SMART ENVIRONMENTS PROJECT

Module 2 Creative Technology

Flotilla (Team 19)

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Introduction

Water is one of the basic necessities that humans cannot survive without. Even so, it would seem that humanity has forgotten this, as it has continuously polluted water sources over the course of multiple decades. As of right now, there are multiple giant garbage patches floating in the oceans, accumulating to about 1,15 to 2,41 million tonnes of waste [13]. As a result, the environment has been gradually altering, the rise of our waters' pH level, which is a threat for species calling the ocean and rivers home, just being one example out of many [31]. If this trend is allowed to persist unchecked, it will undoubtedly endanger the living conditions of humans.

One of the main reasons why pollution is still occurring, despite greater environmental awareness, is because pollution often remains anonymous as it is near impossible to trace pollution back [32]. We therefore initiated a project in which we will manufacture a device that will float on the surface of any body of water and detect when pollution occurs. In such cases, it will rapidly alert local authorities so that firstly, the spill may be salvaged and secondly, perpetrators may be punished accordingly. We therefore respectively named our device "The BayWatch". Our name is team Flotilla, and we will apply ourselves to unveil this as a viable solution. Herewith our procedure documented.

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Chapter 1: Literature review

Article 1

The future of smart home energy

This article talks about using the Internet of Things in order to create a demand-side response for energy. An example of this is an electric car and smart metre connected to the internet. In this case, it is an option to charge your electric car when the energy is cheap.
Moreover, it talks about the solution that the internet gives to let devices from different brands communicate with each other. Something that was previously only possible within the same brand.
A difficulty with this type of energy supply is that a price for the demand needs to be established in order to decide whether or not to change the demand on the price of the supply. [1]

A personal note from Emilie van Eps; It might be an idea to look into this concept of demand-side response and apply it to solar energy. Houses for example sometimes generate too much electricity with their solar panels and have energy left. An option would be to use the energy that is left to, for example, charge an electric car.

Article 2

Decarbonizing Shipping: All Hands on Deck

The maritime shipping industry contributes to 80% of global transport. Deloitte, together with Shell is looking into how to make this industry more sustainable. From conversations with 80 senior executives the research recognizes a need for an approach that is based on 3 principles; adopt an ecosystem perspective, think big, start small and scale fast and focus on behaviours and triggers. Based on these principles, the report has 12 possible solutions to enable the industry to get net zero ships on the water by 2030.
The shipping industry is building momentum but there is little time to lose in order to meet the IMO 2050 ambition. [2]

Article 3

Introducing the Sustainability Challenge of Textiles and Clothing

The clothing industry is a massive contributor to the emission of carbon dioxide and therefore to the change in climate. There are certain reasons why this is the case. The fast globalisation of trade and an increasing market for clothing contributes to the mass production of clothing, therefore also for a lot of harmful activities concerning the environment. Cheap labour and outsourcing to countries make it easily possible for massive organisations to mass produce without really taking the environment into consideration. The fashion industry today changes quickly with trends switching fast.

This, of course, introduces the challenge for this industry. Since the supply chain is extremely long it is quite difficult to identify and solve problems concerning sustainability. Some measures are already being taken. NGO's stimulate consumers into pressuring the supply to make more sustainable and fair-produced clothing. Making the demand section aware of the sustainability problems of this industry is one part of the solution. We should also, according to the article, implement better rules and regulations for the countries which aren't strict on environmental rules. Also, the suppliers should take more responsibility for making the industry more sustainable. Scholars are also needed for researching and developing ideas for more sustainable production chains [3].

Article 4

Meat consumption

The food industry is responsible for a large part of climate change. It's responsible for about a third of the earth's emissions. The meat industry has a big impact on emissions. These animals feed on other plants thus the demand for plants goes up when the demand for meat goes up. 1kg wheat creates 2.5 kg of greenhouse gas while a single kg of beef creates 70 kg. The change in climate will also affect food production, about a third of the production will be in danger due to the change in climate. Suggested is that people change their dietary habits if they are willing to. The carbon footprint will be way less when you stop eating meat or just eat less meat [4].

Article 5

Third of global food production is at risk from the climate crisis

Climate change is the cause of making it harder to grow or produce crops. Growth for crops has been declining. This is caused by change in temperature, which may cause floods, droughts, or other natural disasters. With a part of the earth already without much food, this climate crisis will have an effect on an ever bigger group of people. Estimates say that about a third of the food production will be at risk if we don't do something about it. Some measures that can be taken are changing your diet to more plant-based foods, instead of meat and dairy products. Also more efficiently using land could help. Planting trees, a more general solution for dealing with carbon dioxide, could also assist in slowing down the earth's temperature increase [5].

Article 6

Wildfire damage

Wildfires can occur because of varying reasons, but the data asserts that they are more likely to occur in high temperatures. Apart from the threat to life, wildfires release a caustic amount of CO_2 into the atmosphere, a phenomenon that is parallel to exhaust fumes from vehicle engines. Overmore, it is predicted that as temperature rises, the number of wildfires will become more frequent with increasing severity [6].

