GATHERING THROUGH **WATER INTEGRATION**

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GATHERING THROUGH WATER INTEGRATION: INTEGRATING WATER AND ITS NATURAL CYCLES IN A HOTEL BUILDING DESIGN FOR AMSTERDAM

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ABSTRACT

Water should be treated differently given the consequences of climate change to water cycles (de Vries, 2000). Adaptations regarding to water cycles can for example be implemented in the built environment, as for a hotel building. For Amsterdam is expected that sea-level will rise and that the rainfall intensity will increase. This rainfall will be alternated with increasing droughts. The rising sea level may cause flooding. Increasing rainfall and increasing drought could cause that mixed sewage systems are more likely to overflow, resulting in residues that are harmful to the environment ending up in nature and an increasing ratio of medication and hormone residues in surface water. In hotel buildings, guest rooms have the greatest impact on the total water consumption. Black and grey flows can be purified from harmful residues and then reused in a hotel building to resolve the predicted problems related to climate change. Rainwater can be stored in and in the surroundings of a hotel to illuminate the sewage system. In addition, awareness for the consequences of climate change should be created.

KEYWORDS: *Water integration, Hotel building design, Marineterrein, Water systems, Amsterdam, Water purification, Water recycling, Water harvesting, Awareness*

I. INTRODUCTION

During the Paris climate conference in December 2015, 195 different countries recognized the dangers of climate change. One of the key points on which the participants of the conference agreed on was that cities should build resilience against the effects of climate change (United Nations, 2017). The changing climate has amongst others major consequences for water systems. In a country such as the Netherlands – which is extremely vulnerable to the consequences of flooding – water should be treated and used differently according to J.M. de Vries, Secretary of State for Transport, Public Works and Water Management, in order to keep the Netherlands safe and livable. The climate will change considerably in the coming decades. The cities and their buildings will be affected (de Vries, 2000). This paper examines how, in the city of Amsterdam in particular, in a hotel building water can be used differently. Therefore, the overall research question of this paper is:

How can water and its natural cycles be integrated in a hotel building design for 'het Marineterrein' in Amsterdam in relation to climate change resilience?

This research focusses on a hotel building because of the fact that a hotel building is a mixed-use building in which waste water is produced by the visitors. It is important to raise awareness of the consequences of climate change. The hotel building can act as a source of inspiration and in this way, raise awareness, because of the fact that a hotel has a semipublic function. This may encourage people to visit the hotel to learn how to address water and climate change issues. This explains the title of the research: *Gathering through water purification.* The research question is investigated by means on four different sub questions. These sub questions are:

1. How do the current water cycles of Amsterdam work?

2. Which problems are predicted in relation to climate change?

3. What is the current state of knowledge about water use in and in hotel buildings?

4. How are integrated water systems in buildings applied in practice?

These questions are answered in three different sub sections. In part one of the results, it has been researched what the current situation is of the water cycles of Amsterdam considering the first two questions. Furthermore, in the second section it has been studied what the current state of knowledge is about is about water use in hotels in relation to the amount of rooms. Lastly, it has been investigated how water is implemented within architecture in practice with the fourth question: In order to make the consequences of climate change in relation to water as delineated as possible, cities need to deal differently with their water circle. Therefore, it is necessary to examine how this change can be integrated into the built environment.

By examining how the water flows of Amsterdam work and what the predicted changes for the future are, an assessment can be made of what the specific problems are that this research can address. That is why the first section of this research examines the natural and mechanical water systems of Amsterdam and the effect on climate change for these systems. This is done by looking into literature on natural water cycles in general and from Amsterdam and by researching different sources about the mechanical water systems of Amsterdam. The results are presented in text in the results and in diagrams in the Appendix. The second section investigates for which parts of the water consumption of a hotel it is interesting to integrate a possible solution. This is done with a literature study into the water use of hotels. The numbers about the water consumption of hotels, found in literature, are then converted, into a calculation model for a small, medium and large hotel. Calculation has been made for a hotel of 20 rooms, 50 rooms and 100 rooms. The calculations can be found in the Appendix. A summary is given in the results of this paper. The fourth sub question has been researched with six case studies. In the third section, it is analysed how integrated water systems are realised in practice. it is considered how the integrated water systems used in the case studies can be implemented in a hotel building, considering the findings made in the previous sections. The three sub sections are then used to answer the main question of this research (Fig. 1).

