells, care should be taken that

- the equipment is designed so as to withstand the aggressive medium;
- the ozone is preferable completely depleted in the processing steps, or further steps need to be taken to remove ozone from any exhaust gas due to its hazardous potential and safety risk;
- in the presence of SAP, this is not overly treated as its crosslinking may undergo a cleavage reaction, which may degenerate its absorbency properties or even completely solubilize the poly-arcylates / acrylic acid.

It should be noted that the present inventions can be executed in a “batch” mode, a “continuous processing” mode, or combinations thereof.

For example, each of the processing units may receive a “batch” of products, ingoing materials, such as treatment fluids, with certain processing steps or a series of processing steps being executed, after which the modified products, materials and/or fluids are removed to be processed by subsequent processing. Such processing units are often vessels with appropriate openings and connections for receiving the respective materials, further comprising particular treatment elements, such as – without intending a limitation, stirring equipment, rotating sieve drums, gas addition, or other processing settings such as temperature. Upon the required treatment is finalized, removal equipment such as screws or beakers for solid or semi-solid materials, or just valve opening, optionally with filters, for fluid removal, may be operated to empty the equipment, before it can be reloaded and the cycle can be repeated.

The equipment can also be operated in a continuous mode, whereby products, ingoing materials, and/ fluids are fed to the equipment continuously, treated in the equipment such as by mechanical action, such as shredding, or a fluid streams are mixed, as a liquid being mixed with a gas.

The equipment can also be operated in a combined mode, such as when gases are continuously fed through a batch tank with liquids, the latter being removed after a certain treatment time.

Also, certain processing steps may be operated in one mode, whilst others in another, which may require interim storage devices such as storage tanks.

It is a particular aspect of the present invention, that it allows modular arrangement of the separate processing units, and that all modules may fit into ISO container for ease of transportation.

It should further be noted, that the present description focuses on relevant aspects for the invention, and additional information about elements or features well known to a person skilled in the art of hygiene products and their handling and recycling are omitted. Such elements may be connecting pipes, control valves, measurement probes, e.g. for temperature, pH, salinity, turbidity, and the like, but also conventional treatment elements like screw feeder, (hydro-)cyclones, drum sieve separators, (membrane) filter separators, etc. Also intermediate storage units may be added, so as to lengthen

residence time for a certain processing step or for managing the transition from batch to continuous processing steps or vice versa.

All % numbers are “by weight” unless expressly referred to differently.

Whilst the present invention has been described and illustrated with reference to particular embodiments, it will be appreciated by those of ordinary skill in the art that the invention lends itself to many different variations not specifically illustrated herein. The skilled person will appreciate that various other suitable apparatuses, other than that explicitly mentioned above may be used. Where in the foregoing description elements or features are mentioned which have known, obvious or foreseeable equivalents, then such equivalents are herein incorporated as if individually set forth.

CLAIMS

1. A recycling equipment

for recovering materials by recycling products comprising plastic materials, superabsorbent polymers (SAP), and optionally cellulosic fibers,

which are loaded with waste materials including human or animal exudates,

said equipment comprising

- a product receiving unit;
- optionally a pre-washing unit;
- a product shredding unit;
- a plastic separation unit;
- optionally a SAP fiber separation and fiber recovery unit;
- a SAP recovery unit,

further comprising an overall fluid handling system,

adapted to minimize, including eliminating, ingoing or outgoing fluid streams,

whereby said ingoing or outgoing fluid streams are preferably aqueous fluids,

and comprising elements for adjusting salt concentrations of liquids for being selectively supplied to and received from said equipment units.

2. A process

for recovering materials by recycling products comprising plastic materials, superabsorbent polymers (SAP), and optionally cellulosic fibers,

which are loaded with waste materials including human exudates,

said process comprising the product recycling steps of

- receiving used products in a product receiving unit;
- optionally pre-washing said products in a a pre-washing unit;
- shredding said used products in a product shredding unit;
- separating plastic materials in a plastic separation unit;
- optionally recovering cellulosic fibers in a SAP /fiber separation and fiber recovery unit;

recovering SAP in a SAP recovery unit,

further comprising the step of operating an overall fluid handling system comprising the steps of

- receiving incoming fluids, preferably aqueous liquids;
- preparing at least one salt solution from said incoming fluids comprising predetermined salt concentration and optionally salt composition;
- distributing said salt solutions to said recycling steps;
- discharging spent salt solutions from said recycling steps, whereby said spent salt solutions

exhibit differing degree of waste loads;

- treating said spent salt solutions into two or more fractions, whereby one fraction comprising a high waste load is discharged to a waste water treatment preferably a biogas generation unit or a composting unit and at least one further fraction is recycled to said product recycling steps,

whereby optionally the high waste load fraction may be reduced to dryness.

3. A fluid handling system

for providing and receiving fluids to and from processing steps for recovering materials from recycled products,

whereby said products comprise plastic superabsorbent polymers (SAP) and optionally cellulosic fibers,

said fluid handling system comprising

- at least one incoming fluid tank;
- at least one spent process fluid tank;
- at least one separation unit for separating spent process fluids into
  - a clean fluid fraction, adapted to be reused in said processing step, optionally fed into said incoming fluid tank,
  - a loaded fluid fraction for being discharged to a waste water treatment preferably a biogas generation unit or a composting unit, optionally comprising a drying unit for solidifying the loaded fluid fraction.

5. An energy management system

for providing and receiving energy to and from processing steps for recovering materials from recycled products,

whereby said products comprise plastic superabsorbent polymers (SAP) and optionally cellulosic fibers,

said energy management system comprising

- at least one solar thermal energy collector;
- at least one thermal energy storage element;
- distribution and control elements for delivering and receiving energy to and from said processing steps.

6. A process control system

for controlling processing steps for recovering materials from recycled products,

whereby said products comprise plastic superabsorbent polymers (SAP) and optionally cellulosic fibers

whereby said process control system comprises

- process parameter monitoring elements;
- process parameter change element that allow change of parameters of said processing steps;
- process parameter input elements that allow process parameters to be set to predetermined parameter;
- process parameter optimization elements that allow calculation of optimal combination of various process parameter according to predetermined optimization targets.