Article 7

Caustic natural disasters

Although the link between climate change and natural disasters such as earthquakes and hurricanes is indirect, an unstable climate catalysed through climate change will result in more severe natural disasters. The article states that events such as earthquakes or hurricanes may already have the necessary setup to unleash, all it requires is a further nudge. Climate change will not be a nudge, but a shove in that aspect [7].

Article 8

Flooding and further damage to infrastructure

A particular case of natural disaster that has been occurring in more northern, western societies is the threat of flooding. Especially in Germany, cities that have been flooded have swept away debris, furniture and inhabitants, of which some are still to be found.
As the climate warms, the atmosphere grows more capable of holding larger quantities and densities of water. As a result, when downfall does occur, it is harsher than in previous years. This is particularly dangerous in urban settings, as it causes mudslides and even destroys infrastructure in the process [8].

Article 9

Three centuries of dual pressure from land use and climate change on the biosphere

Human land use and climate change are placing mounting pressure on natural ecosystems worldwide, with impacts on biodiversity, water resources, nutrient and carbon cycles. This article provides a thorough analysis of the impacts of climate change and land use on the terrestrial biosphere during the last 300 years. By the beginning of the 21st-century land use and climate change have jointly caused major shifts on more than 90% of all areas now cultivated, corresponding to 26% of the land area worldwide. [9]

Article 10

Global response of the terrestrial biosphere to CO2 and climate change using a coupled climate-carbon cycle model

This article describes the response of the land biosphere to climate change by observing CO2 emissions for the 1860–1990 period and by emission scenario for the 1991–2100 period. By the end of the 21st century, we show that the global land uptake is reduced by 56% due to climate change. In the tropics, increasing temperature acts to reduce the soil water content, which leads to an 80% reduction of net land CO2 uptake. As a consequence, tropical carbon storage saturates by the end of the simulation, some regions becoming sources of CO2. In northern high latitudes, increasing temperature stimulates the land biosphere, which in turn leads to a land uptake increase.
Overall, the negative climate impact is much larger than the positive impact simulated, therefore climate change reduces the global land carbon uptake.[10]

Article 11

The terrestrial biosphere as a net source of greenhouse gases to the atmosphere

The terrestrial biosphere can release or absorb greenhouse gases, carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), and therefore has an important role in regulating atmospheric composition and climate. Anthropogenic activities such as land-use change, agriculture, and waste management have altered terrestrial biogenic greenhouse gas fluxes, and the resulting increases in methane and nitrous oxide emissions, in particular, can contribute to climate change. This article describes how gas emissions are greater than gas consumption, which leads to global warming.[11]

Article 12

Ocean pollution/acidification

In this article, they speak about the land-sourced pollution China is pumping into their rivers and thus oceans. The main cause of this pollution is the population growth along the rivers and oceans. So much so, that the environmental pollution of the Yangtze River basin directly impacts the state of the marine environment in the ECS (East China Sea) [12]. The pollution is so drastic that even the health of the population is decreasing in the areas. Though the biggest challenge would be to promote sustainability and environmentally friendly decisions as a priority. But in order for China to accomplish their ideas, they would most likely need support from international cooperations.

Article 13

Garbage disposal within oceans

On the website of The Ocean CleanUp [2], they mention the impact of plastics in our oceans on the wildlife and us humans. In this article, the impact of the Great Pacific Garbage Patch (GPGP) is mentioned in a few examples. One of them is the fact that due to bioaccumulation plastics end up in our bodies as well. This causes health issues for all species affected by the toxins in their bodies. In addition, not only does marine life die due to the toxins in their bodies they also suffocate in the so-called ‘ghost nets’. However, the most forgotten effect of our polluted oceans is the economic effects. On the website of The Ocean CleanUp they stated the following: “According to a study conducted in collaboration with Deloitte, yearly economic costs due to marine plastic are estimated to be between $6-19bn USD. The costs stem from its impact on tourism, fisheries and aquaculture, and (governmental) cleanups. These costs do not include the impact on human health and the marine ecosystem (due to insufficient research available). This means that intercepting plastic in rivers is much more cost-effective than dealing with the consequences downstream.” [13].

Article 14

Damage from wildfires

Wildfires are an increasing phenomenon in our world today due to climate change. The number of wildfires around the world is rapidly increasing. So much so, that in California the biggest wildfire ever occurred in 2018. According to BBC News [14], this is due to “unprecedented drought and heat, combined with historic bad land management,...” But not only people’s homes and animals’ lives are at extreme risk, but also the historic sequoia trees are dying. The 2020 Castle Fire killed over 10.000 large sequoia trees [14]. This endangers our air purity even more. Now, due to the extreme fires, more CO_2 ends up in the air and less is filtered due to the decreasing amount of trees, especially the sequoias. Now in the video, they generate the idea for Greenville, a village that was completely devoured by the fires, to become a city of sustainability. In which they come up with ways to deal with the big fires, which have become the new normal, and try to reduce the frequency and intensity of the wildfires.