II. METHOD

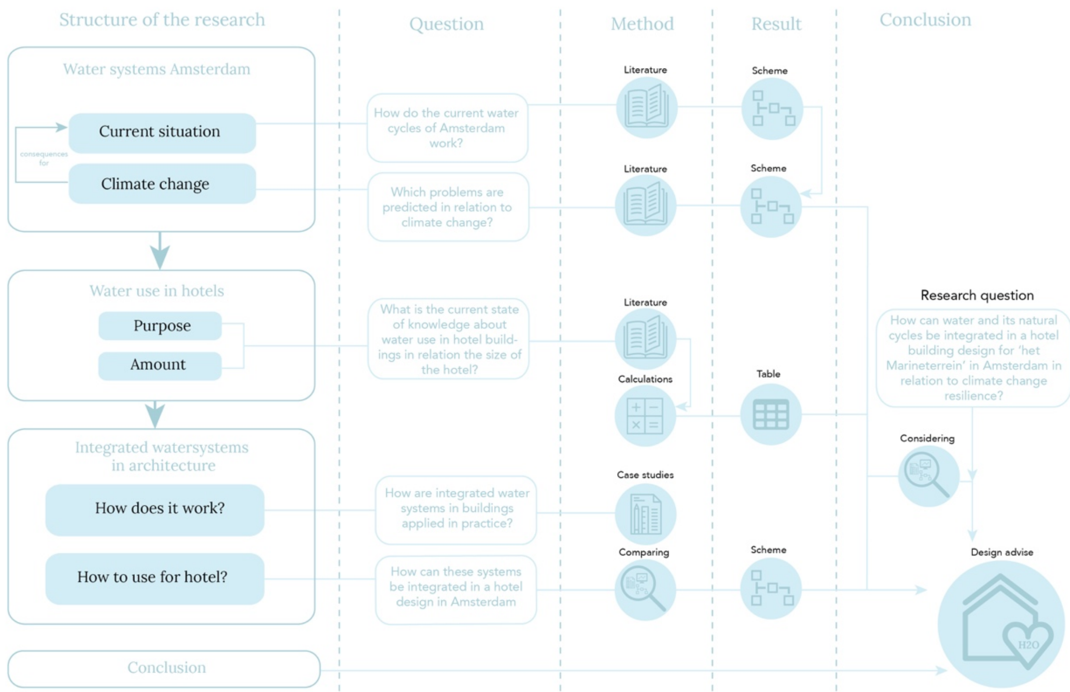

Figure 1. Research diagram

1. The water systems of Amsterdam and the effects of climate change

1.1. The natural water ecosystem

1.1.1. Surface water

The water system of the Netherlands can be divided in a couple of individual system that influence each other. The first system is the surface water system. This system of rivers, ducts and lakes is connected to local systems consisting of streams, ditches and canals. Amsterdam is part of the catchment area of the Rhine and is part of the lower rivers area.
The city of Amsterdam is connected to two important main water structures. These structures are the Noordzeekanaal and the IJselmeergebied. The Noordzeekanaal is significant for the city of Amsterdam because of the fact that water is extracted from here to be processed into drinking water. Due to the shipping sluices, a small amount seawater is flowing into the North Sea Canal. Therefore, this canal has a special ecological character (Baaren, 2010).

1.1.2. Rain water

As already mentioned, the water cycles do not function separately but they are influenced by each other. The motor of the hydrologic cycle is solar energy in combination with gravity. When you observe this cycle in a simplified way, it can be seen as an interchange of evaporation (vaporization of liquid water) and precipitation (condensation of atmospheric water). Evaporation deals with water that is directly evaporated from every non-living surface. This evaporated water condenses into clouds. (Clapham and Clapham Jr, 1973).
When water precipitates above the built environment (for example, above Amsterdam), rainwater enters the sewage system via the gutters. Rainwater that falls onto the pavement flows as well through the gutter into the sewage system. This water is discharged through the sewage system to a water cleaning plant (Waternet, 2017b). Rainwater that does not reach the sewage system via the build environment lands either in surface water or lands on the soil and flows through the soil into ground water.

