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Engineering Design

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Consumer Equipment Design

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Abstract

This report will provide a detailed account of the work undertook to answer the design problem “Could there be a more effective, costly and easy to use solution to provide to the population in order to provide fresh water?”

The first section of the report provides strategic information about the company and the strategy to follow as well as a product design specification:

- The company should focus its efforts on launching the product and developing a market share.
- To achieve its objectives it will rely on its financial and customer focus knowledge.
- Those customers will be retailers (Online, large scale and specialised) with a large portion of end users being a population identified as “backpackers”.
- These end users require a product which is leak proof, filters water fast, easy to drink from and provides a monitoring of the life of the filter.

The second section offers details about potential concept designs as well as methods used to generate ideas and also methods to screen and select a concept (Two phase screening in this case). This part concludes by the selection of “the straw and bottle” concept fitting the PDS as well as customer specifications the best.

Finally, the third section offers a functional chart detailing how the product is operated by an end user with inputs and outputs, detailed CAD models showing the physical aspect of the bottle and straw and an explanation of prototyping methods (in this case fast prototyping) which could be used to produce a physical design to be used for test and manufacturability analysis/improvement.

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Introduction

This report will detail the various steps taken to answer a design brief and provide a product prototype. The first part will focus on defining the product design specifications through actions such as: defining the problem, defining the strategy of the company for this new product and analysing the market to find customer generated opportunities for new products. Secondly, the report will give an overview of how concepts were generated and the steps taken to select a suitable design using the previously gathered information. Finally, the report will offer a description of the functions of the selected design as well as models and information about prototyping methods.

I Product Design Specifications.

A. Design Problem.

In the UK, the NHS advises people should drink about six to eight glasses minimum of fluid a day in normal weather conditions to stop getting dehydrated (NHS.uk, 2019). Although despite the earth being covered at 70% by water only 2.5% is fresh or drinkable water (National Geographic, 2019). This is a well known issue which affects a large part of the worldwide population. Not only the water reserves in some countries are running dry, the population cannot easily use it to drink. The question is could there be a more effective, costly and easy to use solution to provide to the population in order to provide fresh water?

B. Design Specification Parameters.

From the design problem, and using brainstorming as a group, the problem was decomposed to define features and characteristics. These could be necessary to take in account when defining the product design specifications and creating concepts.

Additional Design Problem Features identified:

1. Speed – How fast does the system provide drinking water?
2. Weight – How will the weight influence the product usage? (linked to Volume feature)
3. Cost – What would the production costs be? What would the sale price? And how would those influence the overall strategy of the company?
4. Materials – Which materials will the product be made of? How available are they?
5. Quality – How will the quality of the product be defined (aesthetics, ease of use, manufacturing, drinkable water...)?
6. Volume – How voluminous of the product affects its use? (linked to Weight feature).
7. Packaging – How will the product be packaged?
8. Storage – How will the product be stored? Will it allow to store the filtered water?
9. Environment (Eco-Friendly) – How eco-friendly will the product be for the surrounding environment?
10. Maintenance – Will the product be maintainable? Will spare parts be off the shelf components? How easy will it be to maintain?.

11. Power – Will the device be powered or passive? If powered, which source will it use?
12. Health and Safety – Which Healthy and Safety aspects are to be considered to provide a product fulfilling its function safely for the end user?
13. Process – Which technical principles will allow the product to filter the water?
14. Assembly and Manufacturing – The assembly feature will cover how easy is it for the end user to put the product together to use it? Manufacturing will cover the aspects of making the product but also the pre-assembly of the finished product to be delivered to the end user.
15. Wastage – What form will the waste take? How will it be dealt with?
16. Measurements and Instrumentation – Will the product allow for measurements of certain values (Water left in storage, filter life/replacement, water quality...)
17. Transportation – Does the product have to be transportable? Assuming it does, how easy would it be to move it? (Feature linked to Volume and Weight)
18. Efficiency – How efficient will the product be in terms of energy used to quality of the water outputted.

Once the list of features was realised, they were compared against each other in a matrix (Appendix 1) to allow regrouping and a better understanding of the design problem.

Three distinctive groups were identified from the matrix:

- **Product characteristics:** This group describes features with a direct link to the product and more notably its physicality.

Features present: Material, Quality, Volume, Maintenance, Weight, Power, Cost, Manufacturing (was separated from assembly later on in the process. It was decided the assembly related to the customer usage rather than producing the product).

- **Usage Characteristics:** This group englobes features related to the use of the product and geared towards the customer experience.

Features present: Assembly, Transportation, Wastage, Health and Safety, Eco-Friendly, Packaging.

- **Process characteristics:** This last group represents the technicalities of the product allowing it to function.

Features present: Efficiency, Speed, Process, Storage, Measurement and Tolerances.

C. First Definition - Product Design Specifications.

This section proposes a first Product Design Specifications (PDS) from information extracted from the previous steps. These PDS are a starting point to answering the design problem. They will be reviewed, modified and developed as knowledge is gathered.

Performance:

The system should filter water within a reasonable time (30s to 1 minute).

The water should be filtered when passing through the filter when refilling and drinking .

The product should have a shelf life of at least 3 years with filters lasting at least 3 months.

Environment:

The product should be resistant to the erosion and shocks due to transport and handling.

The liquid should not leak. Appropriate waterproof materials and sealing should be present.

The liquid stored should stay cool or at ambient temperature.

Quantity:

The product is likely to be mass produced. Although at this point other solutions are being considered which could lead to custom designs.

Aesthetics and ergonomics:

The product should be easy to use for the customer and as simple as: Refilling, replacing the filter and drinking.

The product should be easy to handle by the users.

The product should be recognised has a water filtering system by an uninformed user.

Company constraints:

The company being new it has no current image in the mind of consumers. It is free to develop its image to fit with the product.

It would be good to present a health and environmental conscious image to fit with the product purpose.

Market constraints:

The market is well established since it is a well known problem. There are a multitude of industrial and consumer targeted solutions.

The lifecycle of the product should be relatively short (4 years).

The customers' needs will be defined through specific research.

Competition:

Again there are a multitude of options available on the market with strong competition.

A particular attention will be given to identifying current customers wishes in order to solve issues not currently answered by current products.

Materials:

Food grade materials will have to be used to offer a safe and sure product for the consumer.

An effort should be made to use recycled or repurposed materials.

Target product cost:

This will be defined at a later stage once the target market will be identified.

Packaging and shipping:

Attention will be taken to balance safe packaging and avoid over packing the product to reduce waste.

D. Quality Function Development.

1. Phase 1 - Strategy.

a. Strategic Target.

First, five main strategic targets were identified. The company being recently created, it was agreed it could focus on those main points: Launching the product, developing a market share, finding partners to collaborate with, encouraging innovation in its activity and finally create customer loyalty for the brand and product.

Then, using the Strategic Target Matrix, in appendix 2, the core business objectives have been identified. At this time, the company should focus on Launching the product (37.93%), Develop a market share (33.92%) and finally finding partners (14.18%).

b. Core Competency.

The core competencies were identified as: Creative thinking, financial understanding, manufacturing experience, customer focused strategy and social responsibility.

These competencies were rated against the strategic targets. From the matrix, in appendix 3, the competencies which will be mostly used to meet the strategic targets are the financial understanding (30.02%), the customer focused strategic thinking (27.97%) and the manufacturing experience (23.96%).

c. Customer Segmentation.

Comparing the core competencies to various potential customer segments allowed to choose to focus on specialised retailers (24.92%), online retailers (24.15%), backpackers users (17.63%) and large scale retailers (17.41%).

2. Phase 2 - Customer Analysis.

d. Gemba.

It was agreed that to save time the Gemba analysis would be realised using Amazon reviews from nine products offering liquid filtering features. Looking at the reviews it was easy to identify which features were appealing to customers, which need to be rethought and which would be a great additions to the product. The results from the analysis have been organised per products in the appendix 4. This research will be put through the Kano model in order to organise and identify useful features.

e. Kano.

Using the recommendations extracted from the Gemba analysis, it was possible to evaluated those features using the Kano model. The results have been summarised in Table 1 below. The one dimensional, must be and attractive quality will be retained to be used in the pre-plan matrix but also to help in the definition of the product design specifications.

Table 1: KANO model.

| | | Present | |
|-------------|---|--|---|
| | |  |  |
| Not Present |  | One dimensional quality: 1) Quality product parts. 2) Affordable price. 3) Improvement water taste. 4) Portability. 5) Long filter life. 6) Good storage amount. 7) Easy to refill. 8) Clear set-up instructions. 9) Easy to drink from. 10) Fast filtering. 11) Good product design. 12) Leakage proof. | Must be quality: 13) Environmentally friendly. 14) Easy to change the filter. 15) Affordable price filter cartridge. 16) Filter life monitoring. 17) Easy to assemble. |

| | | | |
|--|---|---|--|
| |  | <p>Attractive quality:</p> <p>18) Stylish design of the product.</p> <p>19) Fits into the fridge.</p> <p>20) Colour variety.</p> <p>21) Quality Manufacturing.</p> <p>22) Good filter positioning.</p> <p>23) Replacement filters available from various suppliers.</p> <p>24) Measurement of water left.</p> | <p>Indifferent quality:</p> <p>25) Pink/Gold colour</p> <p>(Personalisation).</p> <p>26) Dishwasher safe.</p> <p>27) Large storage of water.</p> |
|--|---|---|--|

Short definition of each features:

- 1) **Quality product parts** - The parts should be resistant and not easily break.
- 2) **Affordable price** - The product price should stay within range with the competition pricing.
- 3) **Improvement water taste** - Impurities should be filtered leaving the water having a good taste.
- 4) **Portability** - The item should be small enough to fit in a bag.
- 5) **Long filter life** - the replacement filters should be able to offer a decent amount of filtering cycles.
- 6) **Good storage amount** - The item should be able to store the water.
- 7) **Easy to refill** - The product should not required complex disassembly to refill.
- 8) **Clear set-up instructions** - Instructions should be provided and not require extensive reading.

- 9) **Easy to drink from** - The water flow should be good enough to drink from.
- 10) **Fast filtering** - Water should be quickly filtered within a few seconds.
- 11) **Good product design** - The solution should try to provide every features expected by the customer.
- 12) **Leakage proof** - If the item is storing water it should stay properly sealed.
- 13) **Environmentally friendly** - As much as possible the materials should be environmentally friendly.
- 14) **Easy to change the filter** - Filter changing should not require complex disassembly.
- 15) **Affordable price filter cartridge** - Filters should not be costly to replace.
- 16) **Filter life monitoring** - The filter should be change according to its use and not just time.
- 17) **Easy to assemble** - When receiving the products the instructions should clearly state how to assemble the product.
- 18) **Stylish design of the product** - The aesthetics aspects should be different but recognisable.
- 19) **Fits into the fridge** - The item should fit with other items in a fridge.
- 20) **Colour variety** - A selection of colours should be available.
- 21) **Quality Manufacturing** - The items should show attention was taken to offer a product well manufacture and of quality.
- 22) **Good filter positioning** - The filter should be positioned in a logical way as not to shorten its lifespan.
- 23) **Replacement filters** available from various suppliers.
- 24) **Measurement of water left** - A user should easily be able to see how much water stored is left.
- 25) **Pink/Gold colour (Personalisation)** - Personnalisation of item should be possible.
- 26) **Dishwasher safe** - The item should be able to go through the dishwasher to be cleaned.
- 27) **Large storage of water** - The item should be able to store large amounts of water.

f. Preplan Matrix.

Using the customers requests extracted from the Gemba and the Kano analysis, it was possible to realise a pre-plan matrix (appendix 5). These requests were then compared to two competitors products currently available on the market. To define the assessment target it was agreed the concepts should try to at least attain the same score as the best competitor for each features.

Using the previous research about customer needs and discussions, it was decided which features would represent a strong or medium sales point.

This matrix would allow to identify which features would have to be implemented in the various concepts and in the end product, in this case: Filter life monitoring (15.87%), Fast filtering (5.65%), Leakage proof (4.46%) and easy to drink from (5.13%).

E. Conclusion - Customer Analysis meets Company Strategy.

This section introduced the various steps taken to help extend the design brief, define the company's objectives, who the clients may be but also what their expectations would be in terms of a product filtering liquids.

From the information gathered the House of Quality (Appendix 7) was realised. It summarise the various correlations between the technical aspects of the product, the customer requirements and the current competition. From the house of quality, it is noticeable the material selections will have a big impact on the product. This technical aspect is linked with most other aspects of the product. Then, maintenance could be an interesting feature to develop (For example: offering a product which is modular in order to provide replacement parts instead of buying a full new product). The weight is also an important aspect, customers would expect to be able to carry the product around without the risk of leaks (for example: a bottle). The monitoring of the life of the filter was an important feature which appeared during the customer

requirements research. It is a feature rarely available which could be a strong competitive differentiation and sales point for the product.

Following this analysis the problem and customer expectations were better defined. it was now possible to complete the previous product design specification to reflect the knowledge gained from the research.

Developed Product Design Specifications:

Materials – food grade materials will have to be used to offer a safe and sure product for the consumer. An effort should be made to use recycled or repurposed materials. All materials used for the filtering process and those coming into direct contact with the inlet water shall meet the regulations for materials in contact with food [11] and [12] in accordance with BS EN 17093:2018.

Quality of the filtered water – for compliance with the European Standard for filtered water, its quality has to adhere to the national implementations of the European drinking water directive 98/83/EC, Annex 1, Part A and B and any further amendments.

Packaging – all components will be packed with care, using adequate eco-friendly protective equipment. Special care will be addressed to the filter cartridges, these will be appropriately protected from any mechanical damage and/or scratches which may occur during shipment and the depository process. Special attention will be offered not to overpack the product, these actions will help to reduce the unnecessary waste of packaging materials.

Performance – the product has a shelf life of at least 3 years and each individual filter can last at least 3 months (depending on usage, the amount of life-time may increase or decrease). The unit is able to filter the water within a reasonable amount of time, which is approximately between 30 second to 35 seconds.

Chemical requirements – reduction of scale, free chlorine water and nitrate contents should not exceed the maximum permissible concentration in the filtered water after it being tested. These maximum values can be found in the Table of the BS EN 17093:2018 (Appendix 8).

Manufacturer's guidance for use – the producer will include a leaflet with instructions on preparation, setting the bottle filter system into operation and its successive hygienic handling and usage. The leaflet will include advice concerning the volume of water that needs to pass through the filtering device before starting to use it, and instructions for usage in case the filtering system follows an extended not-in-use period of time. It will also include information, regarding conditions to follow to safely store the cartridges and the bottle filtering system in use.

The producer will provide instructions regarding the timing to change the cartridge, a reference to other compatible cartridges made by other manufacturers, and disposal guidance for the user in relationship to the used cartridges. The producer will clearly display a notice, on the outside packaging of the bottle filter system, showing that the device is designed to be used only with drinking water.

Marking and labelling – in accordance with BS EN 17093:2018 (BSI Standards Limited, 2018), and with each item sold and/or replacement cartridge, the manufacturer has the obligation to attach a leaflet which will contain at least the following information:

1. Manufacturer address and contact details.
2. Number and year of this European Standard.
3. A determination for which this standard is being claimed.
4. Product batch code.
5. Total cartridge capacity in litres.

Taste and odour improvement – the product will contribute to improve the taste of the water and to eliminate the undesired odour. For this end, the concentration of the Geosmin and Chloroform (these elements are the main cause of this problem) in the filtered water will not exceed 0.05% of the total amount of the liquid.

Aesthetics and ergonomics – the product is designed to be easily and intuitively used by the customers, it is made to be handled without any difficulties. Its aesthetics and ergonomics characteristics allow it, to be quickly recognised as a water filtering system, by an uninformed user. Special attention was provided to the following stages:

1. Refilling the bottle.
2. Replacing the filter.
3. Drinking position.
4. Easiness to clean the device.
5. Filter life monitoring.

Environment – the product is designed to be resistant to erosion and shocks due to transport and handling operations. These qualities will help to prolong the life-time of the product and to prevent undesired early damages. The company also proposes, to use at least 50% of recycled material for the production of the packaging materials and the leaflets with information contained with each unit sold.

Quantity – the product will be mass-produced. Although, at this starting point, other options are being considered which may be determined by different custom requests.

Company constraints - The company being new, it has no current image in the mind of the consumers. This position offers the freedom to develop its image to fit with the product in different ways. An analysis of the following aspects will be developed:

1. Budget constraints.
2. Presence of any limited supply.
3. Price risk strategy.
4. Sales forecast accuracy.
5. Storage availability.
6. Volume of units produced.

7. Special promotions and traceability of the items.

Market constraints - The market is well established since the need to employ a water filtering device, is a well-known problem. The company will focus on the following major issues:

1. Market penetration.
2. Product development and product diversification.
3. Capacity to satisfy the external demand.
4. Target consumers study.
5. Time and resource limitations.
6. Competition.

II Concept Generation and Selection.

A. Concepts.

The Concepts are available in the Appendices section at the end of this report. They were generated using various methods explained in part B of this section.

Table 2 below summarises and references the concept designs.

Table 2: Concepts.

| Concept Number | Name/description for first Screening | Appendix Reference |
|----------------|---|--------------------|
| 1 | Rotating mist catcher. | 11 |
| 2 | Jug water filtering. | 12 |
| 3 | Modular bottle with filter at the middle. | 13 |
| 4 | Rain/Water catching mineral filtering fountain. | 14 |
| 5 | Moisture/mist catching towel. | 15 |
| 6 | Cooking pot made of purifying materials. | 16 |
| 7 | Distillation Method. | 17 |
| 8 | Home station water treatment plant. | 18 |

| | | |
|----|--|----|
| 9 | Water bottle straw. | 19 |
| 10 | Valve built in filter method. | 20 |
| 11 | Ball filter | 21 |
| 12 | Straw filter water bottle. | 22 |
| | Improved and Combined Concepts for Screening 2 | |
| 13 | Jug Design improvement | 23 |
| 14 | Ball filter improvement (Replaceable disc filters) | 24 |
| 15 | Water bottle improvement (Probe and filter life display) | 25 |
| 16 | Ball filter with bottle improvement. | 26 |
| 17 | Combinaison of design 12 and 9. | 27 |
| 18 | Combinaison of design 6 and 7. | 28 |
| 19 | Improvement of design 7 | 29 |
| 20 | Improvement of design 5 | 30 |
| 21 | Improvement of design 3 | 31 |

B. Discussion on the Concept Development Methods.

The team implemented various methods to generate ideas for its product. Some of these concepts were more productive, others were less effective. A discussion about these methods is available below:

Brainstorming method – This procedure was the first step to be implemented by the group. The design problem and the desired characteristics of the product were specified. Subsequently, a list with different ideas was gathered in, by the four members of the group. All the ideas were noted down, none of them were criticized nor disapproved. The ideas were displayed on a post sheet. After the brainstorming session had finished, all the concepts were evaluated.

K-J method – The ideas obtained using the Brainstorming method were organized in groups. The newly obtained groups were given suitable titles. This method did help the team to identify and to focus on the main characteristics of the desired item. To the groups were offered various levels of importance. Also, the relationship and the connecting links between different groups were established. The groups are as follows (each group did contain more ideas attached to it, which are part of the project but were not attached to the following list):

- 1) The Speed (at which the water is filtered).
- 2) Filtering process.
- 3) Filter replacement (easiness).
- 4) Storage of the drinkable water and portability of the item.
- 5) Maintenance of the item.
- 6) Cleaning process.
- 7) Reliability.
- 8) Easiness to use the product.

C-Sketch method – At this stage, part of the substantial features of the desired product were established. To further help generate the ideas for the remaining features and characteristics of the item, each individual of the group did produce a sketch proposing a solution. After a short period of time, the sketches were interchanged by the group members. Followingly, changes were made, adding, erasing, or modifying part of the sketch solutions. The process was repeated several times.