Article 15

Consumption pattern alternation

There is a value-action gap. A majority of people might be for pro-environmental beliefs, but not many would give up the personal benefits(i.e. Price, convenience) in favour of buying greener products. Dark and ominous climate change predictions have shown to instill a sense of fatalistic helplessness. A message of constructive optimism would counter this. Campaigns using social norms had the most effect when getting people to buy greener products. Green behaviour has a negative and positive spillover effect. Households that focused on one green aspect were shown to be more polluting in others. Green action, not in self-interest, but rather self-transcendence increases others' green behaviour. Making green consumerism not a moral choice but more a standard would increase it the most. [15]

Article 16

Information regarding climate change

The role of knowledge in changing people's behaviour towards a more sustainable lifestyle is debatable. It may be more effective to engage the individual's cognitive, experiential and emotional aspects of the individual. These factors, also known as transformative sustainability learning (TSL) should be incorporated to obtain a more effective environmental and sustainability education (ESE). Being properly educated on this subject could change the consumer culture making it possible to focus on more challenging upstream behavioural changes on the part of the individual rather than addressing downstream solutions. [16]

Article 17

Recycling in urban settings

The paper is based upon recycling rates in the Borough of Burnley in the UK. It was found that people from a lower socioeconomic background tended to recycle less, mainly because of the smaller availability of storage space in probably smaller properties. Those who did recycle were people with more time (elderly, non-parents) and bigger properties. An overwhelming majority was for recycling plans but were unsatisfied with the provided services which include the easily accessible information and implemented recycling schemes. Making it more reliable and convenient would have the biggest impact on the number of people who would recycle. [17]

Article 18

Vehicle emissions

Transport accounts for 26% of global CO2 emissions and is one of the few industrial sectors where emissions are still growing. So, this paper focuses on approaches to reduce emissions from big emission groups, such as the use of cars, road freight and aviation. In this article, it appears that technological innovation is unlikely to be the only answer to the climate change problem. Because when we want to reduce the emissions of the transport branch, a more important thing to change is the behaviour of the people. In summary, behavioural change is the key factor to reduce the emission of most of the transport sector, although technology will help to a certain extent. And with behavioural change is meant, for example, high occupancy vehicle lanes which would encourage colleagues to carpool and share the trip to work via a common travel plan.[18]

Article 19

Industrial vehicle emissions

In this paper, it becomes clear that passenger and freight transport is responsible for nearly a quarter of global primary energy use and also energy-related greenhouse gas (GHG) emissions. Because of the rise in industrialising countries, like China and India, this fraction is expected to increase in the next few years. Because it is necessary to reduce the greenhouse gas emissions and also the climate change due to these emissions, this paper addresses the following question: Should most of our efforts to reduce transport energy use and GHG emissions concentrate on reducing emissions (or energy) per unit of transport task (e.g. kg CO2-equivalent per passenger-km), or should we rather focus on reducing the passenger transport task itself? The answer they are giving in the article is vague, but the main point they are making is that the reductions in kg CO2 per vehicle per km would be difficult to achieve, because of the high input energy costs per litre of fuel delivered to the vehicle tank. A solution that is not mentioned before, is that they also talked about the reduction of emissions of normal cars. This can be done by adopting transport policies that lower the door-to-door speed advantage of car travel. Such as, lower speed limits, road closures, restricted vehicular access in the inner city, and restraints on parking. [19]

Article 20

Geoengineering

As global temperatures continue to rise, several types of solutions are being considered to mitigate climate change. One of these is geoengineering ((literally "Earth-engineering")= the currently fashionable term for making large-scale interventions in how the planet works to slow down or reverse the effects of climate change. In theory, the word "geoengineering" could be used to describe almost any large-scale concept for tackling climate change).
This paper considers how one individual action (reducing CO2 emissions from private vehicles), when adopted at a global scale, may have an effect that is comparable to that of geoengineering.[20]

Chapter 2: Identification of General Problems and Challenges

1. CO2 emissions natural disasters

   The forest fires cause a lot of CO_2 emissions which according to the concerned inspected articles is a large contributor to global warming. Of course, the damages to biospheres from such fires bring further negative externalities, such as withering wildlife and immediate threat to lives, amongst which are human ones as well.

2. Increase in natural disasters

   Through the increase in temperature and for instance deforestation, there will be a higher risk of natural disasters like forest fires and flooding, which is also bad for the environment and people.

3. Inefficient energy use

   Many households are using more energy than they actually need. For this reason, a lot of energy is wasted. Examples are plugging devices in at night to charge, in this case, electricity is used throughout the whole night to charge the device even though it is fully charged after a maximum of a couple of hours.

4. Ocean pollution

   The ocean is polluted with microplastics as well as acids. This is a big problem for the fish in the ocean because they are the ones that get in contact with these materials causing them to, amongst other things, swallow, eat or die from the acids. This has a bad consequence on the biodiversity in our ocean but also means that people that eat fish are also eating plastic.