1.1.3. Ground water

Ground water is water that is located underground in the enclosure between solid particles such as sand grains. The upper surface of ground water is called the phreatic surface. This surface is relatively close to the ground surface in the Netherlands (Dufour, 1998). When rainwater flows into the soil, the phreatic surface rises. This means that during the construction of a building, water often has to be pumped out, which in return leads to a small rise in the groundwater level in the surroundings close to the construction site (Dufour, 1998). In some neighbourhoods in Amsterdam polder sewage systems have been constructed. The polder sewage systems will discharge groundwater into the sewerage network, to prevent the ground water level from being too high (Waternet, 2017a).
As a result of man's actions (e. g. because of peat bogs) parts of the Netherlands, particularly in the West Netherlands, are continuously under threat of flooding. In some parts of the Netherlands, the ground water level is constantly kept artificially low in order to prevent this from happening.
Holocene deposits lie beneath and next to the dunes in the Netherlands. These Holocene deposits are often called the coating layer. It is a protective layer that seals against increasing water pollution. When human intervention affects the coating, this leads to an increase in salty seepage. In some parts of the Netherlands the torment is not salty. For example, fresh water rises to the surface in the Bethunepolder. The municipality of Amsterdam uses this fresh water that comes to the surface for the drinking water supply (Dufour, 1998).

1.2. Mechanical water systems of Amsterdam

1.2.1. Drinking water

Since 1853, on average 66 percent of the drinking water of Amsterdam is pre-purified at the dune works. This water originally flows through the river Rhine and is pumped from the Lekkanaal near Nieuwegein to the dunes after pre-purification, where it is naturally purified by the dune sand for 3 months. This water follows its way to the treatment plant at Leiduin where it is cleaned mechanically. After this process, the water enters the pipes

which are connected to the city (Amsterdamse Waterleidingduinen, 2017).
The municipality of Amsterdam acquires water from the Bethunepolder near Maarssen, as has already been mentioned. This water is first purified naturally in the Loenderveense plassen. The Loenderveense plassen area is a conservation area from which part of the lakes are used to purify the water. The seepage water from the Bethunepolder is pumped through the water supply duct to the pond. Here water is purified naturally. After 100 days, the purified water is pumped to Weesperkarspel where it is purified into drinking water by means of a treatment plant installation. Approximately one third of the drinking water for Amsterdam is obtained from this process (Waternet, 2017c). When the water from the Bethunepolder is not available, for example due to drought, the intake point Nieuwersluis is used.

1.2.2. Sewage systems

After the water is used in a building it flows into the sewage system. Amsterdam has two kinds of sewage systems. In the old neighborhoods of Amsterdam, a mixed sewage system is in use. In this system, the wastewater and rainwater come together in the same system. This mixed water continues its way to the sewage pumping station. After being purified the water reaches the surface water through the water purification system.
Newer neighborhoods have separate sewage systems. Rainwater has its own sewage system and is routed directly into the surface water. Wastewater is led into the water purification system before its flows into the surface water.

1.2.3. Wastewater cleaning

Water that is used in buildings flows back into the sewage system and can be divided into black and grey water (Timmeren and Tawil, 1999). Grey water is domestic wastewater that does not originate from the toilet. For example, It results from water being used by the washing machine, shower and in the kitchen (Killan Water, 2017). Grey water can contain large quantities of heavy metals, e. g. from pipes. In addition, grey water can contain different of residues from soaps, cosmetics, hairs and skin flakes (Stowa, 2017a). Black water flows as well from households into the sewage system. This black water is water that is derived from the toilet and it can contain organic substances, fertilizers, medication residues, hormones and pathogenic bacteria from urine and faeces. In addition, it contains as well toilet paper and other waste that is thrown into the toilet (Stowa, 2017b).
Sewage water also includes rainwater originating from mixed sewage systems or from the drainage of the streets. This water is channeled via the sewage system to the sewage water purification installation called RWZI (Rioolwaterzuiveringsinstallatie) in Amsterdam West. Here, the water is purified as much as possible. Unfortunately, this is not always entirely possible. When more and more water is going to the RWZI, the system is flushed through faster and then the wastewater is cleaned less diligent. The RWI Amsterdam West then discharges the water into the IJ, as a result of which the water ends up in the surface water again. Cleaned waste water is then diluted with water from the IJ (Amsterdecks, 2017). In this case, water that ends up in the IJ still contains very small amounts of residues from soaps, cosmetics, hairs and skin flakes, fertilizers, medication residues, hormones and pathogenic bacteria from urine and faeces. However, this is strongly diluted with large amounts of surface water. The water systems of Amsterdam are illustrated in a diagram in Appendix 1.