Design Catalogs of Solution – At this level, the team did implement an analysis of the achievements and the design solutions which were obtained. It was identified that the team's intention is to produce an object in form of a bottle, its main functions would be to filter and to store drinkable water. The initial position of the filter was planned to be at the middle level of the bottle. A later examination has shown that is more convenient to position the filter closer to the top of the bottle, as a result, allowing for more space to store the filtered water. It was determined that the bottle

will be made of a light and durable material. To make the product more portable, it was decided to attach a nifty little rope on the top of the lid.

C. Evaluation and Selections of the Concepts.

1. First Concept Screening.

(The Concept Screening Matrix 2 is available in Appendix 10).

The First Concept Screening Matrix gives the score of each design compared to the reference design (Design #3, the filtering bottle) using the product characteristics as parameters.

Design #11 ranked as the best design, followed by design #9 and design #12 which have the same score. Due to their similarities, the latter two designs and design #6 with design #7 can be implemented in order to have the best advantages from both of them. The further step is to improve the following designs: #2, #3, #11 and to implement #9 & #12 and #6 & #7.

2. Second Concept Screening.

(The Concept Screening Matrix 2 is available in Appendix 10).

In this second Screening, the “Modular Bottle” (improvement of the design #3) ranked first, resulting balanced in most of the characteristics and having the lead on the Filter Life Monitoring feature. The company will pursue this design, using it as the final product.

Although they scored slightly less than the Modular Bottle, both “The Jug” and “The Straw” designs (respectively design #2 and implementation of design #9 & #12) are kept for future products, thus having a bigger range of products which might be more

useful than the Modular Bottle in certain scenarios. The combination of Design #6 and #7 will be discarded due to its low score.

3. AHP Process.

Decision model.

The goal of this process is to select best water filtration concept using the main 5 criteria that were generated in pre plan matrix, which are: affordable price, easy to drink from, filtering speed, leakage proof and filter life monitoring. The concept used in this process are Straw bottle, the jug and twist bottle. These concepts were chosen from the second screening matrix as plausible concepts.

Deriving relative priorities for the criteria.

The next step in AHP process is deriving relative priorities between criteria. First table shows each criteria in respect to each other ranging from 1 to 9 using the Saaty's pairwise comparison scale.

Table 3.1: Criteria comparison matrix.

| Criteria | Affordable price. | Easy to drink from. | Fast filtering. | Leakage proof. | Filter life monitoring. |
|-------------------------|-------------------|---------------------|-----------------|----------------|-------------------------|
| Affordable price. | 1 | 0.2 | 0.2 | 0.2 | 0.11 |
| Easy to drink from. | 5 | 1 | 0.3 | 0.25 | 2 |
| Fast filtering. | 5 | 3 | 1 | 2 | 6 |
| Leakage proof. | 5 | 4 | 0.5 | 1 | 4 |
| Filter life monitoring. | 9 | 0.5 | 0.16 | 0.25 | 1 |
| SUM | 25 | 8.7 | 2.16 | 3.7 | 13.11 |

After normalising the comparison matrix and calculating the column average value it can be concluded that the most important criteria is fast filtering and least important is price. The bigger the column value the more important the criteria.

Table 3.2: Normalized comparison criteria matrix.

| Criteria | Affordable price. | Easy to drink from. | Fast filtering. | Leakage proof. | Filter life monitoring. | Average |
|------------------------|-------------------|---------------------|-----------------|----------------|-------------------------|----------|
| Affordable price. | 0.04 | 0.022989 | 0.092593 | 0.054054 | 0.008391 | 0.043605 |
| Easy to drink from. | 0.2 | 0.114943 | 0.138889 | 0.067568 | 0.152555 | 0.134791 |
| Fast filtering. | 0.2 | 0.344828 | 0.462963 | 0.540541 | 0.457666 | 0.401199 |
| Leakage proof. | 0.2 | 0.45977 | 0.231481 | 0.27027 | 0.305111 | 0.293326 |
| Filter life monitoring | 0.36 | 0.057471 | 0.074074 | 0.067568 | 0.076278 | 0.127078 |
| SUM | | 1 | 1 | 1 | 1 | 1 |

Deriving local priorities for the alternatives.

To calculate local preferences for 3 alternative concepts (the jug, twist bottle and straw bottle) 10 matrices were calculated one comparison matrix and one normalized for each criteria. It was concluded that the cheapest concept would be twist bottle, the easiest to drink from is straw bottle, and the fastest filtering would be the jug. Most leakage proof is straw bottle concept and the filter life monitoring would be the best in the jug concept. All matrices can be seen in the appendix 37.

The consistency ratio was calculated for each local priority using the consistency index and random index. All random indexes were less than 0.10 which means they are in the limits.

Deriving overall priorities.

To calculate the AHP ranking for each concept it is needed to calculate priority vector. For our 3 concepts the results were:

Table 3.3: Rank priority table.

| Alternative | Priority | Nr. |
|--------------|----------|-----|
| Straw bottle | 0.345927 | 2 |
| The jug | 0.482732 | 1 |
| Twist bottle | 0.171341 | 3 |

Making the preferred concept – the jug. In second place the straw bottle and lastly the twist bottle.

Sensitivity analysis.

The chosen modified scenario is where all criterion are with the same value – 0.2 in which the priority vectors came out different.

Table 3.4: Modified scenario rank table.

| Alternative | Priority | Nr. |
|--------------|----------|-----|
| Straw bottle | 0.38626 | 1 |
| The jug | 0.383142 | 2 |
| Twist bottle | 0.230598 | 3 |

The new top concept is the straw bottle making the jug second and twist bottle third. It can be noticed by changing the criteria values, the preferred concept ranking changes.

Final decision.

Following the AHP process evaluation and group meeting it was concluded to use the straw concept.

Changing the weight of criteria impacts the result. If the criteria weight and the concepts scores are high in the same local priority matrix then it becomes the favourite in the overall ranking. By making the criteria weighting equal or similar to each other the ranking becomes based on the actual feature value not the importance of it.

D. Discussion on the concept evaluation and selection of the best concept.

The Screening Matrix method helps choosing the best concept by comparing every design using features as parameters. Most of these features can be also found in both QFD Analysis and PDS characteristics, meaning that the selected design is not only suitable according to the Screening method, but it complies with the other two Analysis resulting in a viable solution.

The Screening method uses two matrices because the first matrix put all the features at the same level, whereas the second matrix also takes into account the weight of each feature, giving a more accurate score for each concept.

III Initial Embodiment Design.

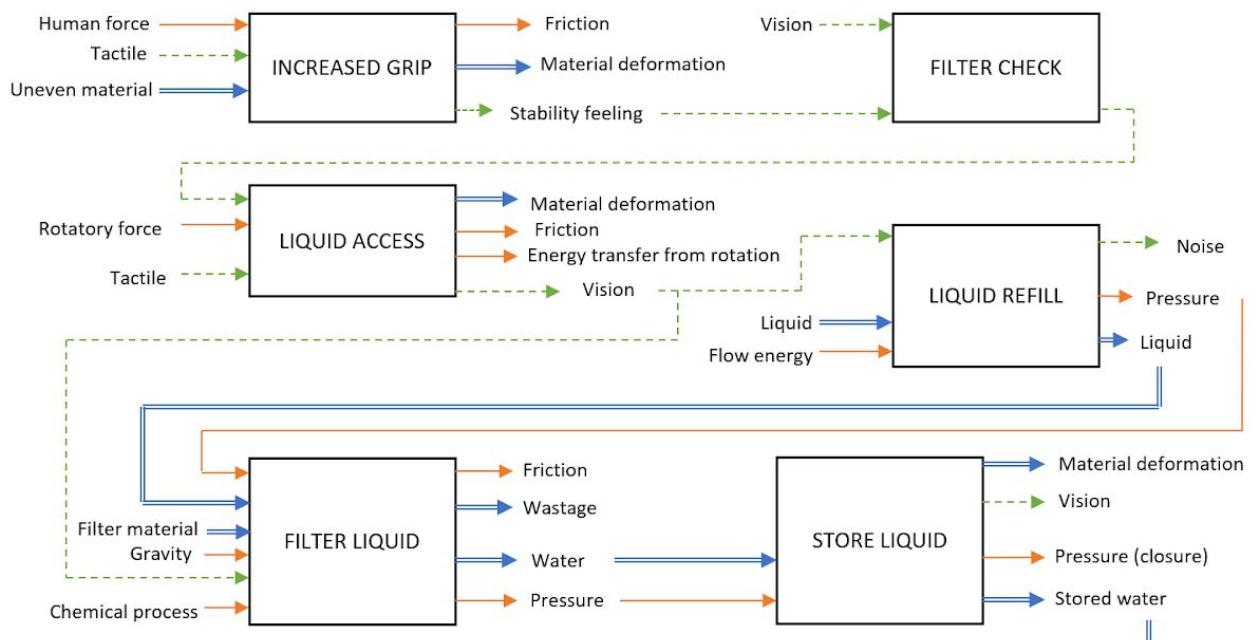
A. Functional Representation.

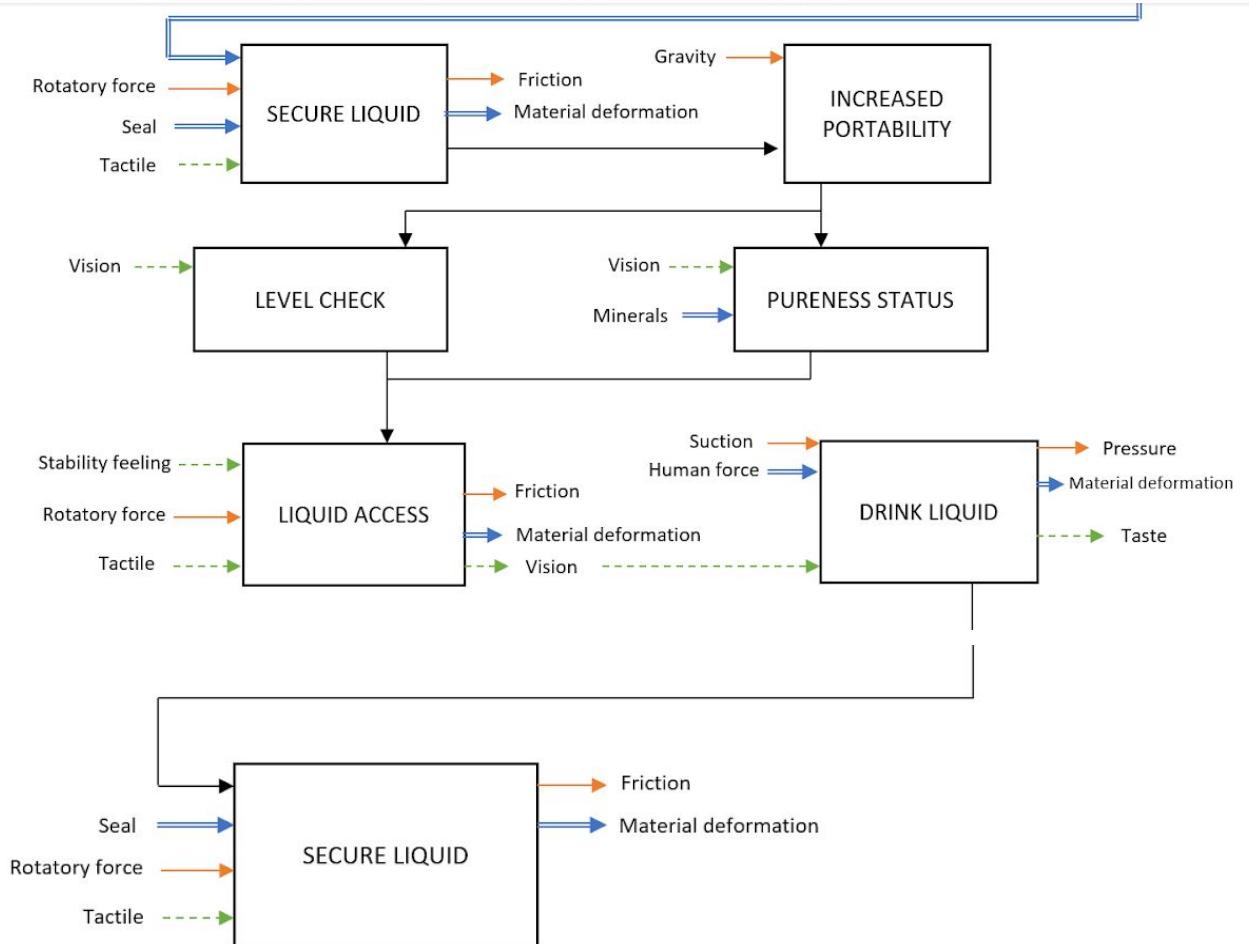
This section will offer a graphical representation of the primary, sub functions as well as the relevant inputs and outputs of the selected design. The functions were identified using a “customer journey” approach. This meaning, a person was observed using the product and the scenario was then deconstructed to identify the steps taken by the user.

Primary Function



Subfunctions





B.CAD Models.

From AHP evaluation and second screening matrix it was decided to develop the straw bottle concept. The concept was realised using Autocad inventor and the assembly photos can be seen in appendix 32-36. The assembly was made from 4 parts that screw into each other or clip into each other. The parts are:

- **Main body**, that slimes inwards to middle for stability, rubber bands around the middle of the body for better handling.
- **Cap** that screws on top of the main body. The cap houses a LCD that displays information about the water in the bottle. The LCD is controlled by microcontroller that is connected to water sensor next to the straw. The cap has a pull out mechanism to drink from the top and is airtight when pushed down. Has a ring for a possibility to attach a strap.
- **Bottom straw holder**, that filters big chunks from the water and holds straw in place.
- **Straw/sensor**, which houses multiple carbon filters. The sensor is attached to the side of the straw.

The dimensions of the bottle are 292 mm long and 58 mm wide at the top and 60 mm wide at the bottom.

C.Prototyping Method Explanation.

Method and Material.

There are several methods to prototype a plastic device such as a bottle. However, since Fast Prototyping is required, Injection Moulding process will not be suitable and it would also be more expensive than Additive Rapid Prototyping methods using 3D Printers. (Tony Rogers, 2015)

The best Additive method to prototype a filtering plastic bottle is the “Fused Deposition Modelling” (FDM). This method is the most used nowadays, meaning the cost of the process will be much cheaper than using other additive methods. It's also

able to create a product in high resolution and strength, depending on the material used.

“Selective Laser Sintering” (SLS) is usually better than FDM method in terms of material quality and durability, the disadvantage is that this method is more expensive than FDM.

Although ABS is the most common material used for plastic prototypes, it's not recyclable, hence being against Company values. The best material would be the “Polyethylene terephthalate” (PET), a thermoplastic, due to its ability to be completely recyclable.

PET is rigid and durable enough, but its great advantage over other materials is that “it doesn't release any odour during the printing process and it works great when in contact with food or liquid.” (Alexandra P. , 2018)

PET is also suitable for the filter cartridge since it has a good chemical resistance, quite important for the filtering process since it uses chemical reaction.

Process.

In order to achieve the best results using PET, the printing process has to be between 75 and 90 degrees.

“The 3D Printer uses an extrusion process, depositing the plastic material chosen layer-by-layer until the filtering bottle is finished.” (Ronan Ye, 2018)

D.Discussion on the usefulness of the Functional Representation, CAD and Prototyping.

The role of the Functional Structure is to have a clear picture of all the functions performed by the filtering bottle. It also breaks the general function down into several sub-functions representing each action performed by each component of the product, giving an idea of the inputs each function needs and all the outputs generated after every action. This Analysis also shows the transformation of the inputs into different outputs.

CAD modelling and Prototyping are two useful methods to have a representation of the product itself. While CAD modelling gives a virtual design of the product, Prototyping focuses more on the physical design, thus giving a tactile feeling of the product to check how the bottle feels in hand. Both of these methods also helps understanding if all the components fits into each other, potential leads to simplify the design and improve manufacturability.

Conclusion

From this report it can be concluded that it is possible to design and produce a more cost effective, easy to use water purification device. The final concept uses a water bottle as a base with a straw that would filter the water. The concept CAD model can be found in appendix 32-36. The product would use carbon filters in combination with quality parts. This product would improve on mistakes made by competitor products but also by providing features that were not available on other products.

The core business objectives were identified as, first, Launching the product, second, develop a market share and finally finding partners.

The customer analysis identified the most important features of the product desired by the customers, which would then be implemented in the final concept. The most important feature was filter life monitoring, second, fast filtering, third, leakage proof and, lastly, easy to drink from.

23 concept sketches were produced. There were 10 basic concepts in the first screening from which only the 3 best were kept and improved into 6 more sketches. Following the second screening, 3 designs were kept with the “straw bottle” being the design fitting the PDS the best.

One CAD model was produced of the “straw bottle”, that contains 4 main parts, which would be prototyped using Fused Deposition Modelling for rapid prototyping. The CAD model shows the set dimensions of the product.

Although there aren't many innovation in terms of water filtration methods, some features were added to stand out and offer a product simple to use with a good price quality. Parts can be easily replaced and manufactured due to the choice of offering a modular product.