5. Climate change caused health issues

   Air pollution and ocean pollution can cause us to breathe and eat harmful substances. This is a big problem, especially in the long run.

6. Bad government regulations

   Bad government regulations can cause certain industries to be very harmful to the environment. Just like the clothing industry, like we talked about in one of the articles. No regulation of chemicals and emissions can cause more pollution than necessary.

7. CO2 emissions for luxury consumer products

   The consumer society is used to (for instance) changing fashion styles quickly. Phones aren’t repairable and we are getting used to the idea that throwing a lot away is okay. Focussing on repairability and renewability could improve sustainability.

8. CO2 emissions from transportation

   Transportation nowadays steadily becomes a serious problem in the air pollution, which can lead to climate change. Because of the commodity of private transport, the majority resort to getting private cars instead of using public transport. And because the population is rising, the number of cars increases, which consequently increases the emission of gases in the atmosphere

9. Inefficient water use

   People often let a tap run or wait for the shower water to get to the right temperature. All of this, and much more, leads to inefficient and unnecessary use of water. More and more technologies are emerging in order to fix this problem, however, there is still a lot that needs to be done.

10. Deforestation

    A lot of deforestation is caused to create agricultural areas/build cities and this could potentially lead to a bigger emission of gases in nature, without enough sources to consume them.

11. Demotivation of household green behaviour

    Most households do want to be more environmentally friendly but find it too difficult, time-consuming, or expensive to do so. Being able to change the consumers’ behaviour would have a positive impact on the environment compared to that of geo-engineering.

Chapter 3: Identification of General Problems and Challenges

These are our 5 general problems

- Inefficient use of energy in households

Everyone can improve their energy consumption. We could possibly provide a range of solutions for optimising this problem.

- Water pollution

Water pollution in both oceans and rivers leads to damaging ecosystems. Damaging these ecosystems will cause problems for humans in the long run. Furthermore water pollution causes our drinking water to be filled with bad substances that we better not consume. For a sustainable future we need sustainable water.

- Inconsideration towards climate change

Changing the behaviour of the common consumer will have a huge impact on all parts of the clean environment crisis, from water and electricity use to recycling and global warming. This is also a big driver for normalising nature-friendly solutions.

- Floods

With increasing downfall, floods are bound to become an increasing concern, especially for countries with urbanisation close to water domains. They have already proven to be deadly and are a threat that must be dealt with in the short term to reduce life loss.

- Traffic jam/ bad infrastructure

The traffic jams occur in almost every city and bad infrastructure worsens them. The traffic jams cause the cars to be active more time than it needs to be and meanwhile a lot of gases are emitted into the atmosphere. This situation is even worse in the winters when cars need more fuel to consume to keep the interior warm enough.

Chapter 4: Problem Selection and Motivation

Problem selected: Water pollution.

Drinkable water is becoming more and more scarce [21]. Chemicals and plastic objects are being dumped into rivers and oceans. Filtering water can become more and more of a problem. Ecosystems depend on rivers, if the mayfly doesn't survive because of river pollution birds don't have enough food and die. This will enforce a domino effect in this ecosystem and eventually cause problems for humans [22]. More and better monitoring of rivers or other water bodies could give us indicators on where certain problems are. This information could be passed onto the right authorities enabling quick problem-solving.

Water filtration centres will have less difficulty filtering water if it isn't so polluted. We depend on rivers for our water. Filtering is getting harder and harder, if we want to filter the bad quality water that floats through our rivers now we need more expensive filtering solutions. The toxins in the water can be a major health risk in the long run for our population. Making an effort to find a possible solution for this problem can cause improvement in public health.

In addition to this it may boost ecosystems and nature, since these both depend on rivers for their fuels and water. When nature thrives it will cause more CO_2 to be filtered to O_2, which is helping against all the greenhouse gases in our atmosphere.

In addition to this, bringing more awareness to the problem of water pollution may make people aware of their water consumption and pollution. This will improve the knowledge and may cause the public to be more careful about how they handle their water.

Everything depends on this one substance, hence the importance of this problem.

The foundation Drinkable Rivers, founded by Li An Phao, is a local organisation that advocates for river health, stating that rivers should naturally be so clean that you can drink from them. We had the opportunity to speak with Li An personally, she confirmed that water pollution is one of the more pressing issues, while also giving us interesting insights, for instance that microplastics, hospital waste (pills etc) and sewage chemicals are the main polluters present here in the Netherlands.

Chapter 5: Potential Solutions

Sensor-equipped boats

This solution is about boats that can scan and track the amount of toxins in the water that is underneath the boat. These toxins can be tracked when there are a lot of them in one place, which aims at a polluted area in the water. When an area like this is detected it could send a signal and warn the people to clean at that particular place. So it will actually track the health of the water and warn of polluted areas in the water with a lot of toxins.