1.3. The effects of climate change on the water system of Amsterdam

1.3.1. Predictions in relation to water

Industry, energy generation, transport and agriculture are emitting more and more greenhouse gases. Due to the increase of these gases, the atmosphere is absorbing heat from the sun increasingly. As a result, climate is changing and the earth is warming up increasingly (Ministerie van Infrastructuur en Mileu, 2017). Since the Industrial Revolution started, the temperature has already risen 1.5 degree in the Netherlands (Rijksoverheid, 2017). This will increase if measures won't be made quickly. Water management is one of the most important aspects that will be degraded. Firstly, it is expected that sea level will rise (Smith, 2012). Due to among others the melting of the ice caps and expansion of the water volume, sea levels will rise. When sea levels rise significantly, this means that parts of the Netherlands, including Amsterdam, can flood. Climate change will also increase the amount of rainfall. rainfall will become increasingly severe. These increasing wet periods will alternate with an increase of the number of more extreme dry periods (Rijksoverheid, 2017).

1.3.2. Consequences for the water systems of Amsterdam

Climate change has several consequences for the water system of Amsterdam (Fig. 2). Because of the increase of the amount of rainfall the sewage water system will be less able to cope with the amount of water. This will be a particular problem for mixed sewage systems. These systems will overflow faster, as a result of which not only the rainwater will flow into the surrounding area, but as well a diluted portion of the untreated grey water will flow out of the sewage system. As a result, residues that are harmful to the environment ending up in surface water. In addition, dry periods will also have an impact on the environment. Because of the fact that in certain areas the water levels will be lower, the concentration of grey and black water residues in surface water becomes higher. This means, for example, that the amount of medication and hormone residues in the water will increase. The ageing of the population will also lead to an increase in the use of medicines, thereby increasing concentration. These residues are damaging to the environment and ultimately also to humans because they end up in our drinking water via surface water. This is partly due to the fact that the RWZI cannot filter all types of medication residues from the water and due to the fact that the pressure on the system is increased by the more extreme rainfall. The residues not only derive from hospitals but also from residential areas (Moermond et al., 2016). Possible effects of medicines and hormones in our surface water include behavioral changes, tissue damage and effects on the reproduction of aquatic organisms, which can disrupt the ecosystem as a whole. The impact on the environment cannot be estimated precisely because not all substances are known to have an impact on the environment (Moermond et al., 2016). The consequences of climate change on the water systems of Amsterdam are illustrated in a diagram in Appendix 1.

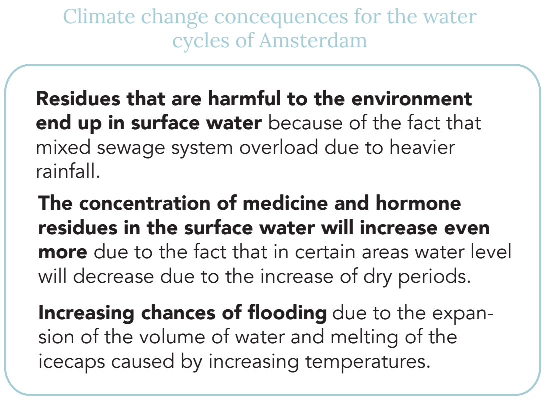

Figure 2. Climate change consequences

2. Water use in hotels

Hotels use relatively large amounts of water (Cohen, 2017). Water usage in hotels can be illustrated in different ways, namely: by user, room or hotel type. Since the design of the hotel building has not yet been made, it has decided in this study to calculate an average of the water use per day, per function, for different sizes of hotels. It was chosen to do calculations for a hotel with 20 rooms, 50 rooms and 100 rooms. The data of these three types can be compared, such that the eventual type of hotel can be selected later in the design process. For now, a standard hotel with an average amount of public space and outdoor space has been assumed.
Because of the fact that the hotel will be a new building, a favorable standard will therefore be assumed. It is possible to opt for water-saving equipment (Seneviratne, 2007). Exact calculations can be found in Appendix 2.