Appendices

Appendix 1 - Design Problem Decomposing Matrix

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|--------|-------|--------|-------|
| 1. Speed | Black | Orange | Orange | White | Orange | White | White | White | Orange | White | Orange | White | Orange | White | Orange | White | Orange | White |
| 2. Weight | Orange | Black | Orange | White | Orange | White | Orange | White | Orange | White | Orange | White |
| 3. Cost | Orange | Orange | Black | Orange | Orange | White | White | White | Orange | White | Orange | White | Orange | White | Orange | White | Orange | White |
| 4. Materials | White | Orange | Orange | Black | Orange | Orange | Orange | Orange | Orange | White | Orange | White | Orange | White | Orange | White | Orange | White |
| 5. Quality | Orange | Orange | Orange | Orange | Black | White | White | White | Orange | White | Orange | White | Orange | White | Orange | White | Orange | White |
| 6. Volume | White | Orange | White | Orange | White | Black | Orange | Orange | White | White | Orange | White | Orange | White | Orange | White | Orange | White |
| 7. Packaging | White | Orange | White | Orange | White | Black | Orange | Orange | White | White | Orange | White | Orange | White | Orange | White | Orange | White |
| 8. Storage | White | Orange | Orange | Orange | Orange | Orange | Orange | Black | White | White | Orange | White | Orange | White | Orange | White | Orange | White |
| 9. Environmental Friendly | Orange | White | Orange | Orange | Orange | White | White | White | Black | Orange | Orange | White | Orange | White | Orange | White | Orange | White |
| 10. Maintenance | White | White | Orange | Orange | Orange | White | White | White | Orange | Black | Orange | White | Orange | White | Orange | White | Orange | White |
| 11. Power | Orange | Orange | White | White | White | Orange | White | White | Orange | White | Black | White | Orange | White | Orange | White | Orange | White |
| 12. Health and Safety | White | White | Orange | Orange | Orange | White | White | White | Orange | White | Black | White | Orange | White | Orange | White | Orange | White |
| 13. Process | Orange | White | Orange | White | Orange | White | White | White | Orange | White | White | Black | White | White | Orange | White | Orange | White |
| 14. Assembly and Manufacturing | White | Orange | Orange | Orange | Orange | Orange | White | White | Orange | Orange | Orange | White | Black | White | Orange | White | Orange | White |
| 15. Wastage | Orange | White | Orange | Orange | Orange | Orange | White | White | Orange | Orange | Orange | Orange | White | Black | White | White | Orange | White |
| 16. Measurement and Tolerance | White | Orange | White | White | White | White | Black | White | White | White | White |
| 17. Transportation | White | Orange | White | White | White | White | White | Black | White | White | White |
| 18. Efficiency | Orange | White | White | Orange | Orange | Orange | White | White | Orange | White | Orange | White | Orange | White | White | Black | White | White |

| | |
|---------------------------------|-------------|
| Relation between the parameters | Orange |
| Group - Product Characteristics | Light Green |
| Group - Usage Characteristics | Light Blue |
| Group - Process Characteristics | Pink |

Appendix 2 - Strategic Target Matrix

| | Strategic Target Matrix | | | | | | | | | | | Target Priority in % | |
|--------------------------|--------------------------|---------------|-------------|-----------------|---------------------|-------------------|------|------|------|------|-----------------|----------------------|---------|
| | Strategic Targets | | | | | Normalised Values | | | | | | | |
| | 1) Launching the Product | 2) Innovation | 3) Partners | 4) Market Share | 5) Customer Loyalty | 1) | 2) | 3) | 4) | 5) | ABSOLUTE WEIGHT | | |
| 1) Launching the Product | 1 | 7 | 3 | 1 | 9 | 0,39 | 0,33 | 0,31 | 0,37 | 0,49 | 1,90 | 37,93% | |
| 2) Innovation | 0,14 | 1 | 0,2 | 0,33 | 0,2 | 0,05 | 0,05 | 0,02 | 0,12 | 0,01 | 0,25 | 5,09% | |
| 3) Partners | 0,33 | 5 | 1 | 0,2 | 3 | 0,13 | 0,24 | 0,10 | 0,07 | 0,16 | 0,71 | 14,18% | |
| 4) Market Share | 1 | 3 | 5 | 1 | 5 | 0,39 | 0,14 | 0,52 | 0,37 | 0,27 | 1,70 | 33,92% | |
| 5) Customer Loyalty | 0,11 | 5 | 0,33 | 0,2 | 1 | 0,04 | 0,24 | 0,03 | 0,07 | 0,05 | 0,44 | 8,87% | |
| TOTAL | 2,58 | 21 | 9,53 | 2,73 | 18,2 | | | | | | TOTAL | 5,00 | 100,00% |

| | |
|--------------------------|------|
| Equally as important | 1 |
| Slightly more important | 3 |
| More important | 5 |
| Much more important | 7 |
| Very much more important | 9 |
| Slightly less important | 0,33 |
| Less important | 0,22 |
| Much less important | 0,14 |
| Very much less important | 0,11 |

Appendix 3 - Strategic Target/Core Competency Matrix

| Strategic Target - Core Competency Matrix | | | | | | | |
|---|----------------------------|-------------------|-------------------------|--------------------------|-------------------------|-----------------------|--------|
| | Core Competency Deployment | | | | | | |
| | Priority Targets | Creative Thinking | Financial Understanding | Manufacturing Experience | Customer Focus Strategy | Social Responsibility | TOTAL |
| Launching the Product | 37,93% | 1 | 9 | 3 | 3 | 1 | |
| Innovation | 5,09% | 9 | 1 | 1 | 9 | - | |
| Partners | 14,18% | 1 | 9 | 3 | - | - | |
| Market Share | 33,92% | 1 | 3 | 9 | 9 | 3 | |
| Customer Loyalty | 8,87% | - | 1 | - | 9 | 9 | |
| ABSOLUTE WEIGHT | 1,319 | | 5,847 | 4,667 | 5,448 | 2,195 | 19,477 |
| CORE COMPETENCY (%) | | 6,77% | 30,02% | 23,96% | 27,97% | 11,27% | |

| | |
|--------------------|---|
| No correlation | |
| Weak Correlation | 1 |
| Medium Correlation | 3 |
| Strong Correlation | 9 |

Appendix 4 - Core Competency/Customers Segments Matrix.

| Core Competency - Customers Segments Matrix | | | | | | | |
|---|-------------------|-----------------------|-------|------------------|----------------------|------------------|-----------------------|
| | Core Competency % | Customers Segments | | | | | |
| | | Large Scale Retailers | NGOs | Online Retailers | Developing Countries | Backpacker users | Specialized Retailers |
| Creative Thinking | 6,77% | - | - | 1 | - | 1 | - |
| Financial Understanding | 30,02% | 9 | 3 | 9 | 1 | 1 | 9 |
| Manufacturing Experience | 23,96% | 1 | - | - | 3 | 3 | 1 |
| Customer Focus Strategy | 27,97% | 3 | - | 9 | 1 | 9 | 9 |
| Social Responsibility | 11,27% | 1 | 3 | 1 | 9 | 3 | 1 |
| ABSOLUTE WEIGHT | | 0,039 | 0,012 | 0,054 | 0,023 | 0,039 | 0,056 |
| % | | 17,41% | 5,54% | 24,15% | 10,35% | 17,63% | 24,92% |

| | |
|--------------------|---|
| No correlation | |
| Weak Correlation | 1 |
| Medium Correlation | 3 |
| Strong Correlation | 9 |

Appendix 5 - Gemba Analysis

Table 1

| Water Filter Jug with Replacement Cartridge - Cool Water Purifier - BPA-Free - Dewberry Slim - Blue | BRITA Fill and Go Vital Water Filter Bottle BPA Free Includes 1 Microdisc Lasting 150 Litres, Purple, 600 ml | Bobble BPA-Free 550 ml Water Bottle, Magenta | BRITA Elemaris XL Water Filter Jug and Cartridge, White | BRITA Flow water filter tank and cartridge, 8.2L, Blue |
|---|---|---|---|---|
|  |  |  |  |  |
| https://www.amazon.co.uk/Water-Filter-Jug-Replacement-Cartridge/dp/B073RMJ2L3/ref=sr_1_1?ie=UTF8&qid=1549546992&sr=8-1&keywords=filtering+water | https://www.amazon.co.uk/BRITA-Filter-Bottle-Microdisc-Lasting/dp/B01F3P14ZQ/ref=sr_1_4?ie=UTF8&qid=1549546992&sr=8-4&keywords=filtering+water | https://www.amazon.co.uk/Bobble-BPA-Free-Water-Bottle-Magenta/dp/B003LTFS5Y/ref=sr_1_11?ie=UTF8&qid=1549546992&sr=8-11&keywords=filtering+water | https://www.amazon.co.uk/BRITA-Elemaris-XL-Water-Filter-Cartridge/dp/B01MZZIDHN/ref=sr_1_12?ie=UTF8&qid=1549547287&sr=8-12&keywords=filtering+water | https://www.amazon.co.uk/BRITA-Flow-water-filter-cartridge/dp/B07DWV14T8/ref=sr_1_25?ie=UTF8&qid=1549547039&sr=8-25&keywords=filtering+water |
| removes heavy metals feels like a high quality product rubber feet on the bottom to prevent sliding | leaks terribly design flaw seems to let air in while drinking pressure which pushes water out of the top | after 2 weeks the filter cracked sideways quality of the product is shockingly poor filter tastes | Fill it up and the water sprays off the lid back towards you Every time you fill this up with water, half an inch gets trapped | The "tap" doesn't screw in (which is what a normal designer would have concocted) It merely presses in by way of very unreliable suction cups. |

| | | | | |
|--|---|--|--|---|
| <p>With a longer filter it has a lower centre of gravity so it's harder to knock over.</p> <p>water now tastes "soft"</p> <p>tastes so clean</p> <p>jug itself is very sturdy and a great size (8-9 glasses of water)</p> <p>very easy to use and replace filter cartridges</p> <p>Filter lasts 3 months rather than one month like others</p> | <p>concept is good but the execution is extremely poor sucking in air more than water</p> <p>Visually appealing tiny marks on the bottle of ml just as reminders for people who try to drink certain abouts</p> <p>mouthpiece improved</p> <p>making bubbling noise when drinking</p> <p>Great design and really easy to set up the filter</p> <p>Yes it is somewhat easier to just open the lid and drink from the bottle, a built in straw would have been helpful.</p> <p>The filter helps to remove chlorine, odour and bad taste but keeps in any good minerals & vitamins</p> | <p>horrible, really plasticy, the nozzle is also too large to drink from comfortably</p> <p>The bottle is full of scratches, it looks like it has already been used</p> <p>hard to get water out</p> <p>slightly cleaner taste of filtered</p> <p>Some filters worked better than others.</p> <p>There is an ongoing cost with replacing the filter every 2 months, and it also harms the eco-friendly nature of a permanent bottle because you are constantly discarding the plastic-encased filter</p> <p>loud wheezing noise after I drink from it</p> <p>I do not like it you cannot take a big long draft of drink effectively filtered the water and was</p> | <p>beneath the filter and the plastic mold that houses the filter. So I have to dismantle the entire thing every time and drain out the trapped water after each refill</p> <p>The filters ran out even when there was no water in it</p> <p>leaks water through the handle</p> <p>maxi filters are only lasting 20 days before indication is given we need to change filter, that could prove costly.</p> <p>too slow with filtering water</p> <p>Good initially but plastic cracking</p> <p>lid coming loose and falling into the top reservoir,</p> <p>There's a little 'well' underneath the filter, this helps prevent filtered water flow back into the filter</p> | <p>refilling requires either another receptacle to transfer water from the tap to the tank</p> <p>dispenser fits perfectly on the top shelf of our fridge</p> <p>dispenser holds enough water to fill once a day (with 3 of us drinking from it)</p> <p>I used to have the jug, constantly filling it up so this was scored off my list</p> <p>easy to assemble, easy to fill up, little countdown monitor at the top to let me know when to change the filter.</p> <p>good size and fits on the shelf perfectly. Lots of filter cold water on tap</p> <p>usually buy loads of bottled water but want to try & save the planet in my own small way</p> <p>Fantastic for a</p> |
|--|---|--|--|---|

| | | | | |
|---|---|--|---|---|
| | <p>surprised to notice that the microdisc made such a difference to the taste</p> <p>Purchasing microdiscs regularly may be off putting</p> <p>reduces the chemical taste of tap water</p> <p>Filter inserts easily and doesn't require any real effort to drink through</p> <p>better than the old design with the straw</p> <p>'filter' sit in the water. (Better than)</p> | <p>easy to clean</p> <p>The bottles don't leak no matter how much you shake them</p> <p>great size and design</p> <p>quality and holds a good amount of water</p> <p>benefit of the BPA free bottle, the fresh tasting filtered water, the choice of filter colours and the cost savings</p> | <p>Stylish to look at and love the water sensor actually tells you the life left in your filter</p> <p>hasn't an ounce of limescale in it</p> <p>gives clear good tasting water</p> <p>Well made and easy to use. Cartridges are available from Lots of sellers on amazon and last two month.</p> | <p>larger family or water enthusiasts</p> <p>Easy to assemble</p> <p>Large quantity means only have to refill every 2-3 days</p> |
| <p>Positive points: Process of filtering (Good taste, heavy metals) Filter long lasting Easy to use Quality design-solid Good storage</p> <p>Negative Points: No measure of</p> | <p>Positive points: Easy to change filter Better to have filter not in the water Easy to drink from</p> <p>Negative Points: Improve drinking nozzle Easier to drink from bottle</p> | <p>Positive points: Material (BPA) Good taste of water Good storage amount No leaks Process filtered the water</p> <p>Negative Points: Slow to drink</p> | <p>Positive points: System to avoid water passing several times through filter Good tasting water Easy to source replacement filters</p> <p>Negative Points: Not easy to use</p> | <p>Positive points: Easy to Assemble Good storage (only recharge every 2-3 days) Environment (no need for plastic bottles)</p> <p>Negative Points: Can't transport it</p> |

| | | | | |
|--|---|---|--|-------------------|
| | <p>the water Leakage Bad sealing Bad design Bad manufacturing</p> | <p>from/ not easy to drink from Regular filter replacement Irregular quality of filters Bad manufacturing (scratches, parts broken quick)</p> | <p>Design problems Leaks Filtering process too slow Filter life too short.</p> | Tap design flawed |
|--|---|---|--|-------------------|

Table 2

| | | | |
|---|---|---|---|
| Berkey Bk4X2-Bb Big Water Purification System With 2 Black Filter Elements, Stainless Steel | Vivida BPA-Free Glass 400ml Water Bottle with Filter and Silicone Sleeve | Spardar Tap Water Purifier, Multi-Stage Advanced Faucet Water Filter System with Transparent Visual Window | Portable Hydrate Glass Alkaline Water Filter Bottle |
|  |  |  |  |
| https://www.amazon.co.uk/Berkey-Bk4X2-Bb-Purificati | https://www.amazon.co.uk/Vivida-BPA-Free-Silicone-Shat | https://www.amazon.co.uk/Spardar-Multi-Stage-Transpare | https://www.amazon.co.uk/Hydrate-Alkaline-Water-Bo |

| | | | |
|--|---|---|---|
| on-Elements-Stainless/dp/B00CYW3EVO/ref=sr_1_54?ie=UTF8&qid=1549925640&sr=8-54&keywords=water+filter | terproof-Eco-Friendly/dp/B07KP1289K/ref=sr_1_127?ie=UTF8&qid=1549927058&sr=8-127&keywords=bottle+filter | nt-Chemicals-Pesticides/dp/B07DWPYT5Y5/ref=sr_1_95?ie=UTF8&qid=1549928220&sr=8-95&keywords=water+filter | tte-Filter/dp/B076HN578N/ref=sr_1_130?ie=UTF8&qid=1549929157&sr=8-130&keyword=water+filter |
| <p>1) It purifies both treated water and untreated raw water from such sources as remote lakes, streams, stagnant ponds and water supplies in foreign countries</p> <p>2) It removes viruses, pathogenic bacteria, cysts and parasites and extracts harmful chemicals such as herbicides, pesticides, VOCs, organic solvents</p> <p>3) It also reduces rust, silt, sediment, foul taste and odours and unhealthy minerals such as lead and mercury</p> <p>4) The system is so powerful it can remove red food colouring from water without removing the beneficial</p> | <p>1) Shatterproof, Reusable and Eco-Friendly.</p> <p>2) Plastic-free 400ml tall design is easy to clean, lasts longer.</p> <p>3) Durable, built of tough, borosilicate glass that is extra transparent with a premium appearance.</p> <p>4) Portable and easy to grip, the silicone grip ensures the glass bottle is protected.</p> <p>5) BPA-free, no harmful, toxic chemicals or taste</p> | <p>1) It does remove Chlorine, Fluoride, Bacteria, Viruses.</p> <p>2) Durable Faucet Filter: Compared with other tap water purifier on market.</p> <p>3) Five-stage technology, to create ultimate clean water, our faucet mount filter adopts the latest, upgraded Activated Carbon Fiber (ACF).</p> <p>4) Convenient Design: Simple switch lever allows quick switch from quality purified water to regular tap water.</p> <p>5) HASSLE-FREE INSTALLATION: The filtered water faucet adopts leak-proof technology and can be attached to your faucet very easily.</p> | <p>1) Increase pH, Reduce Fluoride, Remove Heavy Metals & Chlorine</p> <p>2) No plastic components, long-life filter. Each filter pouch lasts an incredible 300 cups/16 gallons/72 litres</p> <p>2) COMPACT, STYLISH BOTTLE & MADE FROM TOUGH BOROSILICATE GLASS for strength & durability.</p> <p>3) EASY-GRIP SILICONE SLEEVE. FOOD-GRADE STAINLESS STEEL FILTER HOUSING.</p> |

| | | | |
|---|---|---|--|
| minerals your body needs | | | |
| Positive feedback 1) Easy to clean, it has a ceramic filter. 2) It filters plastic particles. 3) Filtered water has a better taste. | Positive feedback 1) High quality product parts. 2) It has a tea infusion section. 3) Adequate size, easy to carry around. 4) It has a nifty little rope on the lid (allowing to carry it easily). 5) Light weight. | Positive feedback 1) Easy to fit and place it around the tap. 2) Cheap, yet good quality product. 3) Improved taste of the water. | Positive feedback 1) Easy to carry around. 2) The design is great, stylish colour and a beautiful bamboo lid. 3) It improves taste of water. |
| Negative feedback 1) Assembling the Berkey is not clear and easy. 2) The bottom water tank never emptied due to poor design. 3) The fluoride filters being too expensive. | Negative feedback No negative feedback found. | Negative feedback 1) It does not fit the tap. 2) Constant leaking. 3) The plastic attachment is being screwed onto a metal tap fitting it just isn't strong enough and the threads get ruined | Negative feedback 1) The bottle is made of glass – is brittle. 2) Product arrived smashed. |

Appendix 6 - PrePlan Matrix

| | PrePlan Matrix | | | | | | | |
|----------------------------|-------------------------------|--|--------------------------------------|-------------------|---------------------|---|-----------------|---------------------------------|
| | Degree of Importance (0 to 5) | Benchmarking | | Plan | | | Weight | |
| Customer Request | | Portable Alkaline Water Filter Ionizer (Invigorated water) | BRITA Fill and Go Vital Water Filter | Assessment Target | Rate of Improvement | Sales Point (Strong=1.5 or Medium=1.2, not a sales point=1) | Absolute Weight | Customer request priority DWQ % |
| Quality product parts | 4.2 | 4.8 | 3 | 4.8 | 1.00 | 1.5 | 6.300 4.88% | |
| Affordable price. | 3.5 | 2.5 | 4.8 | 4.8 | 1.00 | 1.2 | 4.200 3.26% | |
| Improvement water taste. | 4 | 4.9 | 4.2 | 4.9 | 1.00 | 1.5 | 6.000 4.65% | |
| Portability. | 3.8 | 3.5 | 4.8 | 4.8 | 1.00 | 1 | 3.800 2.95% | |
| Long filter life. | 3 | 2.8 | 3.8 | 4.1 | 1.08 | 1.5 | 4.855 3.76% | |
| Good storage amount. | 4.1 | 2.3 | 4.2 | 4.5 | 1.07 | 1.2 | 5.271 4.09% | |
| Easy to refill. | 4.5 | 3.8 | 4.2 | 4.6 | 1.10 | 1 | 4.929 3.82% | |
| Clear set-up instructions. | 3.2 | 3.8 | 2.8 | 4.9 | 1.29 | 1 | 4.126 3.20% | |
| Easy to drink from. | 5 | 3.9 | 2.8 | 4.3 | 1.10 | 1.2 | 6.615 5.13% | |
| Fast filtering. | 4.8 | 2.8 | 3 | 3.8 | 1.27 | 1.2 | 7.296 5.65% | |
| Good product design. | 3 | 4.3 | 2.8 | 4.8 | 1.12 | 1.2 | 4.019 3.11% | |
| Leakage proof. | 4.4 | 4.5 | 2.1 | 4.8 | 1.07 | 1.5 | 7.040 5.46% | |
| Environmentally friendly. | 3 | 4 | 2.8 | 4 | 1.00 | 1 | 3.000 2.33% | |
| Filter life monitoring. | 2.8 | 0.5 | 0.8 | 3.9 | 4.88 | 1.5 | 20.475 15.87% | |
| Easy to assemble. | 3.3 | 4.2 | 4 | 4.8 | 1.14 | 1.2 | 4.526 3.51% | |
| Stylish design | 2.1 | 3.8 | 2 | 4.2 | 1.11 | 1.2 | 2.785 2.16% | |

| | | | | | | | | |
|---|-----|-----|-----|-----|------|--------------|-------------|-------------|
| of the product. | | | | | | | | |
| Easy to change the filter. | 3.7 | 3.9 | 2.8 | 3.9 | 1.00 | 1.5 | 5.550 | 4.30% |
| Fits into the fridge. | 4.1 | 3.9 | 4.1 | 4.3 | 1.05 | 1 | 4.300 | 3.33% |
| Colour variety. | 2 | 2.5 | 4 | 4.8 | 1.20 | 1 | 2.400 | 1.86% |
| Quality Manufacturing | 3.8 | 3.6 | 3 | 4 | 1.11 | 1.2 | 5.067 | 3.93% |
| Replacement filters available from various suppliers. | 3.5 | 0.5 | 4 | 4.2 | 1.05 | 1.5 | 5.513 | 4.27% |
| Measurement of water left. | 2.1 | 3.9 | 4.2 | 4.5 | 1.07 | 1.2 | 2.700 | 2.09% |
| Good filter positioning | 3.5 | 4.5 | 3.5 | 4.6 | 1.02 | 1 | 3.578 | 2.77% |
| Affordable price filter cartridge. | 3.9 | 2.8 | 4.8 | 4.8 | 1.00 | 1.2 | 4.680 | 3.63% |
| | | | | | | TOTAL | 129.02 4 | 100.00 % |