Boats that recycle

With this idea, we thought of an attachable net with sensors hooked up to the underneath of a boat. This net would contain sensors that would measure the quality of water and how much it is polluted with garbage. It will collect a portion of the litter from the river/lake/ocean and notify the boat driver when the capacity is full and the garbage needs to be disposed of. In theory, it would be good to be powered by the motion of the boat with something like fans so that it consumes clean energy.

Rainwater use in irrigation

Because drinking water is getting more and more scarce and the water itself is getting more polluted, it is a great idea to use as much rainwater as possible for irrigation. Rainwater is the cleanest water source we can use for this cause. Irrigation is one of the biggest factors in the consumption of drinking water and reducing this would be fantastic for the environment.

Deployable toxic filters

With this solution, we imaged the following. Here we thought of filters that could be deployable in places where there are a lot of toxins in the ocean. This could be from oil leaks or other chemical waste. The filters would need sensors to observe and detect the toxins. Depending on which chemical it deals with it would need different filtering methods. The filter would get the toxins out of the water and check the health of the water too. In addition, the filter would make sure the residue of the filtered toxins wouldn't have to be dumped elsewhere, but possibly could be turned into something more useful.

Monitoring-Buoy

Having an easily deployable, multi-functional monitoring station would be great for water research and safety. For example, placing these buoys in the waters around industrial sites could help locate nature-threatening spills sooner while collecting data of the local ecosystem. Making these buoys self-sufficient, robust and most importantly, waterproof is a must for a sustainable product.

Chapter 6: Solution Selection

Monitoring-Buoy

The final solution that we settled on is the **Monitoring-Buoy.** We chose this solution, because it is the most realistic and feasible. Besides, it is easier to test after completing the product. In addition, it is the most versatile applicable device; It can both be deployed in rivers and in oceans.

The energy source of the buoy has to be clean, but also enough so that the buoy is self-sustainable, so the idea is to place solar panels on the surface of the object which will power small amount of batteries inside it, which in turn will supply all the sensors. This is the perfect choice, because the solar panels themselves are waterproof and don't need any external energy source besides the sun.

We believe that this device will reduce water pollution, as it should make it more difficult for firms to pollute and decrease the reaction time for salvage teams. The exact plan is sketched in Figure 1; When a spill occurs, the buoy detects it and rapidly alerts local authorities, so that the harm may be controlled and possible perpetrators be charged accordingly.

Figure 1: Purpose

Team planning

In order to maximise efficiency, we saw it as futile to assign one specific role to each member, as teamwork is superior to individualism in this context. Herewith we split our group in two sections: a design team and a programming team.

The way we approached it, there were two main types of tasks that required our attention:

- Designing (layout, shape, visualisation through sketch, floatability, waterproof, 3D printing, video capture, final presentation setup)
- Programming (arduino code, server setup, data stream functionality, sensor calibration, circuitry, power source)

Through this division, each team could handle the issues amongst themselves and solve them through intercommunication. This prevented one person from becoming stuck endlessly on a problem as aid was always within reach. What made this possible more than anything was clear communication of one’s situation and consideration of others’ personal circumstances.

The team leader was Arthur van der Torre, meaning to set meetings, oversee the progress of both teams and to communicate what one requires from the other if needed. This alone was of course not sufficient, so he also worked on documentation and lent a hand wherever it was possible. Besides that, minor tasks such as purchases were given to whoever was available.

Chapter 7: Methodology

Equipment employed:

Arduino related:

- NodeMCU V3 (two)
- Resistors
- Wires
- Solar panels
- Solar controller
- Voltage increaser
- Relay
- Switch
- USB-cable
- USB port module
- Rechargeable batteries
- Battery port
- Internet connection module
- PH sensor
- Turbidity sensor module

Printing the Buoy

The shell for the buoy will be 3D printed, preferably with organic materials so that the decay of the shells will cause minimal environmental damage. It is inevitable that some of the material will decay in the long run, regardless, the water purity and the wildlife within it should remain as untouched as possible.

The BayWatch is meant to be deployed in mainly uncontrolled environments such as rivers and lakes, meaning that the electronics will need to be protected against environmental hazards such as winter frosts or extreme storms. The main concern is making the equipment waterproof while still allowing it to perform its intended tasks.