2.1. Guestrooms

Water use in the guestrooms mainly consists of showers (6 L/min), which are used six minutes per room per day, toilets (6 / 3 L per flush), which are flushed four times a day per room, sinks (6 L/min), which are used three minutes per day per room (Seneviratne, 2007). 10% percent of water use comes on top of this for cleaning (Styles et al., 2015). The calculations show that a hotel of 20 rooms consumes 1400 L per day. For a hotel with 50 rooms, 3500 L of water is used and for a hotel with 100 rooms, 7000 L of water is used per day. 20 to 22 percent of this will eventually become black water, the remaining quantity will end up in the sewage system as grey water.

It has been shown that the main water consumption derives from the hotel rooms. It may be beneficial to take this into account during the design process of the integrated water system of the building. Another important aspect that emerged as a result of the calculation is that the relative water consumption per room decreases as the number of hotel rooms increases.

2.2. Public spaces

The amount of water use in the public space can be calculated by multiplying 0.33 by the amount of water use of the number of rooms. Public sinks (6 L/min) (Styles et al., 2015) are used 0.5 minutes on average per person. Public toilets (6 / 3 L per flush) are flushed 4 times a day per person (Styles et al., 2015).

Calculations for the water use of the public space show that a hotel with 20 rooms results in a water consumption of 125.4 L per day. For a hotel with 50 rooms there is a water consumption of 313.5 L per day and for a hotel with 100 rooms there is a water consumption of 627 L per day. The calculations show that the water consumption of the public space, unlike the hotel rooms, is relatively low.

2.3. Kitchen

The dishes are usually pre-washed before entering the dishwasher. Sinks (6 L/min) (Seneviratne, 2007) are used for 0.7 minutes per guest (Styles et al., 2015). In this calculation, drinking water and water used for cooking are not taken into account because this amount is relatively small.

On average one rack is used per two guests for the dishwasher. The dishwasher uses 3 L of water per rack (Styles et al., 2015). This means that a hotel with 20 rooms uses 30 L for dishwashing per day. A hotel with 50 rooms uses 75 L per day for dishwashing and a hotel with 100 rooms uses 150 L a day. The kitchen also appears to have a relatively low water consumption when compared to the water consumption of the guest rooms.

2.4. Laundry and cleaning

In hotels, laundry can be outsourced or the laundry can be taken care of in-house. When the laundry is done in-house, the washing machine uses about 5 L per kg of laundry (Seneviratne, 2007). 2.8 kg of laundry is provided per room per day (Styles et al., 2015). It turns out that the water used for laundry is about a tenfold of the water use in L of the number of rooms. This means that a hotel with 20 rooms uses 280 L for laundry per day. A hotel with 50 rooms uses 700 L per day for laundry and a hotel with 100 rooms uses 1400 L a day.

2.5. Swimming pool

Because swimming water needs to have a comfortable swimming temperature, part of the water evaporates. Water evaporation from the pool is estimated at 325 L/day. Backwashing is used to ensure the swimming water maintains its quality. This backwashing equates to a water consumption of 1.6 minutes per day and 400 L per minute.

The pool showers are also used before and after swimming. It is estimated that about 25% of guests use these showers for about 2 minutes a day.

The calculations show that having a swimming pool for each type of hotel requires approximately the same amount of water, provided that the pool is the same size. On average, this consumption amounts to approximately 1150 L per day.

2.6. Outdoor area

16% the total of water use is used outside the hotel building, for example for watering the plants (EPA Watersense, 2016). It turns out that the ratio between the water used outside and the water consumed in the rooms increases as the number of rooms increases.