Appendix 7 - House of Quality

| DIRECTION OF IMPROVEMENT | | TECHNICAL REQUIREMENTS | | COSTUMER REQUIREMENTS | | PLANNING MATRIX | | | | | | | | | | | | | | |
|--------------------------|--|------------------------|--|-----------------------|--|--|------|------|-------|-------|-------------------|-------|-------|-------|-----|-----|-----|-------|---------|---------|
| | | | | | | Customer importance | | | | | Overall weighting | | | | | | | | | |
| | | | | | | Percentage of total | | | | | | | | | | | | | | |
| | | | | | | Quality product parts | 5.2 | ○ | ● | ○ | ● | 4.8 | 3 | 4.8 | 1 | 1.5 | 6.3 | 4.89% | | |
| | | | | | | Affordable price | 4.4 | ○ | ● | ● | ○ | ○ | 2.5 | 4.8 | 4.8 | 1 | 1.2 | 4.2 | 3.26% | |
| | | | | | | Improvement water taste | 5 | ○ | ● | ● | ● | ● | 4.9 | 4.2 | 4.9 | 1 | 1.5 | 6 | 4.65% | |
| | | | | | | Portability | 4.7 | ● | ○ | ○ | ● | ● | 3.5 | 4.8 | 4.8 | 1 | 1 | 3.6 | 2.06% | |
| | | | | | | Long filter life | 3.7 | ○ | ○ | ● | ○ | ● | 2.8 | 3.8 | 4.1 | 1.1 | 1.5 | 4.855 | 3.70% | |
| | | | | | | Good storage amount | 5.1 | ● | ● | ○ | ○ | ● | 2.3 | 4.2 | 4.5 | 1.1 | 1.2 | 5.271 | 4.09% | |
| | | | | | | Easy to refill | 5.6 | ○ | ○ | ○ | ○ | ○ | 3.8 | 4.2 | 4.6 | 1.1 | 1 | 4.929 | 3.82% | |
| | | | | | | Clear set-up instructions | 4 | ○ | ○ | ○ | ○ | ● | 3.8 | 2.8 | 4.9 | 1.3 | 1 | 4.126 | 3.20% | |
| | | | | | | Fast filtering | 6 | ○ | ● | ● | ○ | ○ | 2.8 | 3 | 3.8 | 1.3 | 1.2 | 7.206 | 5.65% | |
| | | | | | | Good product design | 3.7 | ○ | ● | ● | ○ | ○ | ○ | 4.3 | 2.8 | 4.8 | 1.1 | 1.2 | 4.019 | 3.11% |
| | | | | | | Leakage proof | 5.5 | ○ | ○ | ● | ● | ● | ○ | 4.5 | 2.1 | 4.8 | 1.1 | 1.5 | 7.04 | 5.46% |
| | | | | | | Environmentally friendly | 3.7 | ○ | ● | ● | ● | ● | ● | 4 | 2.8 | 4 | 1 | 1 | 3 | 2.35% |
| | | | | | | Filter like moon bring | 3.5 | ○ | ○ | ○ | ○ | ○ | ● | 0.5 | 0.8 | 3.9 | 4.9 | 1.5 | 20.475 | 15.87% |
| | | | | | | Easy to assemble | 4.1 | ○ | ● | ● | ● | ● | ● | 4.2 | 4 | 4.8 | 1.1 | 1.2 | 4.526 | 3.51% |
| | | | | | | Stylish design of the product | 2.6 | ○ | ● | ● | ○ | ○ | ● | 3.8 | 2 | 4.2 | 1.1 | 1.2 | 2.785 | 2.16% |
| | | | | | | Easy to change the filter | 4.6 | ○ | ○ | ○ | ○ | ● | ● | 3.9 | 2.8 | 3.9 | 1 | 1.5 | 5.55 | 4.30% |
| | | | | | | Fits into the fridge | 5.1 | ● | ○ | ○ | ● | ● | ● | 3.9 | 4.1 | 4.3 | 1.1 | 1 | 4.3 | 3.33% |
| | | | | | | Colour variety | 2.5 | ○ | ● | ● | ○ | ○ | ● | 2.5 | 4 | 4.8 | 1.2 | 1 | 2.4 | 1.66% |
| | | | | | | Quality Manufacturing | 4.7 | ○ | ● | ○ | ● | ● | ● | 3.6 | 3 | 4 | 1.1 | 1.2 | 5.057 | 3.83% |
| | | | | | | Replacement filters available from various suppliers | 4.4 | ○ | ○ | ● | ● | ○ | ● | 0.5 | 4 | 4.2 | 1.1 | 1.5 | 5.513 | 4.27% |
| | | | | | | Measurement of water left | 2.6 | ○ | ● | ● | ○ | ○ | ● | 3.9 | 4.2 | 4.5 | 1.1 | 1.2 | 2.7 | 2.06% |
| | | | | | | Good filter positioning | 4.4 | ○ | ○ | ○ | ○ | ● | ● | 4.5 | 3.5 | 4.6 | 1 | 1 | 3.578 | 2.77% |
| | | | | | | Affordable price filter cartridge | 4.9 | ○ | ○ | ○ | ○ | ● | ● | 2.8 | 4.8 | 4 | 1.2 | 1.2 | 4.68 | 3.63% |
| | | | | | | TECHNICAL PRIORITIES | | | | | | | | | | | | TOTAL | 129.024 | 100.00% |
| | | | | | | PERCENTAGE OF TOTAL | 7.45 | 11.6 | 4.335 | 9.209 | 28.7 | 7.564 | 9.827 | 21.84 | | | | | | |

Appendix 8 - Chemical reduction requirements for the filtered water

| Parameter for water W2 (Annex B) | Concentration unit | challenge water Concentration Ci | Minimum Average percentage reduction |
|--|----------------------|-------------------------------------|--|
| Scale reduction (Carbonate hardness reduction) | mg/l | 200^{+40}_{-20} | 30 b |
| Scale reduction (Boiling test) | mg/l | 200^{+40}_{-20} | 80 b |
| Nitrate | mg/l NO_3^- | 50^{+10}_{-5} a | 50 c |
| Free chlorine | mg/l Cl_2 | $1^{+0,2}_{-0,1}$ | 80 |

a The concentration of nitrate in the challenge water W1 is equal to the parametric value laid down in the Drinking Water Directive.

b The manufacturer shall state which scale reduction test was used to confirm the performance according to carbonate hardness reduction, boiling test or both whichever is applicable.

c In the case of nitrate, to check that no excessive nitrite formation has occurred, the analysis of filtrate samples shall include both nitrate and nitrite, and the following condition shall be met:

$$\frac{C(\text{NO}_3^-)}{50} + \frac{C(\text{NO}_2^-)}{3} \leq 1$$

where

C is the concentration in mg/l

Appendix 9 - Concept Screening Matrix 1

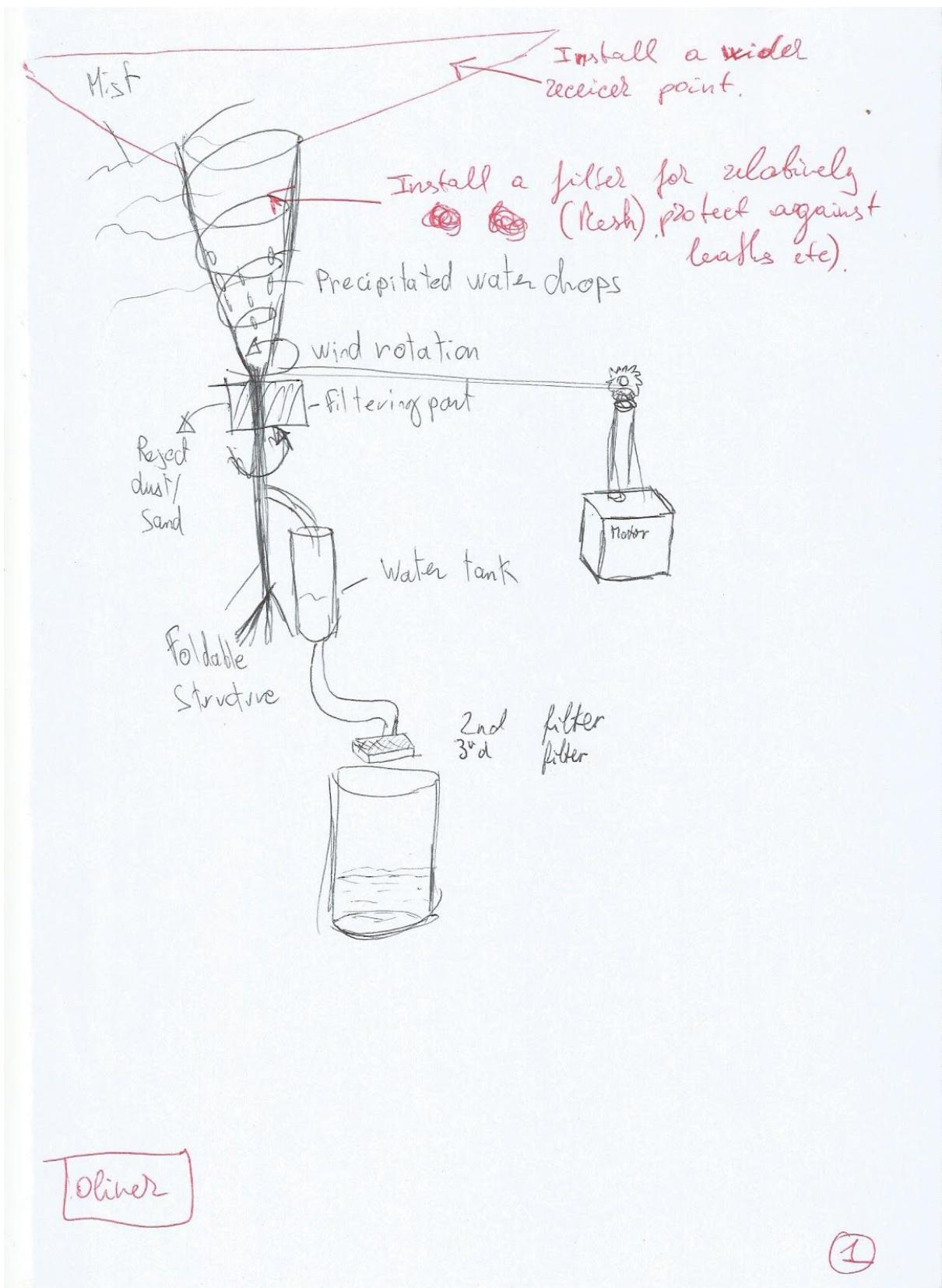
| | | Concept Screening Matrix 1 | | | | | | | | | | | |
|----|----------------------------|----------------------------|----|---|----|----|----|----|----|----|----|----|----|
| | Features/ Design Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | Speed | - | 0 | 0 | - | - | 0 | - | - | 0 | 0 | 0 | 0 |
| 2 | Weight | - | 0 | 0 | - | - | - | - | - | 0 | - | * | 0 |
| 3 | Cost | - | - | 0 | - | 0 | - | - | - | 0 | - | * | 0 |
| 4 | Materials | - | 0 | 0 | - | - | - | 0 | - | 0 | - | 0 | 0 |
| 5 | Quality | * | 0 | 0 | - | - | - | * | * | 0 | 0 | 0 | 0 |
| 6 | Volume | * | 0 | 0 | - | - | - | - | - | 0 | - | * | 0 |
| 7 | Storage | * | 0 | 0 | * | - | * | 0 | * | 0 | - | - | 0 |
| 8 | Environmentally Friendly | - | 0 | 0 | - | 0 | 0 | - | - | 0 | - | 0 | 0 |
| 9 | Maintenance | - | 0 | 0 | - | * | - | 0 | - | 0 | 0 | 0 | 0 |
| 10 | Power | - | 0 | 0 | 0 | 0 | 0 | - | - | 0 | 0 | 0 | 0 |
| 11 | Health and Safety | - | 0 | 0 | - | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 |
| 12 | Process | - | 0 | 0 | - | 0 | 0 | - | - | 0 | 0 | * | 0 |
| 13 | Assembly and Manufacturing | - | 0 | 0 | - | * | * | - | - | 0 | - | * | 0 |
| 14 | Wastage | - | 0 | 0 | * | 0 | - | * | - | 0 | 0 | 0 | 0 |
| 15 | Efficiency | - | 0 | 0 | * | - | - | * | 0 | 0 | 0 | 0 | 0 |
| | "-" count | 13 | 1 | R | 11 | 7 | 8 | 9 | 11 | 0 | 7 | 1 | 0 |
| | "**" count | 2 | 0 | E | 3 | 2 | 2 | 3 | 2 | 0 | 0 | 5 | 0 |
| | "0" count | 0 | 14 | F | 1 | 6 | 5 | 3 | 2 | 15 | 8 | 9 | 15 |
| | Net Score | -11 | -1 | | -8 | -5 | -6 | -6 | -9 | 0 | -7 | 4 | 0 |
| | Rank | 11 | 4 | | 9 | 5 | 6 | 6 | 10 | 2 | 8 | 1 | 2 |

| |
|-------------|
| 0 Same as |
| * More than |
| - Less than |

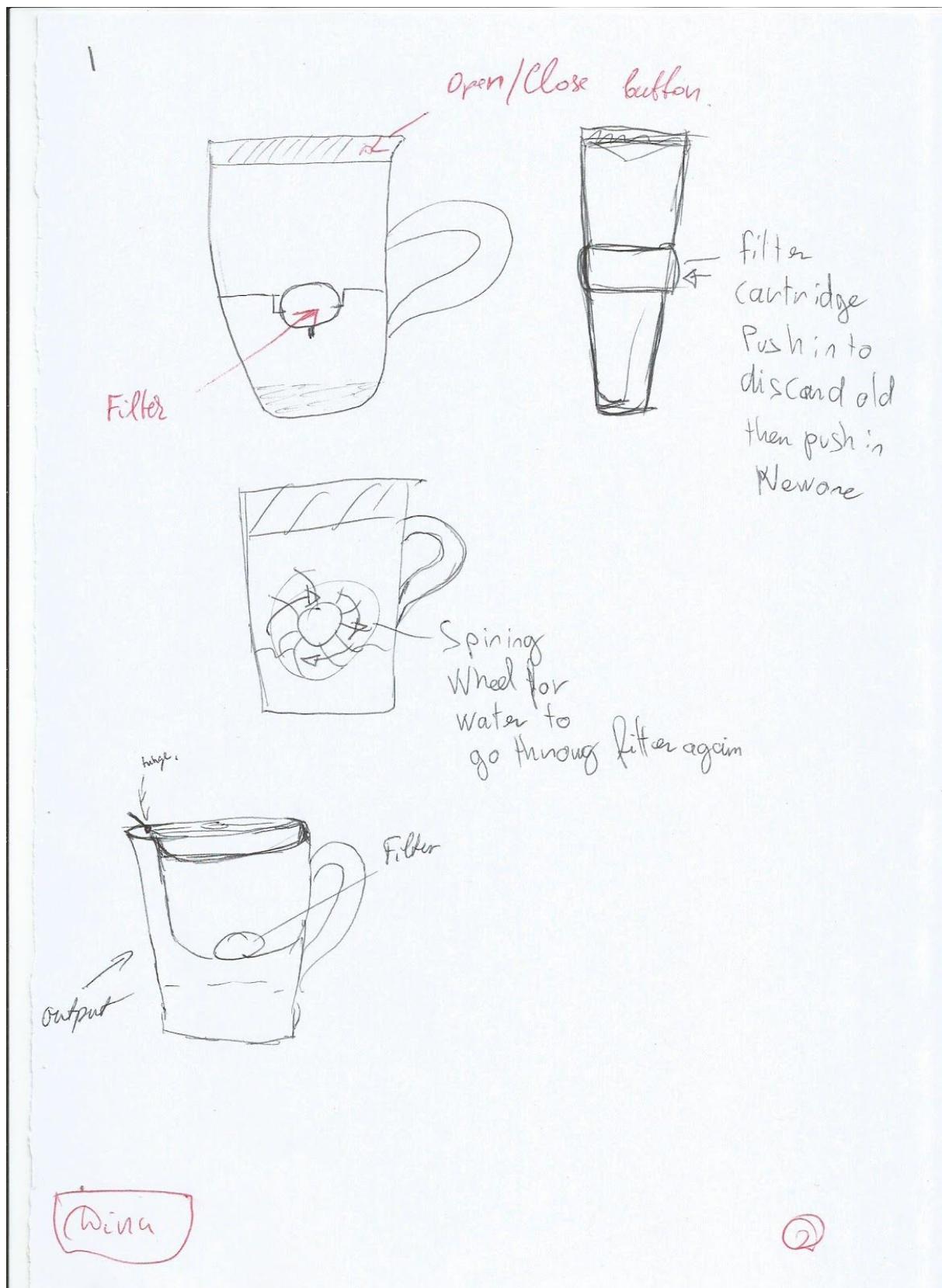
Appendix 10 - Concept Screening Matrix 2

| Concept Screening Matrix 2 | | | | | | | | | | |
|---|-------|---------------|-----------------------|------------------------------------|-------------------------|------------------|------------------|---------------------------------|--------|----------------|
| | | Design Number | Design 9-12 The straw | Modular Bottle (Design 3 improved) | Design 6-7 Distillation | Design 2 the Jug | Design 2 the Jug | Bottle Design 3 basic Reference | | |
| Features | | Weight | Rating | Weighted score | Rating | Weighted score | Rating | Weighted score | Rating | Weighted score |
| 1 Quality product parts | 4.88 | 4 | 0.1952 | 3 | 0.1464 | 4 | 0.1952 | 3 | 0.1464 | 3 |
| 2 Affordable price. | 3.26 | 2 | 0.0652 | 2 | 0.0652 | 1 | 0.0326 | 2 | 0.0652 | 3 |
| 3 Improvement water taste. | 4.65 | 3 | 0.1395 | 3 | 0.1395 | 4 | 0.186 | 4 | 0.186 | 3 |
| 4 Portability. | 2.95 | 3 | 0.0885 | 3 | 0.0885 | 1 | 0.0295 | 2 | 0.059 | 3 |
| 5 Long filter life. | 3.76 | 2 | 0.0752 | 3 | 0.1128 | 4 | 0.1504 | 4 | 0.1504 | 3 |
| 6 Good storage amount. | 4.09 | 2 | 0.0818 | 3 | 0.1227 | 1 | 0.0409 | 4 | 0.1636 | 3 |
| 7 Easy to refill. | 3.82 | 3 | 0.1146 | 3 | 0.1146 | 3 | 0.1146 | 3 | 0.1146 | 3 |
| 8 Clear set-up instructions. | 3.2 | 3 | 0.096 | 3 | 0.096 | 2 | 0.064 | 3 | 0.096 | 3 |
| 9 Easy to drink from. | 5.13 | 3 | 0.1539 | 3 | 0.1539 | 1 | 0.0513 | 2 | 0.1026 | 3 |
| 10 Fast filtering. | 5.65 | 2 | 0.1113 | 3 | 0.1695 | 1 | 0.0565 | 3 | 0.1695 | 3 |
| 11 Good product design. | 3.11 | 4 | 0.1244 | 4 | 0.1244 | 2 | 0.0622 | 4 | 0.1244 | 3 |
| 12 Leakage proof. | 5.46 | 4 | 0.2184 | 3 | 0.1638 | 3 | 0.1638 | 3 | 0.1638 | 3 |
| 13 Environmentally friendly. | 2.33 | 3 | 0.0699 | 3 | 0.0699 | 1 | 0.0233 | 2 | 0.0466 | 3 |
| 14 Filter life monitoring. | 15.87 | 4 | 0.6348 | 5 | 0.7935 | 1 | 0.1587 | 5 | 0.7935 | 3 |
| 15 Easy to assemble. | 3.51 | 2 | 0.0702 | 3 | 0.1053 | 2 | 0.0702 | 2 | 0.0702 | 3 |
| 16 Stylish design of the product. | 2.16 | 4 | 0.0864 | 4 | 0.0864 | 2 | 0.0432 | 4 | 0.0864 | 3 |
| 17 Easy to change the filter. | 4.3 | 2 | 0.086 | 3 | 0.129 | 3 | 0.129 | 1 | 0.043 | 3 |
| 18 Fits into the fridge. | 3.33 | 3 | 0.0999 | 3 | 0.0999 | 1 | 0.0333 | 1 | 0.0333 | 3 |
| 19 Colour variety. | 1.86 | 3 | 0.0558 | 3 | 0.0558 | 1 | 0.0186 | 1 | 0.0186 | 3 |
| 20 Quality Manufacturing | 3.93 | 2 | 0.0786 | 2 | 0.0786 | 4 | 0.1572 | 3 | 0.1179 | 3 |
| Replacement filters available from various suppliers. | 4.27 | 3 | 0.1281 | 3 | 0.1281 | 2 | 0.0854 | 3 | 0.1281 | 3 |
| 21 Measurement of water left. | 2.09 | 4 | 0.0836 | 3 | 0.0627 | 1 | 0.0209 | 4 | 0.0836 | 3 |
| 22 Good filter positioning | 2.77 | 4 | 0.1103 | 4 | 0.1103 | 3 | 0.0831 | 3 | 0.0831 | 3 |
| 24 Affordable price filter cartridge | 3.63 | 2 | 0.0726 | 2 | 0.0726 | 3 | 0.1089 | 2 | 0.0726 | 3 |
| Net Score | | 3.0424 | | 3.2899 | | 2.0788 | | 3.1184 | | 3.0003 |
| Rank | | 3 | | 1 | | 4 | | 2 | | |
| Continue? | | Keep design | Develop | no | Keep design | no | Reference | | | |