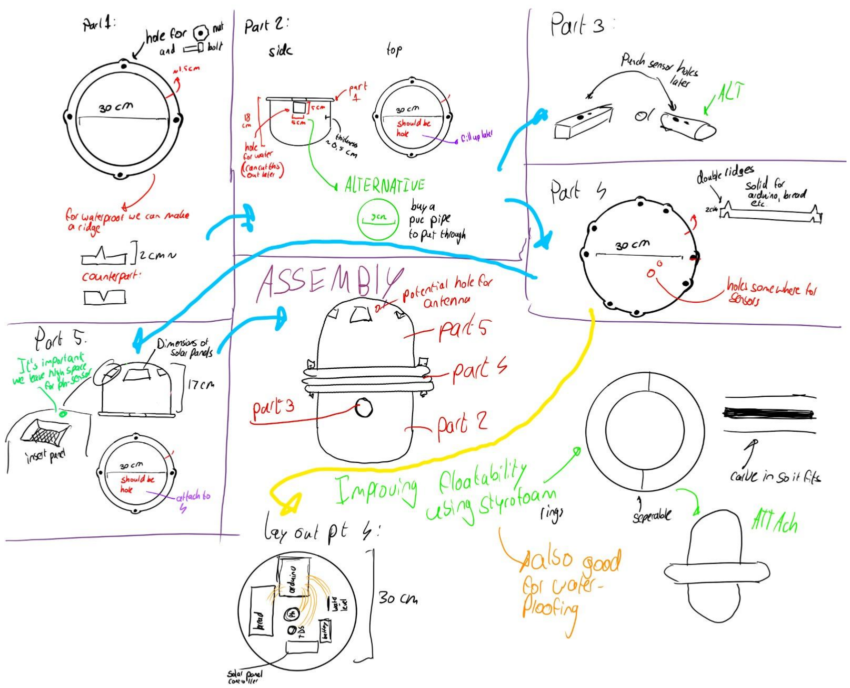

Figure 2. Early sketch of the BayWatch

The BayWatch will thus require a compartment where the sensors can do their task without interference while protecting the more delicate electronics from water damage. As can be observed in Figure 2, we decided to solve this issue by separating the buoy horizontally into two chambers: The lower half is hollow apart from reading sensors, allowing the water to enter and be read unobtrusively, the upper half is filled with circuitry and thus meant to be kept dry. Once sealed, there is no entrance into the latter. Even more so, a form of floating ring is attached to the BayWatch which ensures that the sensitive half is kept above the water surface, nearly nullifying the chance of water damage occurring and granting further stability.

Data collection

The data will be collected on a NodeJS web server which is able to handle data input via a specific port, as depicted in Figure 3 below.

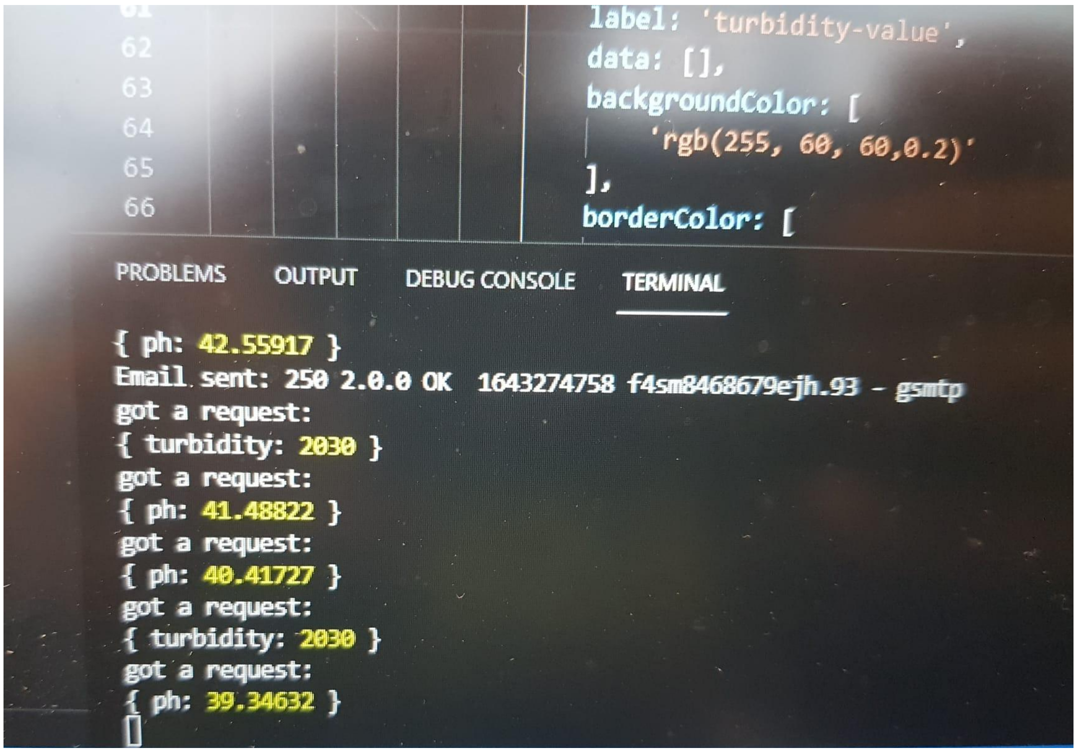

Figure 3. Data transmission of early web server

If we use the arduino with wifi we are able to seamlessly transfer data via the internet. This data will be stored on a database, which will be handled by the webserver. Once a client requests data it can be graphed on the website by receiving the data from the database. Since one of the purposes of the BayWatch is to detect pollution it is of utmost importance that the buoy transmits data on a continuous basis. As such, we aim to collect data through polling at an interval of once every 10 minutes. For the live demo we'll probably lower this interval to demonstrate our product. The web server handles the data and will warn if limits are reached through sending an email. This analysis isn't done by the microcontroller. We are aware of the fact that there is a small chance that there is wifi in the water, but we still chose to do wifi since future development could include 4g cell networks to send the data.