2.7. Cooling

55L per occupied room per night (EPA Watersense, 2016) This will only be used in summer. For a hotel with 20 rooms 1100 L of water will be used per day, a hotel with 50 rooms will be using 2750 L of water per day and a hotel of 100 rooms will be using 5500 L of water a day. With the cooling system, 26 to 35 percent more water is consumed indoor.

2.8. Other

11% of the total water use of the hotel will be used by other matters, for example leakages (EPA Watersense, 2016). This means that a hotel with 20 rooms use 459 L of water a day, a hotel with 50 rooms will use 931 L of water a day and a hotel with 100 rooms will be using 1750 L of water a day.

3. Integrated water systems in practice

According to Peter F. Smith a home ecology improvement with regards to water should contain three elements, namely reducing the consumption, harvesting rainwater and recycling grey water (Smith, 2012). This could also be used for a building with a hotel function. Results in Part 1 have shown that, in particular, increasing droughts are interspersed with extreme wet periods and the risk of flooding. In addition, flooding of the sewage systems is negative for the water quality of the surface water. This can be particularly risky in dry periods. This results in a higher concentration of residues from grey and black water. This case study will examine if these designs involve solutions that can be useful for the storage of water in the event of flooding and the cleaning of waste water inside a building. Therefore, it has been chosen to investigate six projects which include one or more of the four case study conditions shown in Figure 3. No specific attention has been paid to hotel buildings in choosing these projects, because architectural projects on water cycles are relatively scarce. In addition, the different systems of each project are shown in a diagram. It is subsequently examined how these systems could be connected to a hotel building in Amsterdam. A documentation of the case study can be found in Appendix 3.

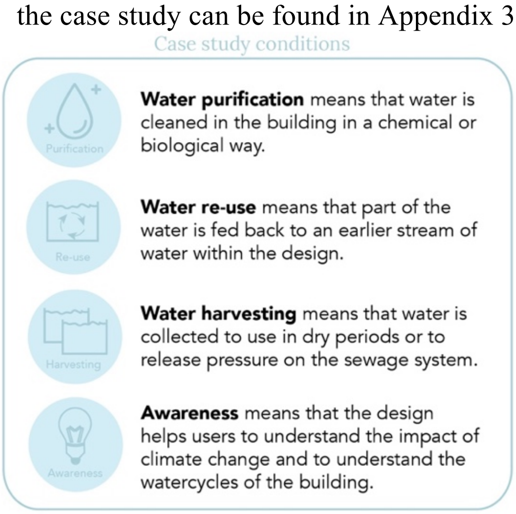

Figure 3. Explanation conditions

3.1. Water integration implemented in practice

1.1.1. Whitney Water Purification Facility – New Haven

3.1.1.1. Project explanation

The Whitney Water Purification Facility is built to provide water to South Central Connecticut and also functions as a public park and as an educational facility. The facility is designed by is Steven Holl Architects. The purpose of the architects was to show how a green design with a watershed management works. The designers tried to combine a water purification building with a public park (The American Institute of Architects, 2017). The facility purifies 68.000 m^3 of water a day. The water treatment plant is situated under the ground below the park (Ryan, 2010).

3.1.1.2. Water system

By letting the water run into the purification plant by use of gravity, little energy is used to get the water in the system (The American Institute of Architects, 2017). The various phases of the water purification system are displayed in the park. In this way, the park has an educational function for visitors as well. The six phases of water cleaning are: rapid mix, flocculation, air flotation, ozonation, granular activated carbon filtration and a clear well (Ryan, 2010). Two examples of how the water cleaning systems are visualized in the landscape design of the park are the agitated grass mounds that are penetrated by little streams to render the rapid mix and the field of wild mosses which corresponds to the bubbling of the ozontation (Steven Holl Architects, 2007).

3.1.1.3. Possible application

The concept of making use of gravity instead of an energy consuming pump might also be valuable for the design of a hotel in Amsterdam. Furthermore, the concept of a mix of a functional and educational design can also be very interesting in the design of the hotel in Amsterdam, as the hotel also should serve as a source of inspiration. The water sewage plant in Connecticut cleans water for the entire area. Of course, this doesn't hold for the hotel design. Therefore, the functionality of the water treatment system in the hotel design is less important.