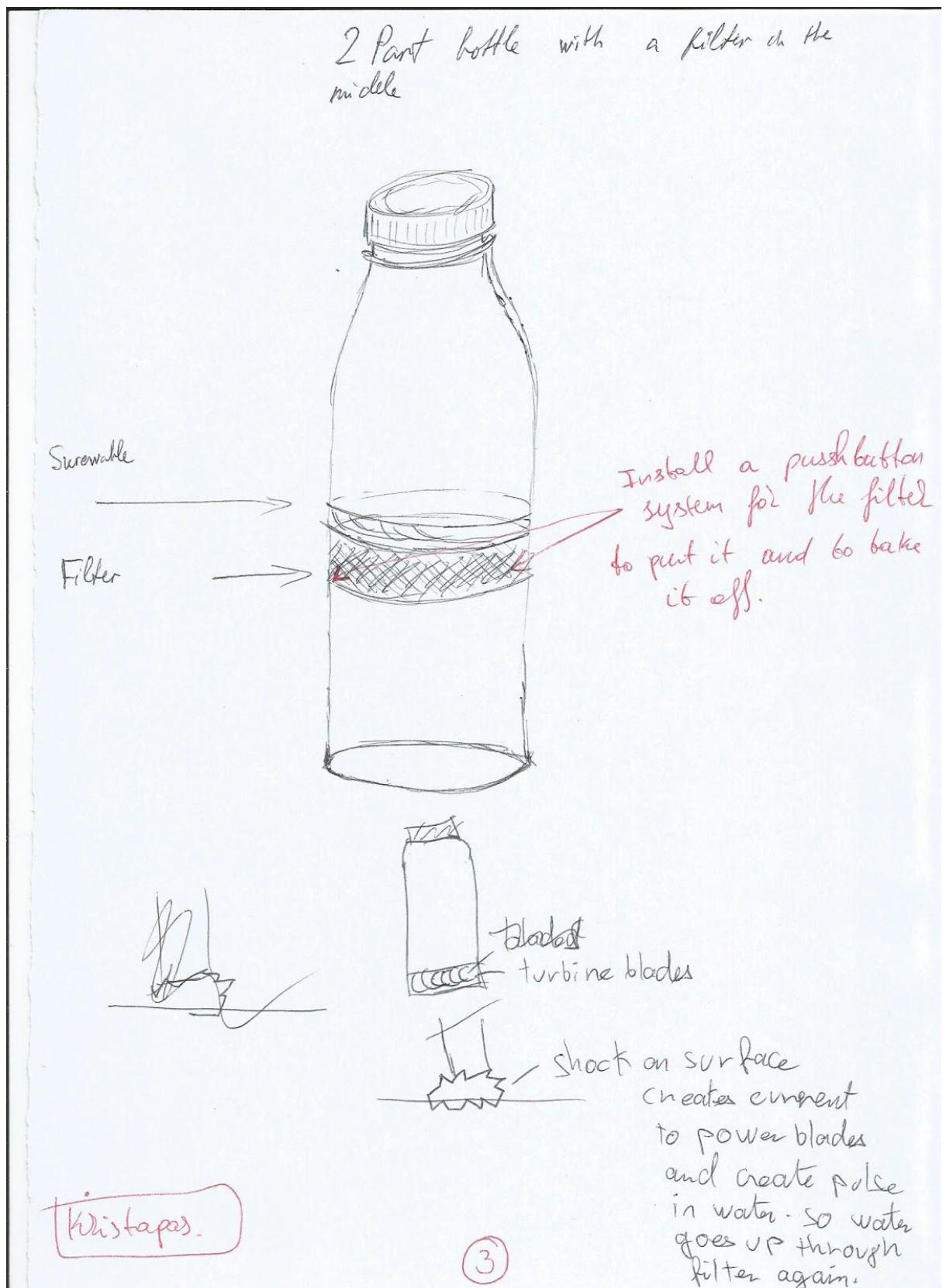
Appendix 11



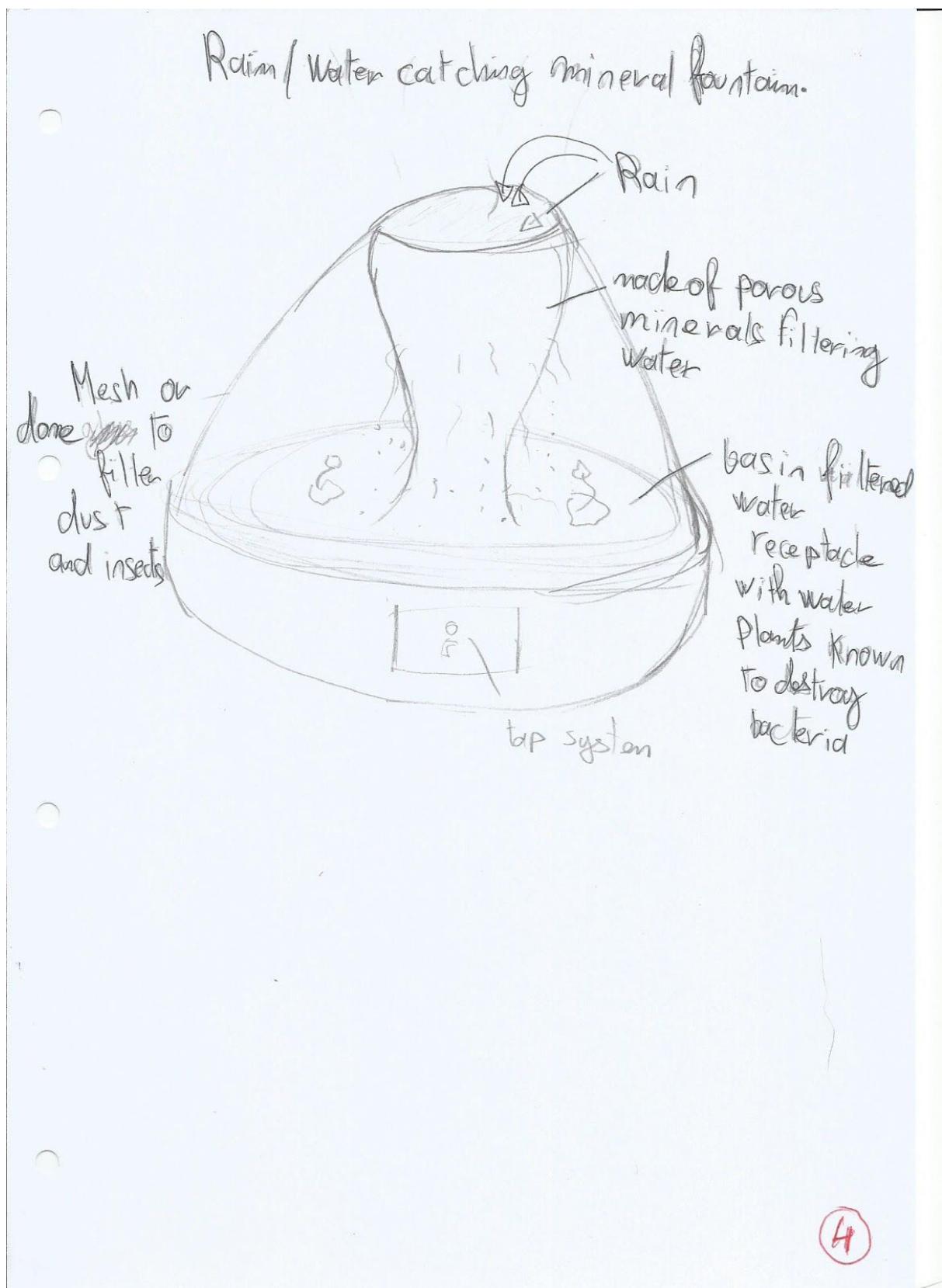
Appendix 12



Appendix 13

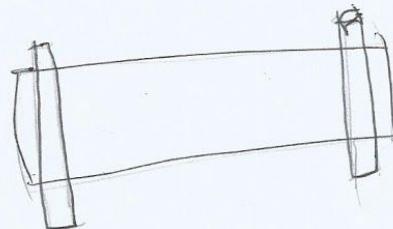
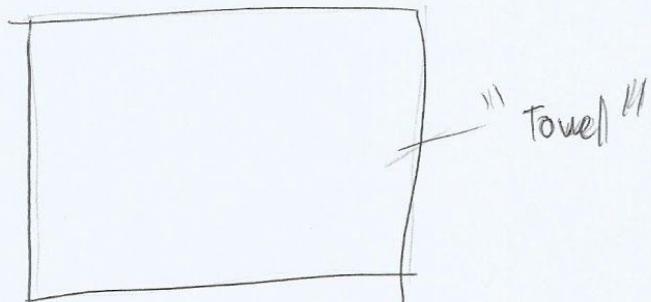


Appendix 14

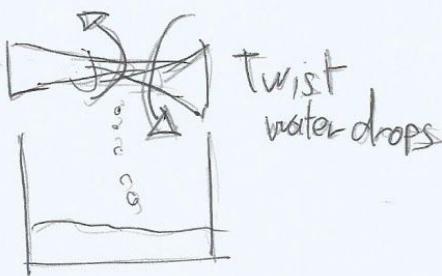


Appendix 15

Moisture / Mist, Towel
catcher



 catches the mist
during the night/early
morning

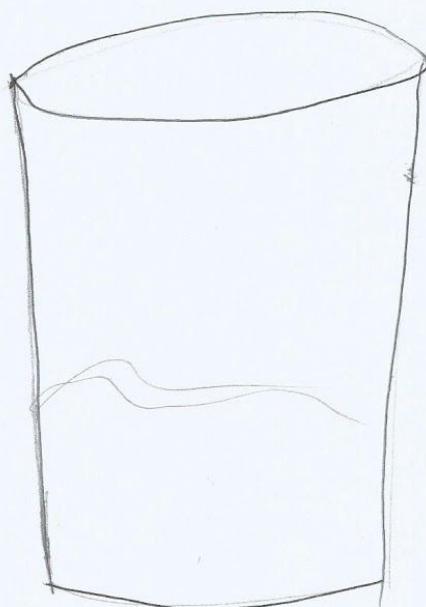


The fiber used for the towel
will absorb toxins/heavy
metals and purify
the water

(5)

Appendix 16

Pot made of purifying materials.

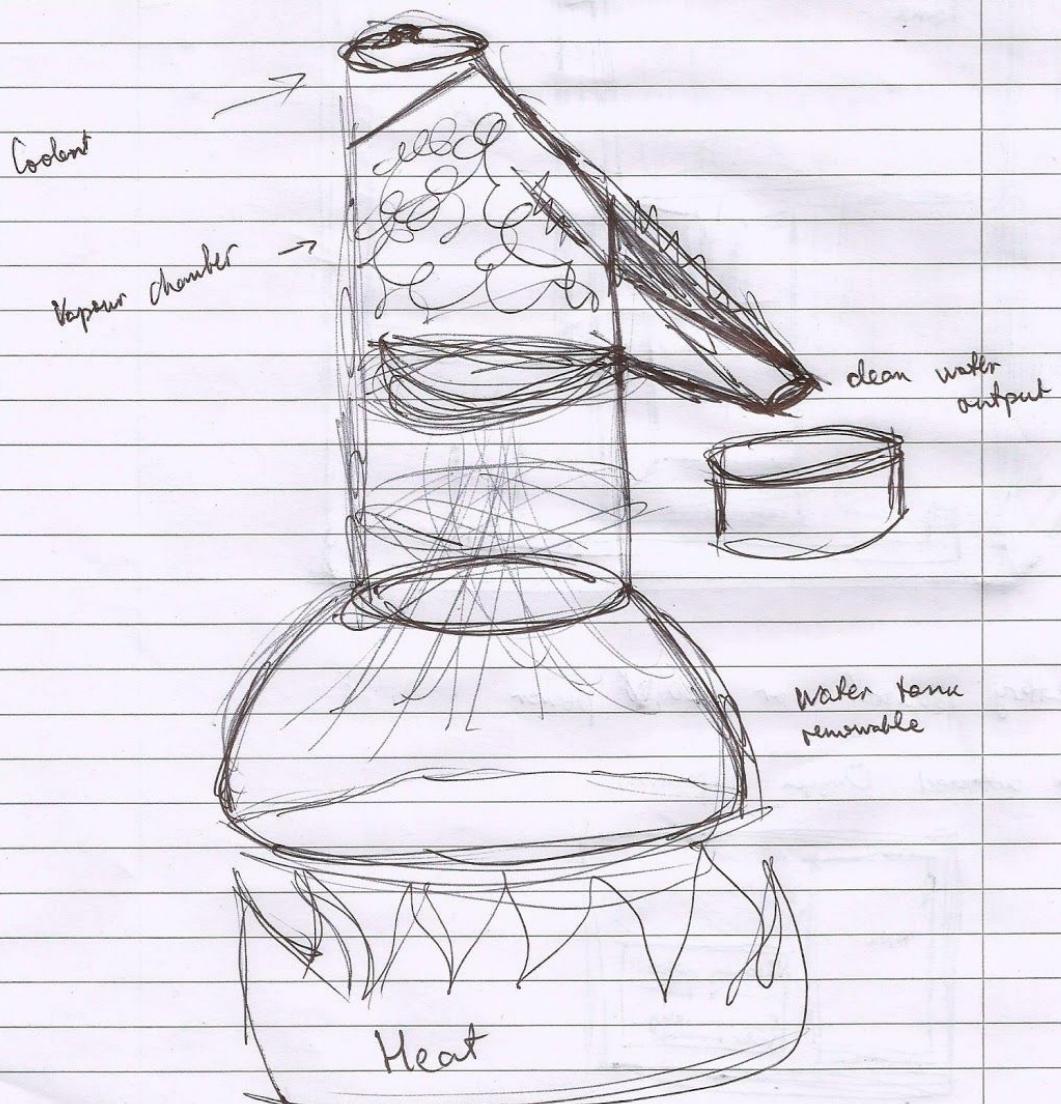


Soup pot made of material absorbing
particles and destroying bacteria.
Can be used as a normal pot

(6)

Appendix 17

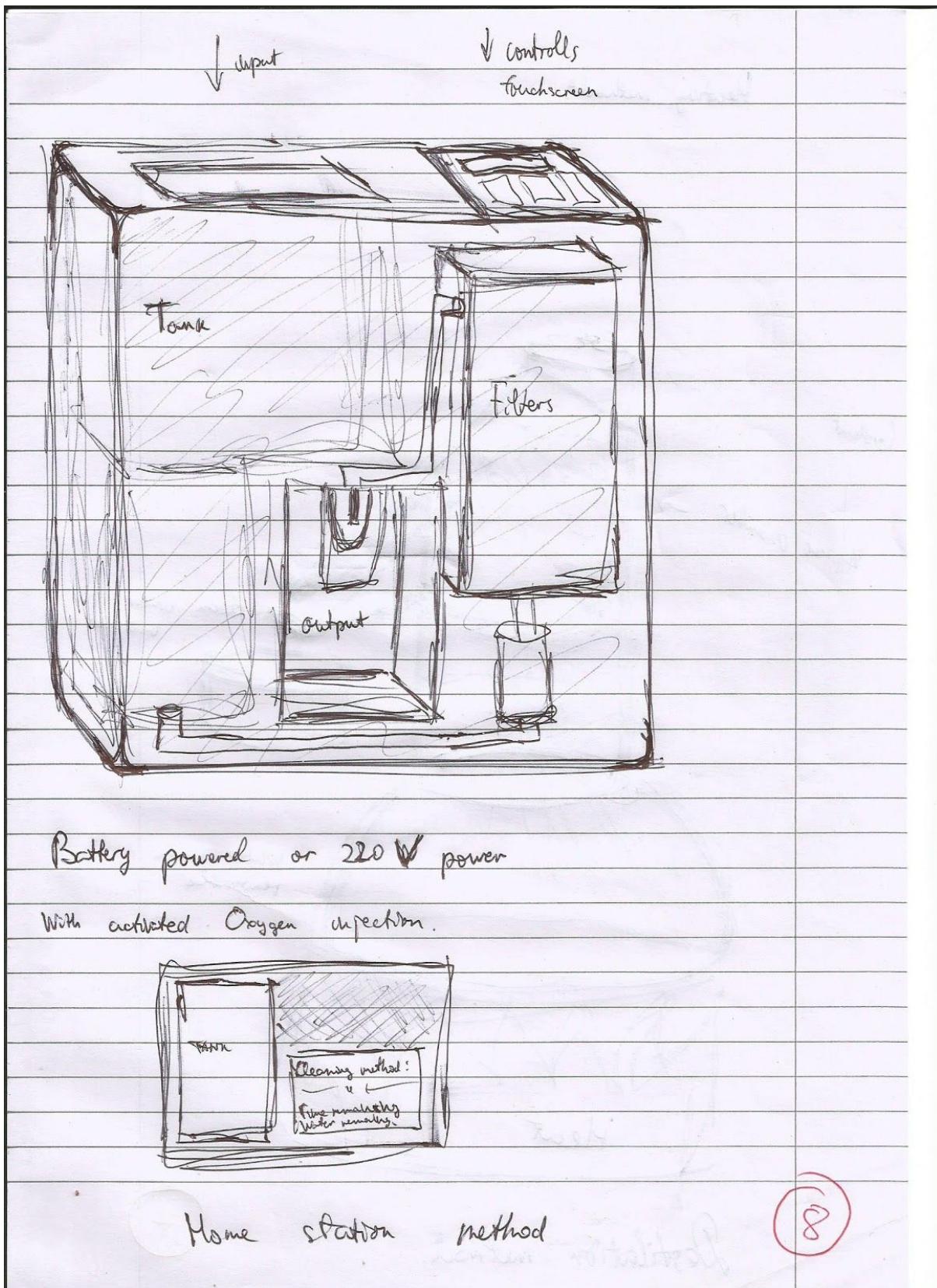
Heating method?