Data use/analysis

The way we will represent our data is through a local website. We will graph the results with a live update feed (Figure 3). The website is interactive and it is possible for the viewer to decide between the turbidity readings and the pH readings. Through such, the immediate state of the water body in which the BayWatch is placed can be analysed.

In the optimal future, we would possess an ad hoc wireless sensor network of all of our buoys at varying river locations and send this data to our (currently nonexistent) public website. With that we can also put in a map which indicates the health of the rivers with, for instance, colours. The darker the red the worse the river's health, and the more blue the better. The hidden data from the public will mostly be the data of the sensors coming in. Even so, the graph will nicely depict the incoming data from the sensors. A range of acceptable values will be given, a surpass on those values would then trigger an alarm and dispatch a clean up team. The publicity of the website may spread awareness and give everyone the opportunity to look at the health of our rivers and thus supply information for the curious.

Data for actuation

The BayWatch is a physically static device that is actuated only by the values it’s sensors read. In order to get the full potential out of our data we want to take action when data values are out of order. For example, when the value measured by the pH-sensor is too high this means that some toxic has entered the water. When we have different buoys in one river we can exactly determine where this toxic came from and subsequently draw a conclusion. For example, if there happens to be a company close to that place, this company could be contacted and asked if this was their doing.

The actuation through the data will be for alerting purposes. Even so, this alert itself will not be sent by the buoy itself, but by the server to which the data is uploaded.

Calibration for the sensors

Because we use a lot of different sensors, we need to look at them all and discuss if each of them needs calibration.
A pH sensor is one of the most essential tools that's typically used for water measurements. This type of sensor is able to measure the amount of alkalinity and acidity in water and other solutions.[25] So, for the PH sensor it is necessary to calibrate it, because if you don’t there might be some measuring errors along the way. (The advice is to calibrate the sensor twice a month. But also when the electrode has been used for a long time or when you need a very accurate measurement for example). The process of calibration is explained in the following chapter.
Then a turbidity sensor. A turbidity sensor works by sending a light beam into the water to be tested. This light will then be diffused by any suspended particles. A light detector is placed at a 90 degree angle to the light source, and detects the amount of light that is reflected back at it.[26] For this type of sensor it is not very necessary to calibrate it, but it is possible. YSI recommends only two types of turbidity solutions for a successful calibration. The first is the AMCO-AEPA turbidity standards prepared and tested specifically for YSI turbidity sensors. The other is Formazin-based standards that can be self-prepared, purchased with specific assigned values, or purchased at high concentrations and diluted.[27]
Unfortunately, we are not in possession of either of those liquids, so we worked with extremes. The naked eye can facilely distinguish between clear water and putrid water, we therefore employed our own senses to calibrate the device, even if this is not very accurate. We will use water, compare it with putting non transparent plastic in the sensor as well as more transparent plastic and note the readings.

Ordered equipment we employ

pH sensor:
https://www.kiwi-electronics.nl/nl/grove-ph-sensor-kit-e-201c-blue-10050?language=nl-nl&currency=EUR&gclid=Cj0KCQiA8ICOBhDmARIsAEGI6o362IgSDGGjH1e8OvwDwsWRGFFP66jBtRzPDtqDfQLjtyDP5yPFDLoaAugXEALw_wcB

Charge controller:
https://www.hobbyelectronica.nl/product/tp4056-usb-c-li-ion-lader-1a/?gclid=CjwKCAiAtouOBhA6EiwA2nLKH1-6qdsx-8S9Q9CZHVInq0tmzFYWVTjq_mmDcI_7a9n6XMJWGmXIlxoCFpwQAvD_BwE

Battery plug
https://www.kiwi-electronics.nl/nl/9v-batterij-clip-naar-2-1mm-dc-plug-4344

Turbidity sensor
https://opencircuit.nl/product/Gravity-Analoge-troebelheidssensor-Arduino