3.1.2. Covent Garden – Brussels

3.1.2.1. Project explanation

Covent Garden is a commercial office building with a retail and shopping area at the ground floor. The architectural firms are Art and Build Architect and Montois Partners. The building consists of two separate buildings which are connected by a garden covered by glass. In this area, called the atrium, there is a plant-based perk responsible for the last phase of the water management of the building (Design Build Network, 2017).

3.1.2.2. Water system

A biological water cleaning is placed in the basement. The atrium houses the water cascading with helophyte filters. The plants clean waste water after the pre-purification process. After a purification process the water is recycled: it can be used again in the building itself (Design Build Network, 2017). Due to the membrane bio reactor, the water is purified from pathogens and chemical pollutants (such as medicine residues) as well. The quality of the water is relatively in a good condition and after following the entire purification process it can be reused for certain functions within the building. The last part of the biological water purification is done by using helophyte filters. Because of the fact that the plants are covered by the atrium, they can grow under ideal conditions all year round and ensure the cleaning of the water. The purified water is used after the process for irrigation and as cleaning water (Luscuere, 2017).

3.1.2.3. Possible application

In terms of scale, this building is comparable to a hotel building. For instance: an atrium could function as a lobby. This case study shows that wastewater is cleaned and later used for cleaning and watering of the plants. This could be applicable to hotel design too. However, care must be taken to ensure a proper balance between the amount of grey and black water supplied and the amount of water required for cleaning and the plants. Therefore, a larger water tank of an actual water harvesting concept should be added. Another solution could be that the cleaned water will be given back to the sewage system after the complete purification process.

3.1.3. De Ceuvel – Amsterdam

3.1.3.1. Project explanation

The Ceuvel is located near the shipyard of the Hasseltkanaal in Amsterdam North. It is intended as a sustainable breeding ground for creative people. The designer of the project has placed houseboats on the ground, creating a small harbour on the quay. The curving landing stage provides an idyllic effect for visitors. Energy and nutrient streams are used as a starting point for sustainability (De Ceuvel, 2017b).

3.1.3.2. Water system

Since it was not possible to install a sewage system because of the contaminated soil, compost toilets are used in the design. The bio filter cleans the waste water from pollutants. Additionally, the used water of the buildings is filtered with helophyte filters.
This water is then used in the aquaponics greenhouse. The vegetables and herbs from the greenhouse are afterwards used in the restaurant (De Ceuvel, 2017a).

3.1.3.3. Possible application

This method of reusing water for the production of food can also be useful for a hotel when a restaurant or shop is linked to it. The use of filtering with a helophyte filter can also be in line with the water focus of the hotel. However, attention must be paid to the ratio between the number of functions that create waste water and those that can use the recycled water. If necessary, a surplus of recycled water could possibly be fed into to the sewage system. In addition, having a restaurant which uses the waste of the hotel can raise awareness for the environmental problems. However, this process has many involved parties and visitors may dislike the idea of eating food that has grown from their ‘own’ toilet waste.

3.1.4. Block 6 Berlin

3.1.4.1. Project explanation

Block 6 is a roof water farm which has a grey water flow and a black water flow separated from each other. The integrated water system of Block 6 was initially intended as an inspiration-based project for the International Building Exhibition 1987 and Experimental Housing and Urban Development research programme. In 2006, the water re-use concept was redesigned.

3.1.4.2. Water system

With the system of Block 6 grey water is filtered until it has a bath-water quality. The hygienic quality of the water is checked during the process. The water is used for growing vegetables and keeping fish. Applicable liquid fertilizer is extracted from the black water, which can be applied to the plant and vegetable products (Roof Water Farm, 2017).

3.1.4.3. Possible application

The fact that in this case study the grey water system is separate from the black water system, can be interesting to use in the design of the hotel. The reuse of the purified water can also be used for the hotel design for growing vegetables, keeping fish and filtering fertilizer. However, the fact that in this system, black water isn't purified, still brings along the problem of getting hormones and medicine residues in our surface water. Therefore, this system is on its own not suitable for a hotel design for the Marineterrein. For this system, it is equally necessary to find a solution for the overflow of purified waste water and as well that people may dislike the idea of a fertilizer made from their own toilet waste.