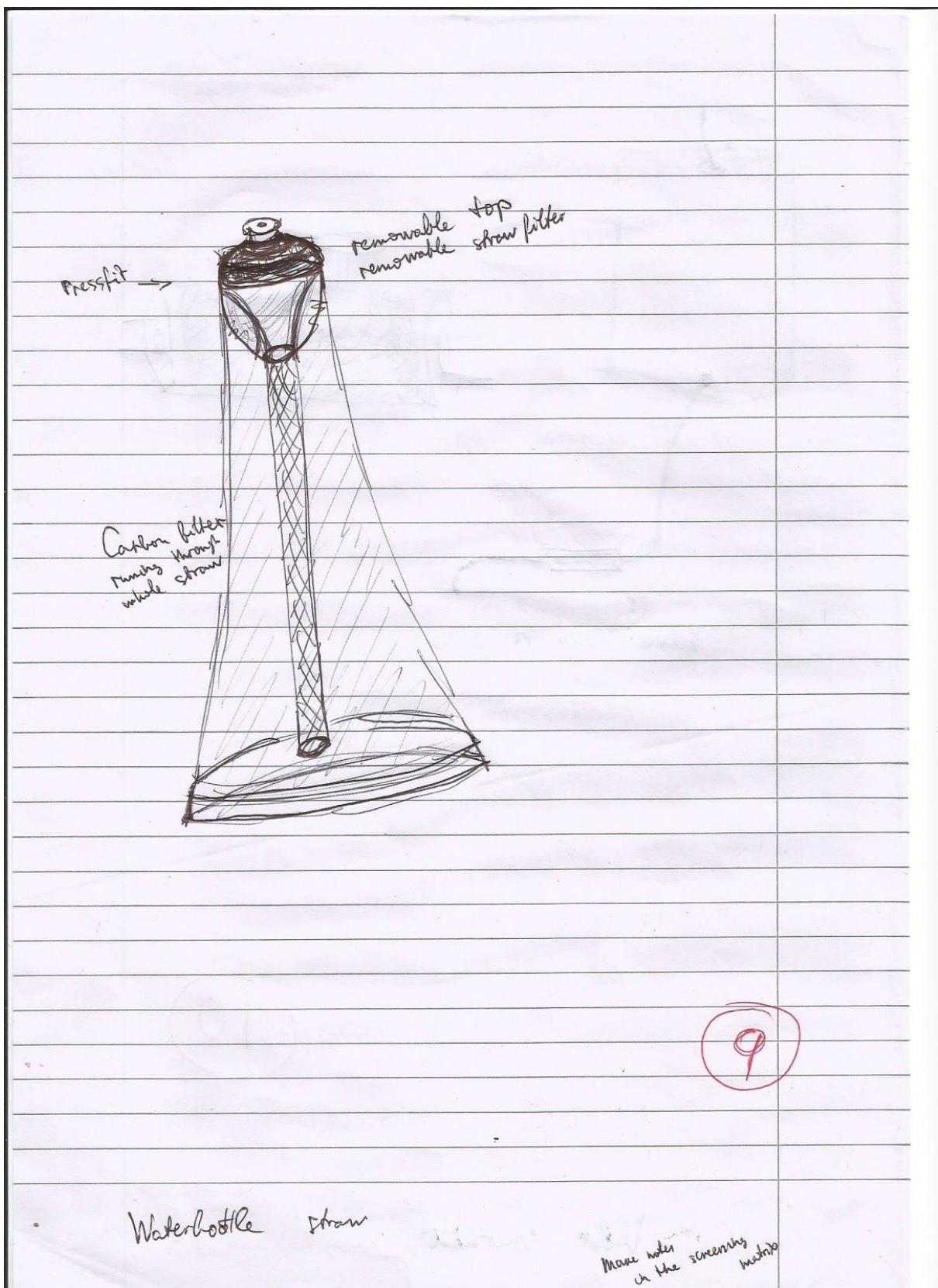
Distillation method.

7

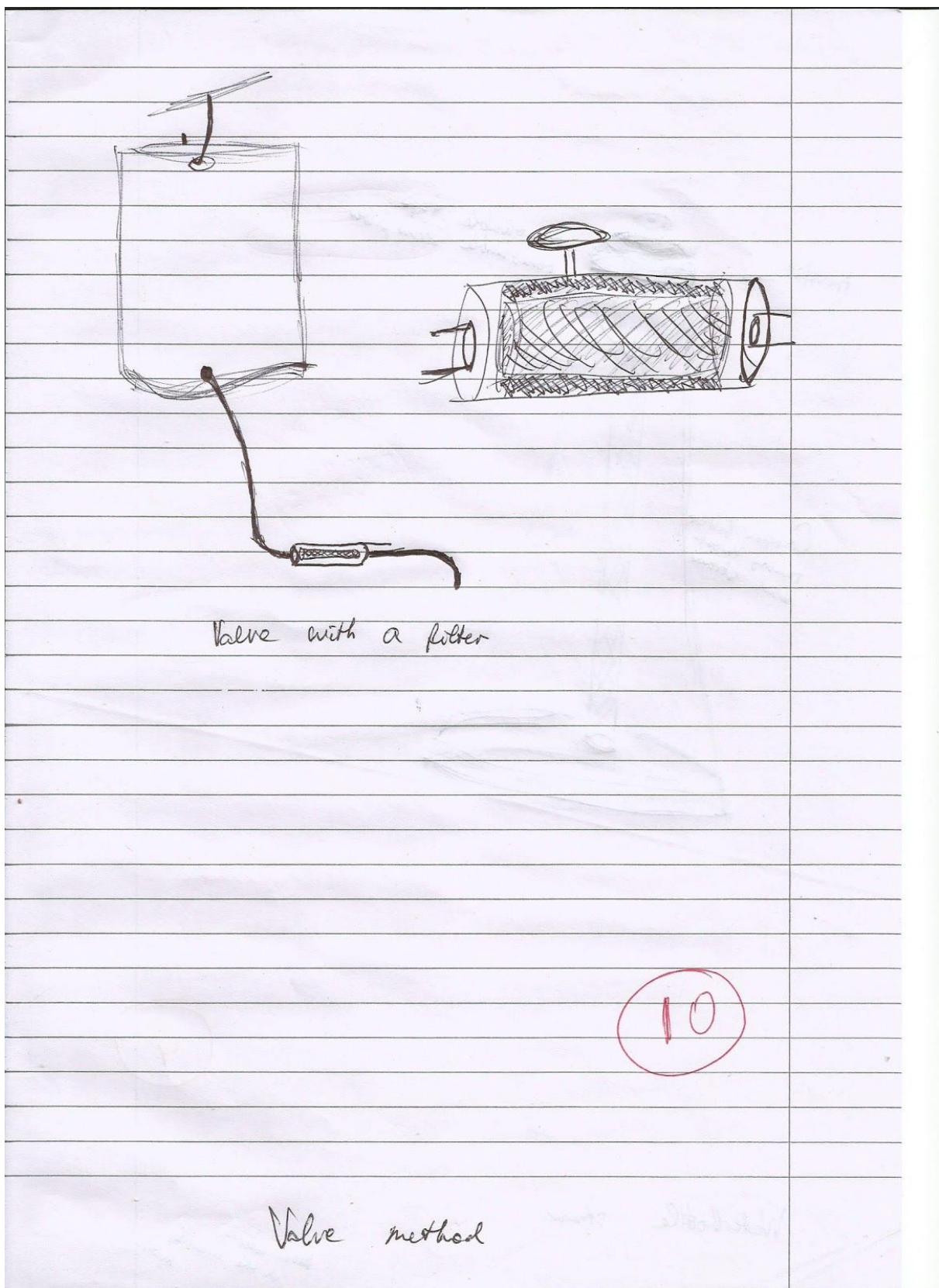
Appendix 18



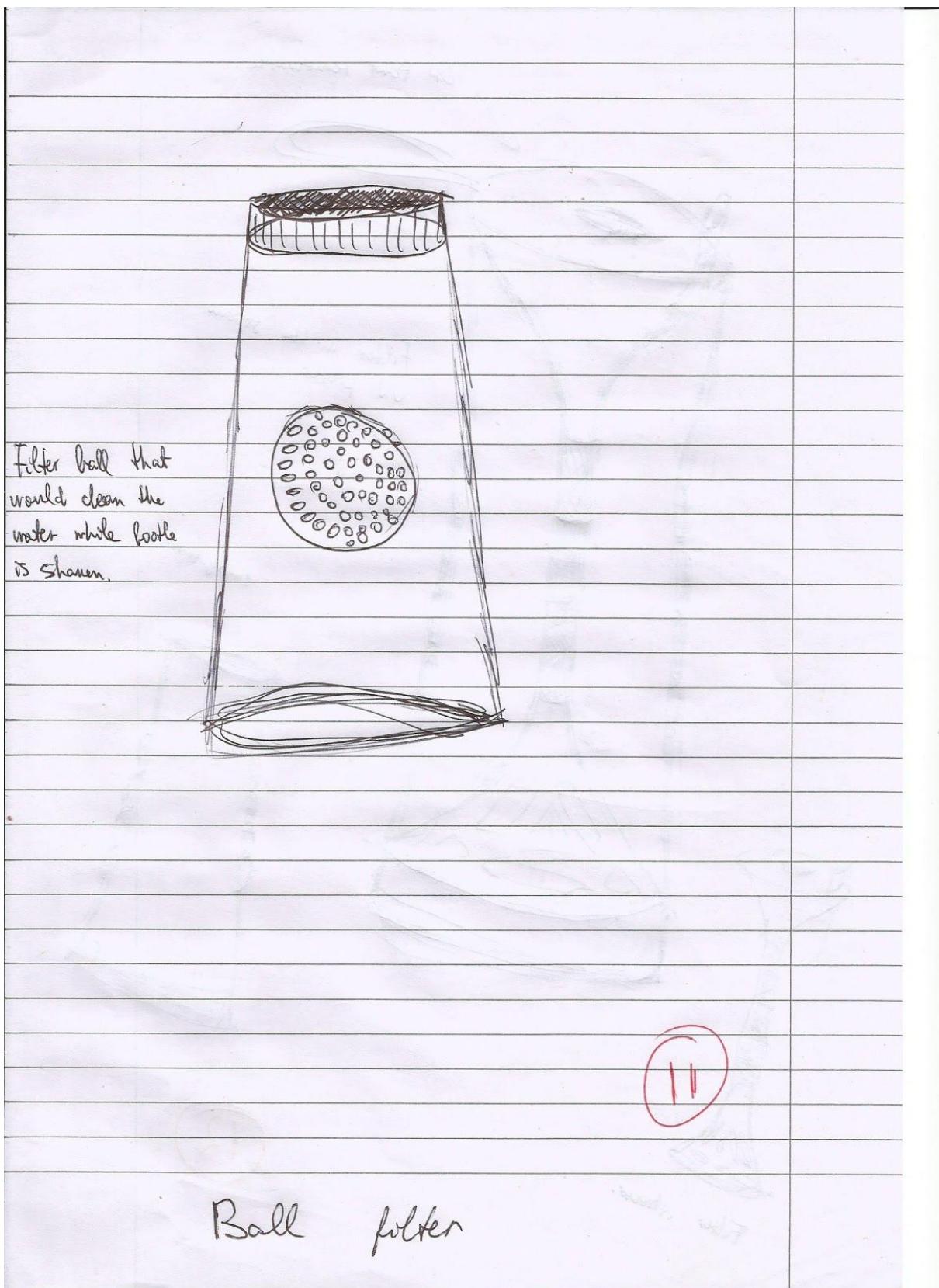
Appendix 19



Appendix 20



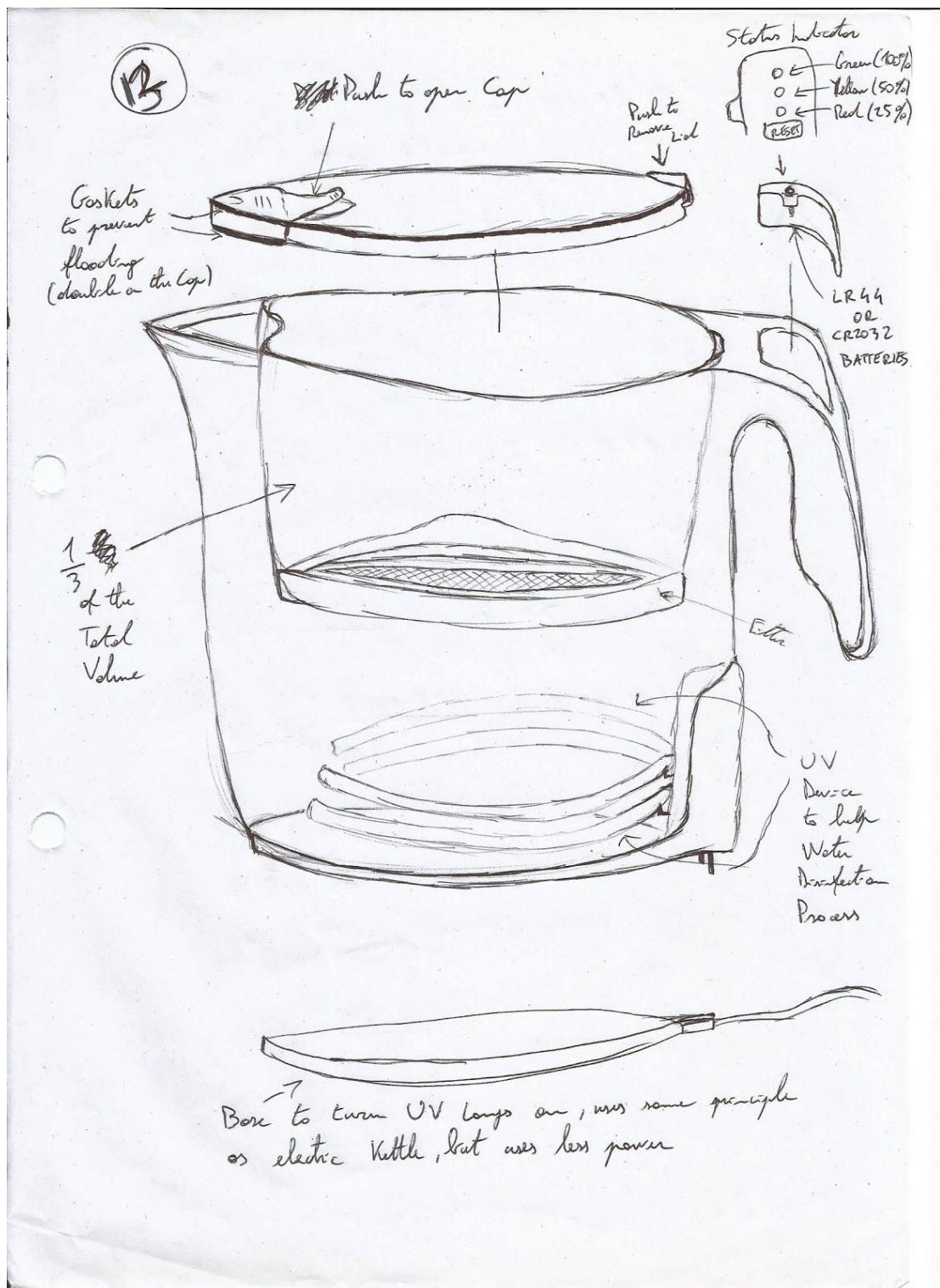
Appendix 21



Appendix 22

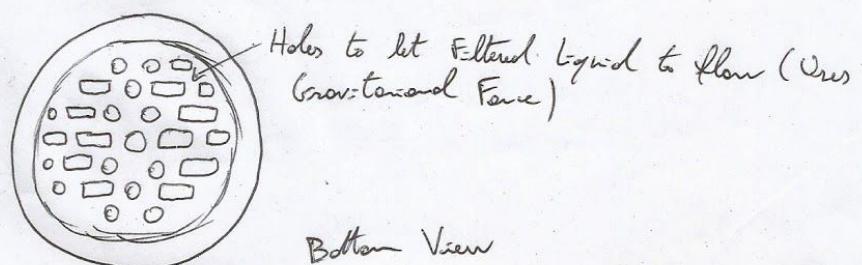
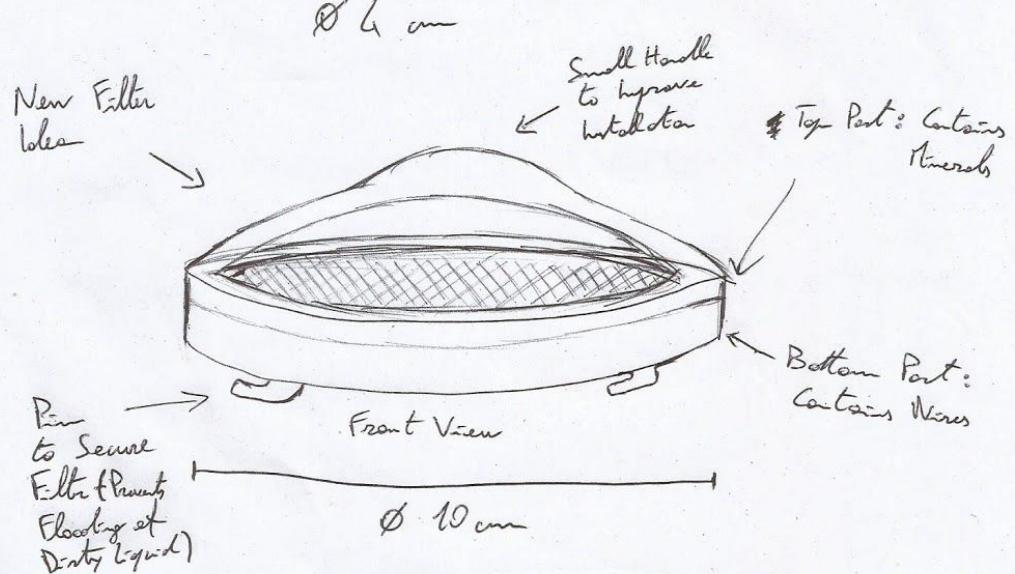
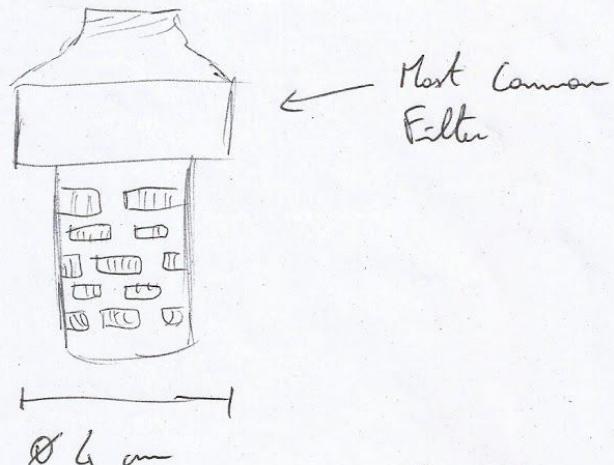


Appendix 23



(B)

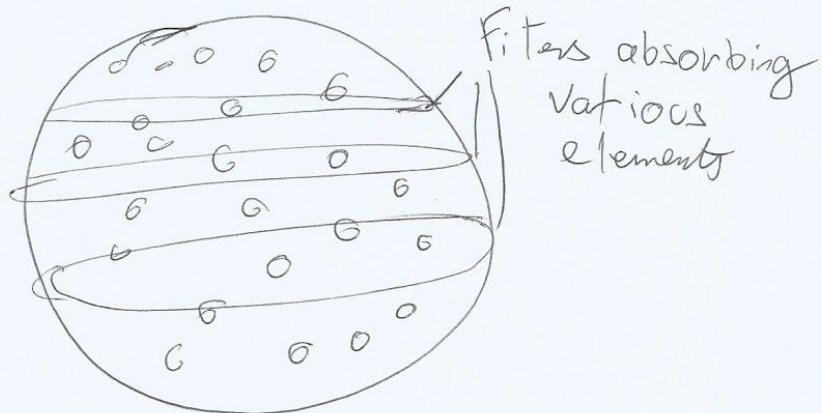
Vertical Filter To Horizontal Filter



Appendix 24

(14)

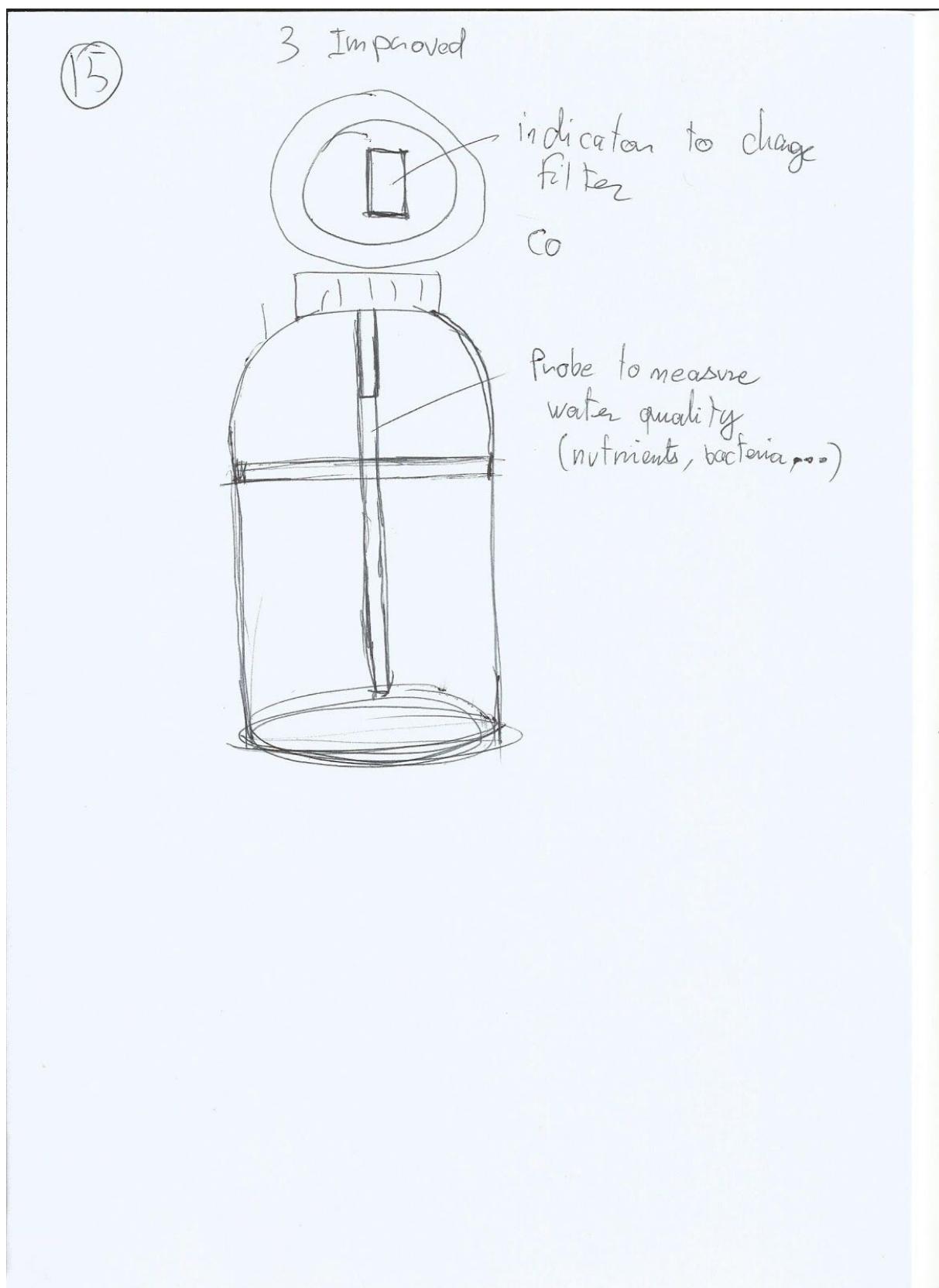
Improved II



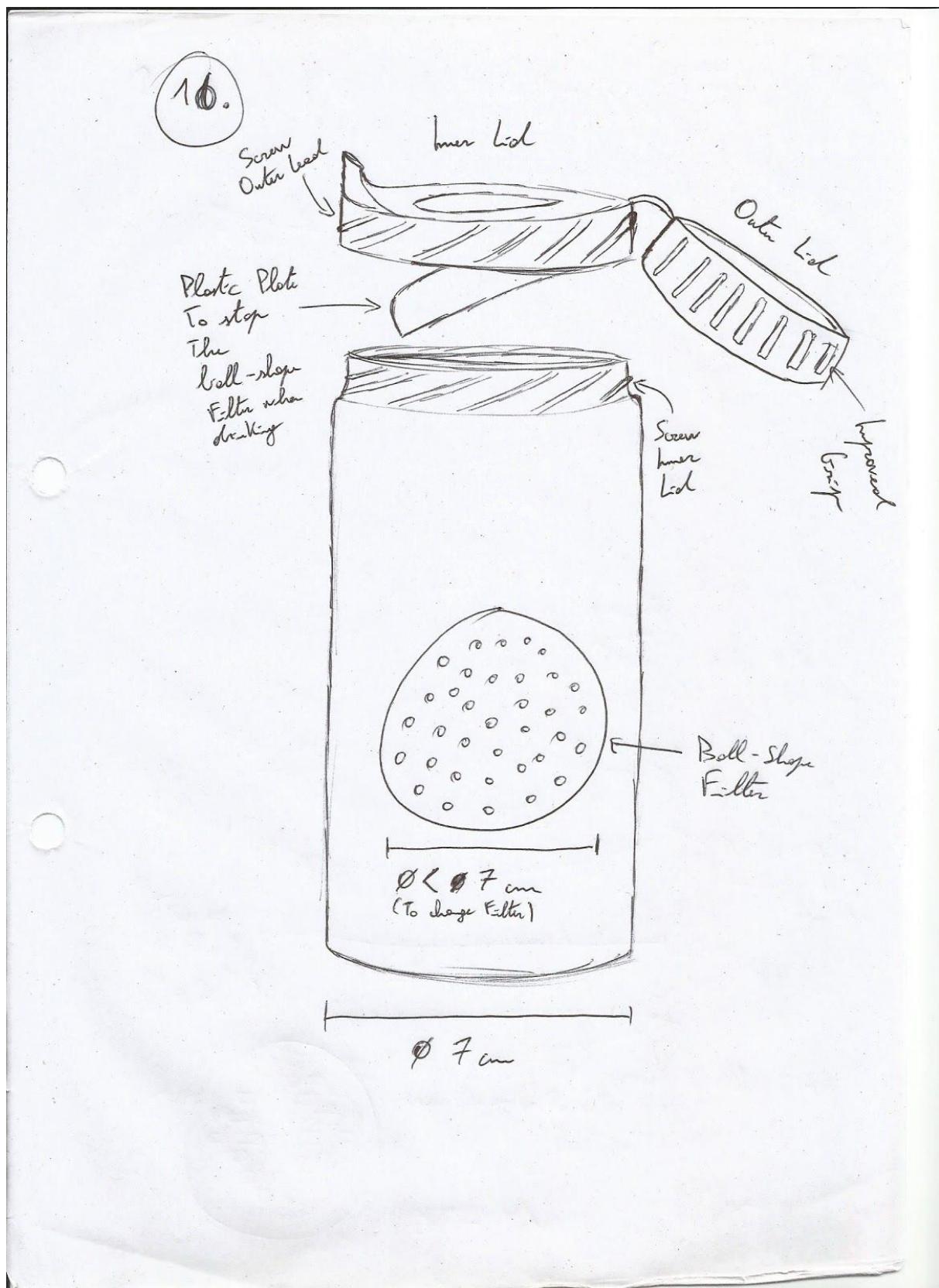
Filters could be discs inserted
in slits in the "ball"

They would change colour when
needing to be replaced

Appendix 25

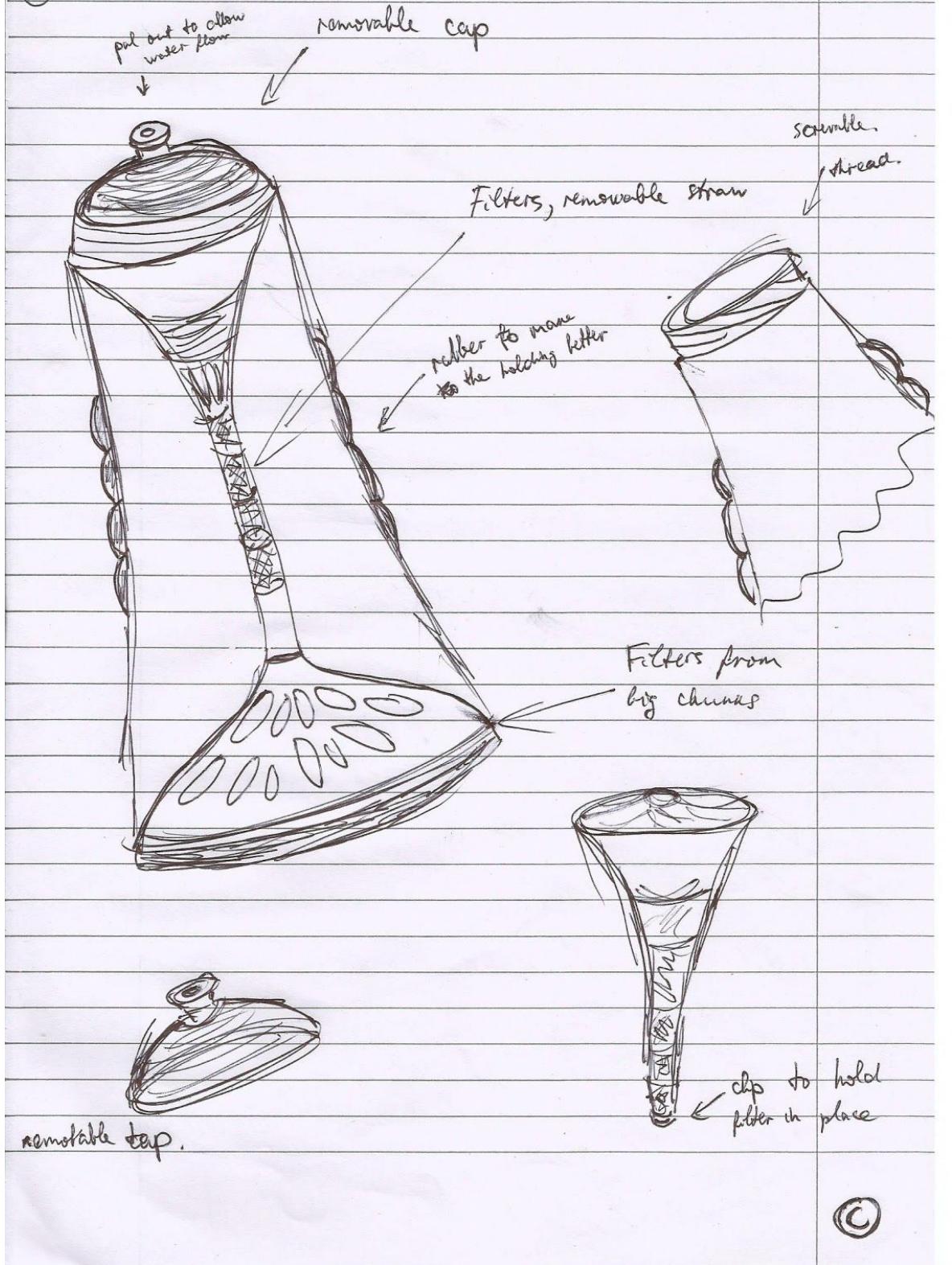


Appendix 26



Appendix 27

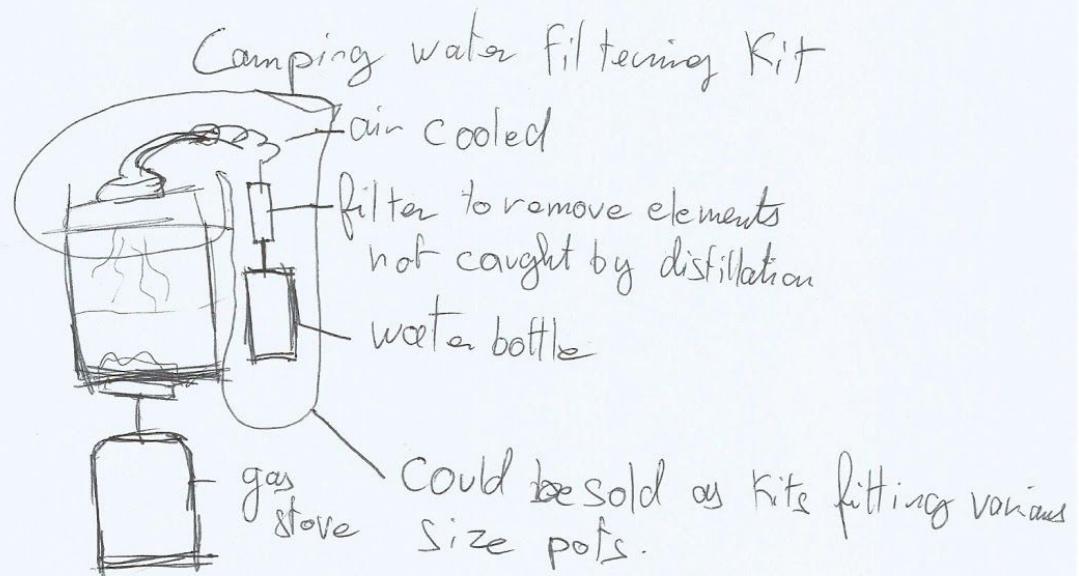
(17) 12 and 9



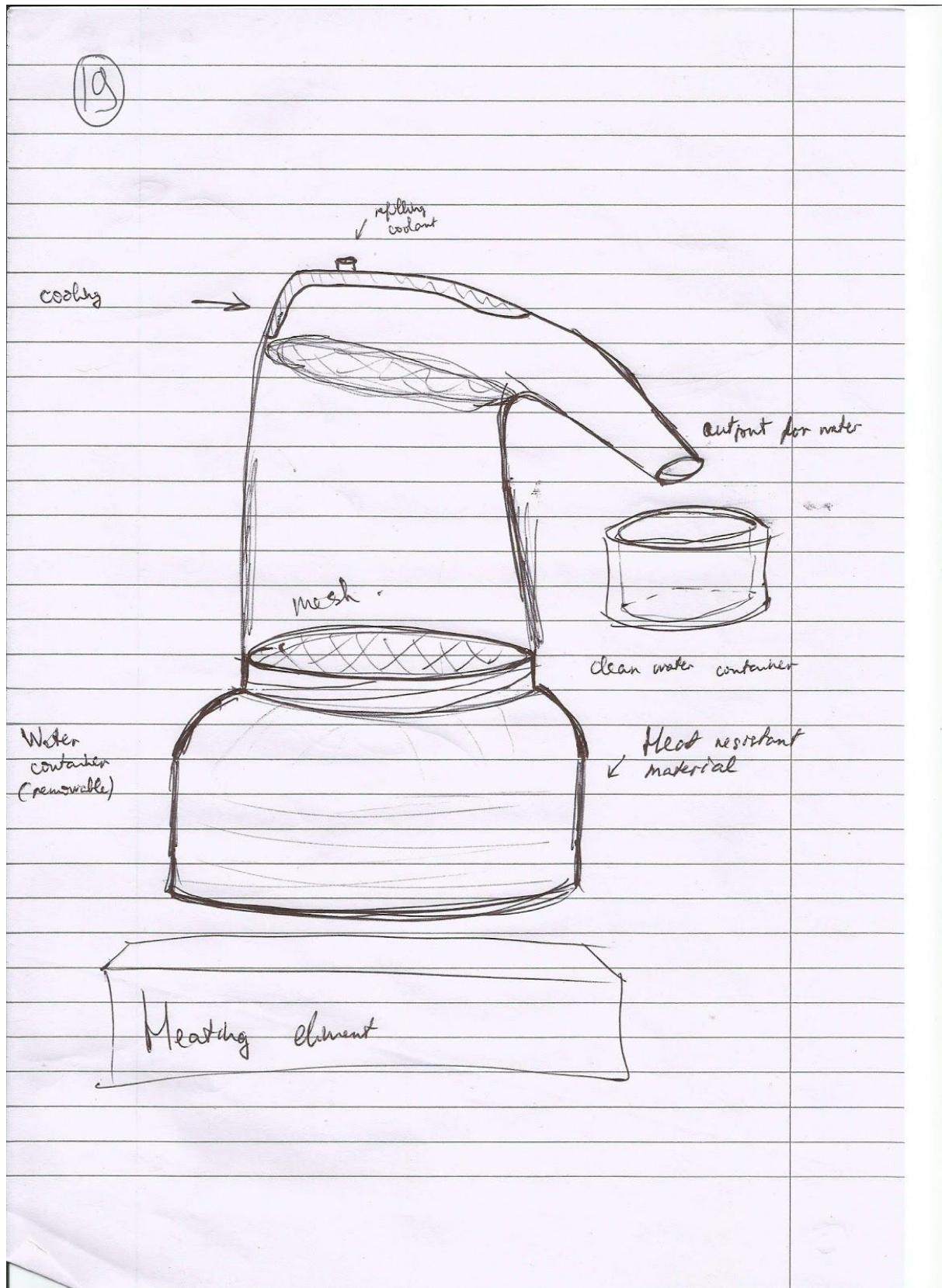
©

(18)