3.1.5. Benthemplein – Rotterdam

3.1.5.1. Project explanation

The Benthemplein square in Rotterdam was designed by De Urbanisten. This design replaced a grey and monotonous city square with an attractive public space in which there was room for green, sports and water (Gemeente Rotterdam, 2017).

3.1.5.2. Water system

In the event of heavy rainfall, the square receives all water from the surrounding roofs. As this stored water does not flow into the sewage water system immediately, the sewage system is relieved, which helps in preventing the system from flooding (Gemeente Rotterdam, 2017).

3.1.5.3. Possible application

The idea of a water square, to store excess water such that the sewage system is relieved in case of heavy rainfall, can be used in the public space around the hotel. In times of drought, the stored water can be released into the sewage system to prevent low water levels. A disadvantage may be that a water square will occupy a large amount of space of the Marineterrein.

3.1.6. Deutzer hafen – Cologne

3.1.6.1. Project explanation

Deutzer hafen is the transformation project of the old harbour area of Cologne. The designer of the project is Cobe. The goal of the architects is to transform this harbour area, in which a sustainable and vibrant area in which a public swimming pool and waterfall draw the attention (COBE, 2017).

3.1.6.2. Water system

The water system of the Deuzer hafen is based on the idea of harvesting water during heavy rainfall. This solves the problem of the flooding of the Rhine in this area and gives the neighbourhood an unique character at the same time (COBE, 2017).

3.1.6.3. Possible application

For a hotel design a natural swimming pool as a solution for flooding can be useful. However, it should be considered that the water should be cleaned well to ensure the health of the users and the water should as well be refreshed constantly to prevent the water from still not being sufficiently clean for swimming. It is as well questionable whether an outdoor swimming pool will be used. A solution could be that the pool would be a decorative pool.

IV. Conclusions

As a result of climate change, it is expected that sea-levels will rise. Rising sea-levels can increase the changes of flooding for Amsterdam amongst others. It is as well expected that climate change will cause more intense rainfall and increasing periods of drought. This can result in mixed sewage systems being more likely to overflow, resulting in residues that are harmful to the environment ending up in nature and an increasing ratio of medication and hormone residues in surface water.

In hotel buildings, guest rooms are the biggest water consumers. It may be interesting to integrate this water flow into a water system for the building. In order to counteract the effects of climate change in a design of hotel building for Amsterdam and to integrate water and its natural cycles in this design, it is important to find solutions that harvest water, purify water, recycle water or to find solutions that raise awareness for climate change and the consequences for water management. When a purification system for black and grey water is used, for example by means of a helophyte filter in an atrium, this purified water can be used for watering the plants of for cleaning purposes. A water purification system in a hotel building for Amsterdam should clean the water amongst others from chemical pollutants such as medicine and hormone residues. This can for example be done with a bio filter or with a membrane bio reactor. Systems that only purify grey water do not meet the requirement. However, most systems cannot immediately reuse the large quantities of waste water from the guest rooms, because an overflow of purified water occurs. For the overrun, another function can be found or the purified water can be directed to the sewerage system. Having a restaurant function in the hotel building which uses the purified water of the hotel can as well raise awareness for the environmental problems. In such a system, waste residues from the kitchen and toilet can be used to obtain alternative fertilisers. The alternative fertilisers can be used to grow plants or feed fish. However, People may dislike the idea of eating food that has grown from their ‘own’ toilet waste. Next to this, this process may involve too many parties.

In addition to recycling and purifying water, excesses of rainwater can be stored in the hotel building or in its surroundings. This could be done in the form of a water square. Such a square is very noticeable, which in turn creates awareness for the consequences of the water system. However, a disadvantage of a water square is that it occupies a large amount of space on a building plot.

Water can be stored and purified with an overflowing pool. It is likely that a decorative swimming pool in the Dutch climate would be more suitable than an actual swimming pool.

For further research, it could be investigated, for example, how the different water flows in a hotel can be reused as efficiently as possible.

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