Combination of 6 and 7



Appendix 29



Appendix 30

20

5 improved

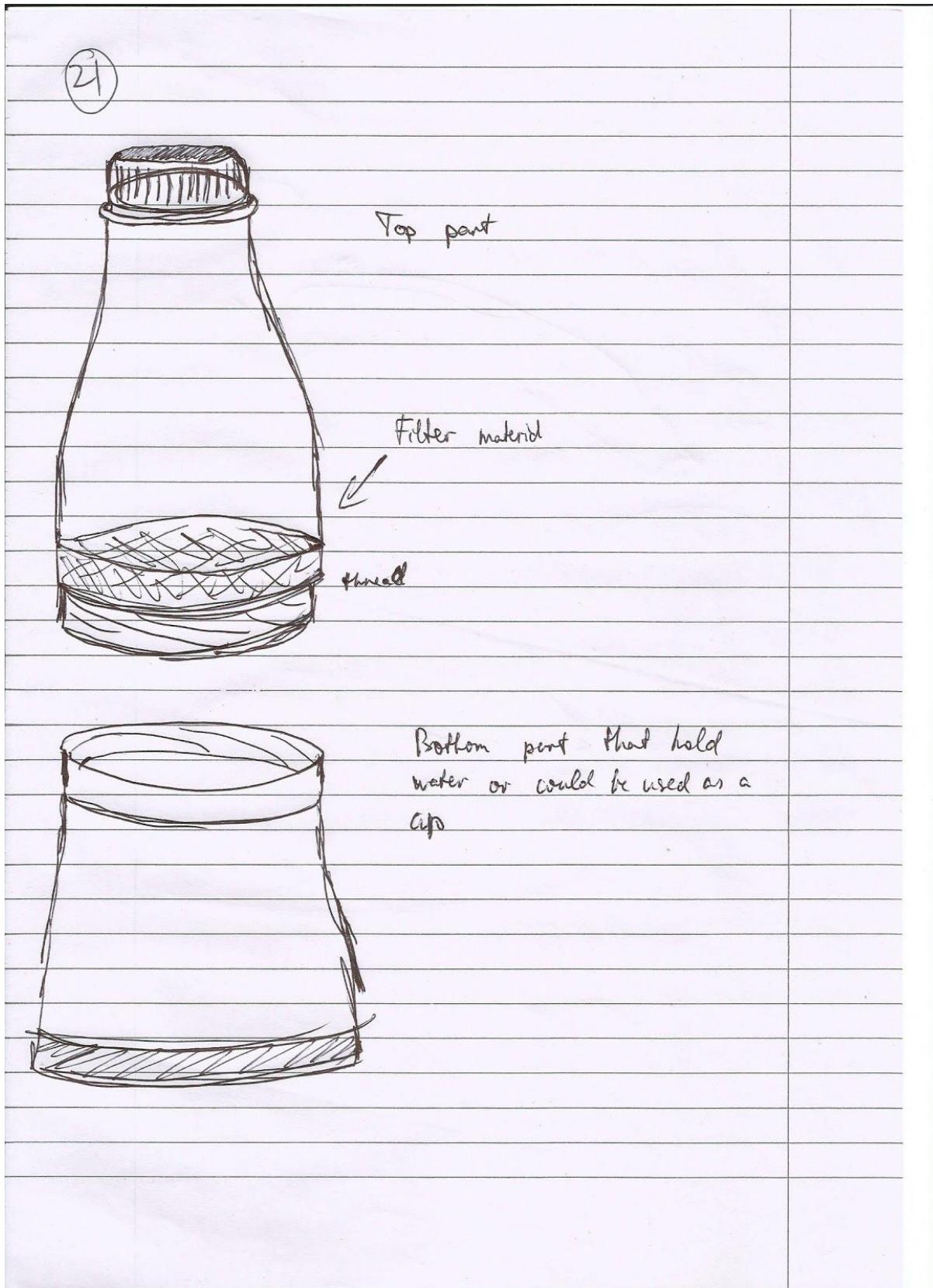
Use tissue material to catch body moisture



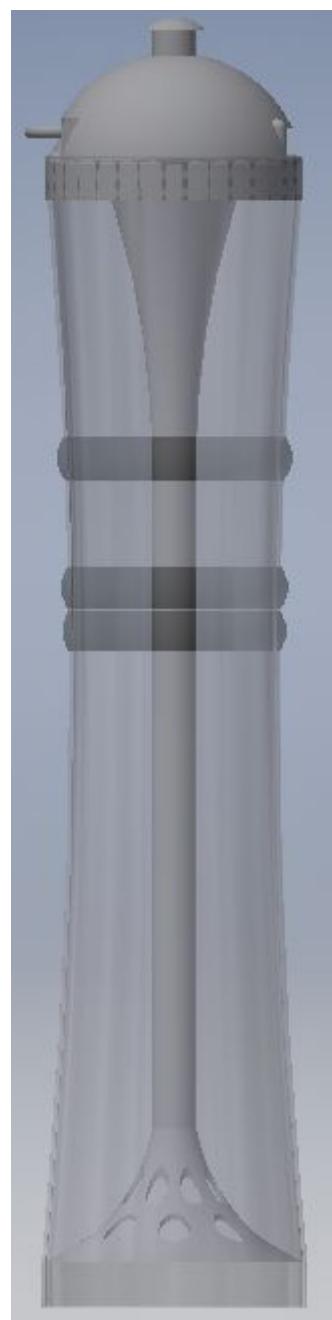
Can also be hung out to catch moisture (rain or mist) in the air



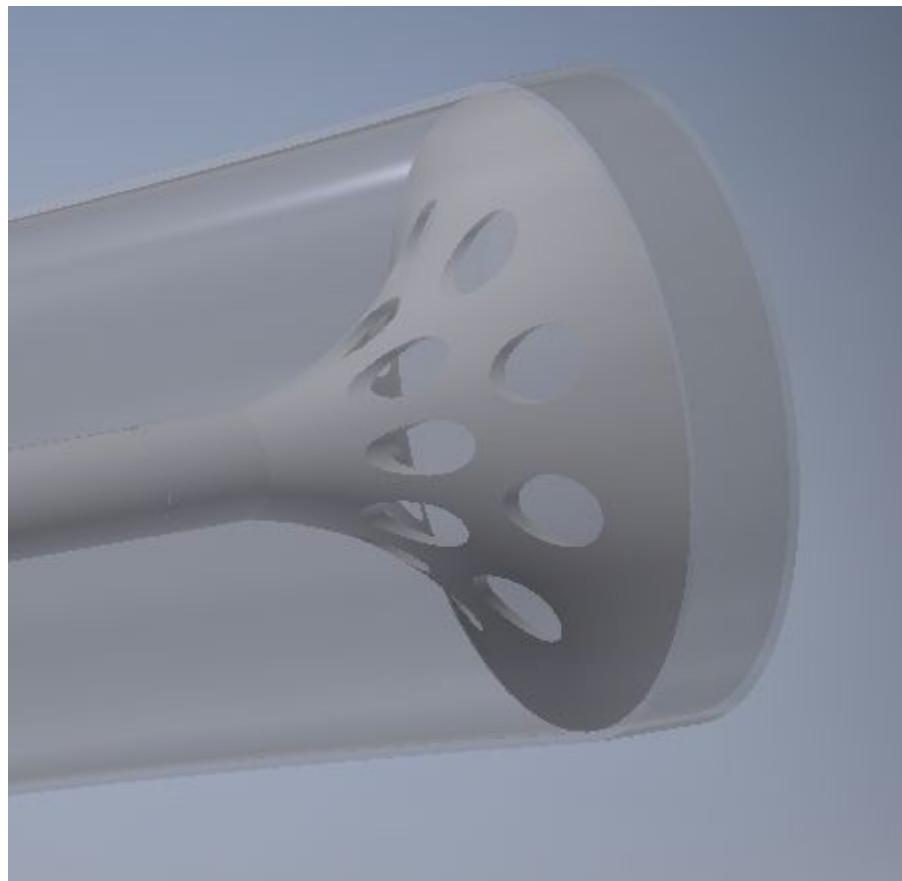
Appendix 31



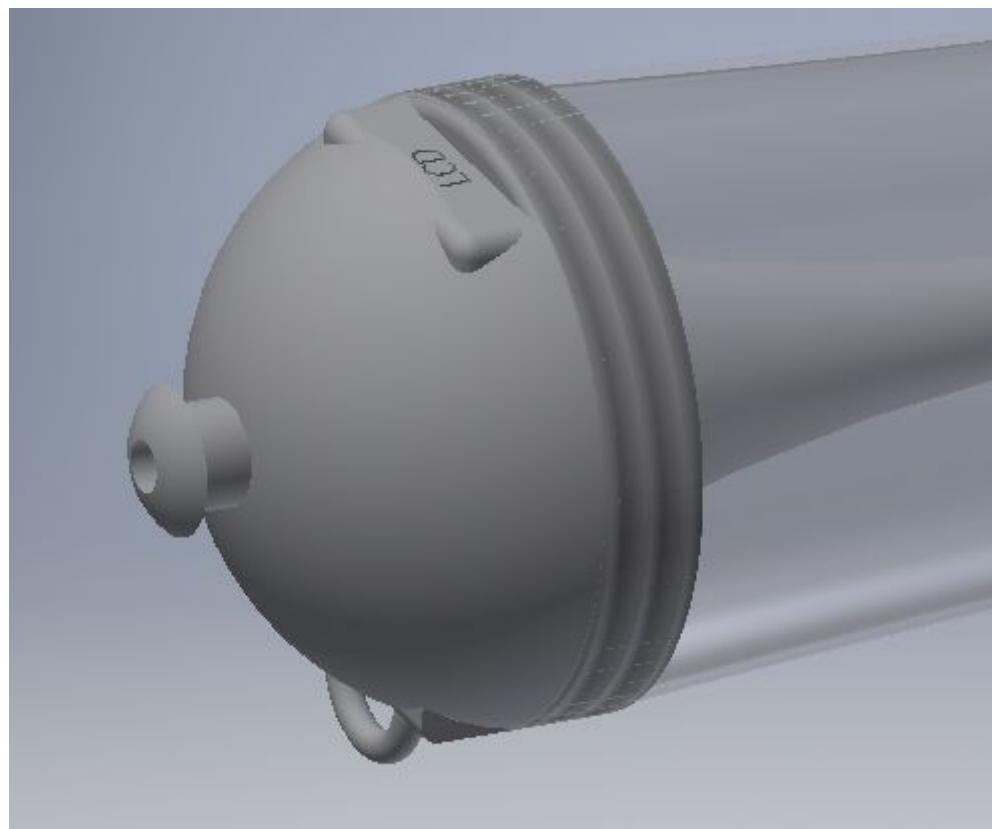
Appendix 32



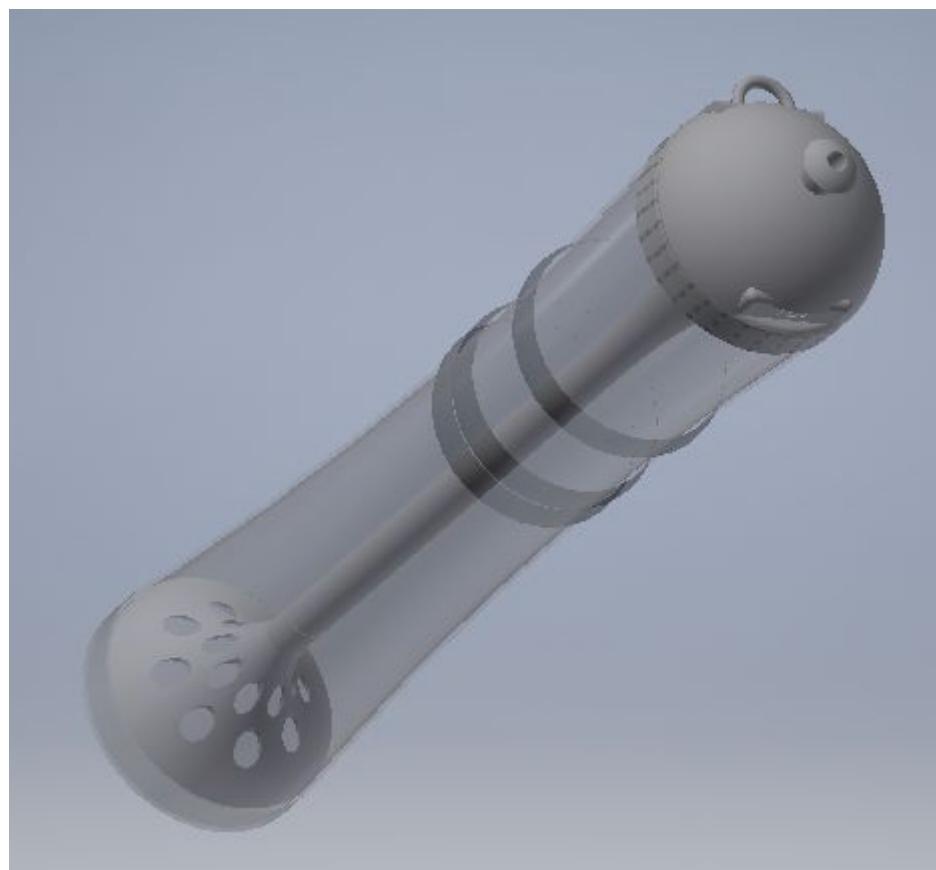
Appendix 33



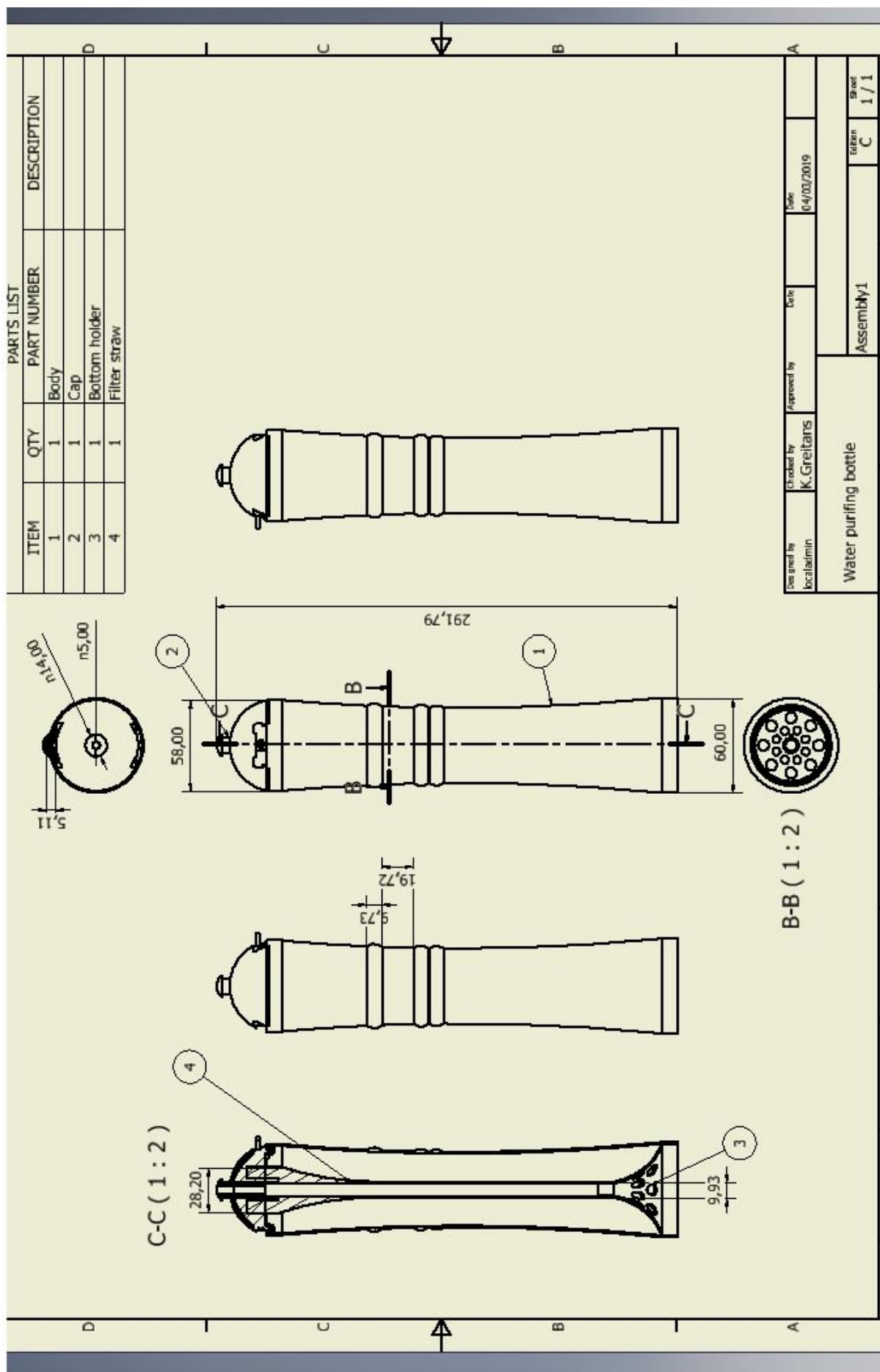
Appendix 34



Appendix 35



Appendix 36 - CAD drawing of straw bottle



Appendix 37 - AHP calculations

| Affordable price. | Straw | Jug | twist |
|-------------------|-------|-----|-------|
| straw | 1 | 5 | 0.5 |
| jug | 0.2 | 1 | 0.2 |
| twist | 2 | 5 | 1 |
| sum | 3.2 | 11 | 1.7 |

| Affordable price. | Straw | Jug | twist | Average |
|-------------------|--------|--------|--------|---------|
| straw | 0.3125 | 0.4545 | 0.2941 | 0.3537 |
| jug | 0.0625 | 0.0909 | 0.1176 | 0.0904 |
| twist | 0.625 | 0.4545 | 0.5882 | 0.5559 |
| sum | 1 | 1 | 1 | 1 |

| | |
|-------------|--------|
| 1.0834 | 3.06 |
| 0.2723 | 3.01 |
| 1.7151 | 3.09 |
| average | 3.05 |
| 0.026954328 | 0.0465 |

| Easy to drink from | Straw | Jug | twist |
|--------------------|-------|-----|-------|
| straw | 1 | 8 | 4 |
| jug | 0.16 | 1 | 0.5 |
| twist | 0.25 | 2 | 1 |
| sum | 1.41 | 11 | 5.5 |

| drink from | Straw | Jug | twist | Average |
|------------|--------|--------|--------|---------|
| straw | 0.7092 | 0.7273 | 0.7273 | 0.7213 |
| jug | 0.1135 | 0.0909 | 0.0909 | 0.0984 |
| twist | 0.1773 | 0.1818 | 0.1818 | 0.1803 |
| sum | 1 | 1 | 1 | 1 |

| | |
|------------|--------|
| 2.23 | 3.09 |
| 0.304 | 3.09 |
| 0.5575 | 3.09 |
| average | 3.09 |
| 0.04531541 | 0.0781 |

| Fast Filtering | Straw | Jug | twist |
|----------------|-------|-----|-------|
| straw | 1 | 0.2 | 0.5 |
| jug | 5 | 1 | 5 |
| twist | 2 | 0.2 | 1 |
| sum | 8 | 1.4 | 6.5 |

| Fast Filtering | Straw | Jug | twist | Average |
|----------------|-------|--------|--------|---------|
| straw | 0.125 | 0.1429 | 0.0769 | 0.1149 |
| jug | 0.625 | 0.7143 | 0.7692 | 0.7028 |
| twist | 0.25 | 0.1429 | 0.1538 | 0.1822 |
| sum | 1 | 1 | 1 | 1 |

| | |
|-------------|--------|
| 0.3466 | 3.02 |
| 2.1886 | 3.11 |
| 0.5527 | 3.03 |
| average | 3.05 |
| 0.027101014 | 0.0467 |

| Leakage proof | Straw | Jug | twist |
|---------------|-------|-----|-------|
| straw | 1 | 2 | 4 |
| jug | 0.5 | 1 | 3 |
| twist | 0.25 | 0.3 | 1 |
| sum | 1.75 | 3.3 | 8 |

| Leakage proof | Straw | Jug | twist | Average |
|---------------|--------|--------|-------|---------|
| straw | 0.5714 | 0.6061 | 0.5 | 0.5592 |
| jug | 0.2857 | 0.303 | 0.375 | 0.3212 |
| twist | 0.1429 | 0.0909 | 0.125 | 0.1196 |
| sum | 1 | 1 | 1 | 1 |

| | |
|-------------|-------|
| 1.68 | 3 |
| 0.9596 | 2.99 |
| 0.3558 | 2.97 |
| average | 2.99 |
| -0.00559775 | -0.01 |

| Filter life monitoring | Straw | Jug | twist |
|------------------------|-------|-----|-------|
| straw | 1 | 0.2 | 2 |
| jug | 5 | 1 | 5 |
| twist | 0.5 | 0.2 | 1 |
| sum | 6.5 | 1.4 | 8 |

| Filter life monitoring | Straw | Jug | twist | Average |
|------------------------|--------|--------|-------|---------|
| straw | 0.1538 | 0.1429 | 0.25 | 0.1822 |
| jug | 0.7692 | 0.7143 | 0.625 | 0.7028 |
| twist | 0.0769 | 0.1429 | 0.125 | 0.1149 |
| sum | 1 | 1 | 1 | 1 |

| | |
|-------------|--------|
| 0.5527 | 3.03 |
| 2.1886 | 3.11 |
| 0.3466 | 3.02 |
| average | 3.05 |
| 0.027101014 | 0.0467 |

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