Chapter 8: Validation of results

Overcoming systematic errors

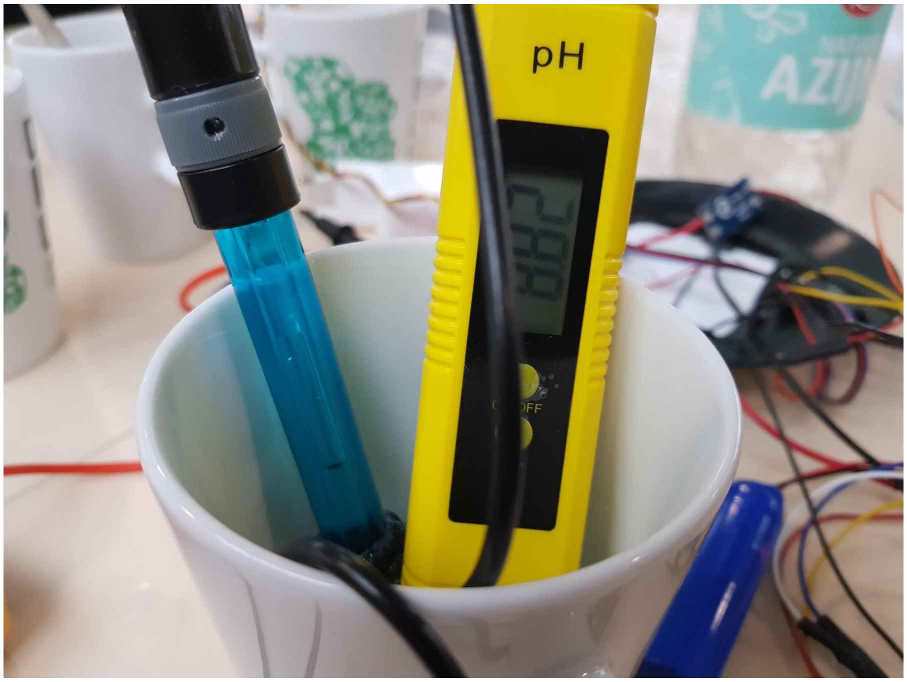

Figure 4. Validating sensor readings with a pH metre in tea

To reiterate, the BayWatch contains two sensors for measuring data: A pH sensor and a turbidity sensor. As with any sensor, especially those that were acquired on a budget, it is salient to validate the incoming readings, such as performed in Figure 4.

For the pH sensor, we were able to acquire a few pH metres which ensured that the given readings are accurate. We tested the sensor in a melange of water and soap, afterwards again with water and vinegar, known to be basic and acidic in respective order.
In order to have the sensor output desired values, it needs to be calibrated first. The pH sensor uses the analog output of Arduino and this output is mapped that way we know the voltage it uses on certain liquids. We need 2 controlled liquids, preferably of opposite spectre of pH values

and with the pH metre we know almost the exact value of the liquids, which will be used to calibrate the sensor.

Then we register how much voltage the sensor output for the 2 liquids.

PH1	4.02	V1	2.06
PH2	8.51	V2	1.82

Figure 5. Data used for calibration of pH metre

In Figure 5, on the left columns are represented the actual pH value of the fluids and on the right the voltage the sensor displays when in contact with them.

For the sensor to be calibrated, we use these values to declare 2 definite values k and Offset.

The final pH value will be calculated as such:

$$\text{pH value} = \text{k} \cdot \text{voltage} + \text{Offset}$$

These 2 values are calculated with the following formulas using the values from Figure 5:

$$\text{k} = (\text{PH2} - \text{PH1}) / (\text{V2} - \text{V1})$$

$$\text{Offset} = [(\text{PH2} + \text{PH1}) - \text{k} * (\text{V1} + \text{V2})] / 2$$

Therefore, for our code the k = 18.70833333 and Offset = 42.55916667 was used.

The pH values are mostly accurate, however it still has an error range, which is also highly influenced by the error range of the pH metre.

The way the voltage is calculated is by taking an average of 40 samples per reading to ensure a more accurate result.

This procedure is useful to ensure that there are no systematic errors in the data readings. A systematic error is when a reading is not accurate, meaning that even precise data readings will all be off from the true value.

As for the turbidity sensor, turbidity metres go far beyond the budget we were provided with, so we did the validation with the naked eye: When the water the buoy was put in became too unclear, the readings of this sensor altered. Although this method is not entirely accurate, we have no choice but to work in such a relative frame.

Also, the fact that the turbidity sensor outputs ~5V on its readings and the NodeMCU we use can only perceive 3.3V, means that we need to map our values, which slightly increases the inaccuracy of the final results.

It may require more accurate calibration but we can still distinguish between dirty water and clean water, which makes it good for our purpose.

Overcoming random errors

However, even well calibrated sensors unavoidably come with uncertainties in the readings, also dubbed random errors.

As data validation is concerned, there exist 3 main manners of validating data: Incoming data correction, faulty data detection and further correction methods [23]. Considering the fact that we merely possess one sensor of each kind, there are not many ways such errors can be eliminated.

What is possible is to process incoming data locally and remove evidently faulty readings. We decided that incoming data should be processed locally on the microcontroller, as this allows it to respond to stimuli faster; In a real-life application, time would be of drastic essence.

The memory capacity of the arduino also allowed for a protocol that can to a certain extent reduce random errors in the readings. As mentioned, data will be polled every 10 minutes, at which the arduino will yield the average of the readings during those 10 minutes. This is what should reduce random errors considerably.

Furthermore, if a reading suddenly flatlines and produces continuous 0s or other forms of impractical data, it is clear that there is a malfunction in one of the sensors. In addition to this, if there is suddenly no data incoming anymore, it serves as an indication that the power supply, meaning the solar panels or the batteries, are inoperable or that the node is no longer connected to the internet. Such cases are signs that the buoy must be collected and repaired manually, for despite it's autonomous design, this is something that the BayWatch cannot repair on its own.

Chapter 9: Final results and conclusions

Final construction and functionality evaluation

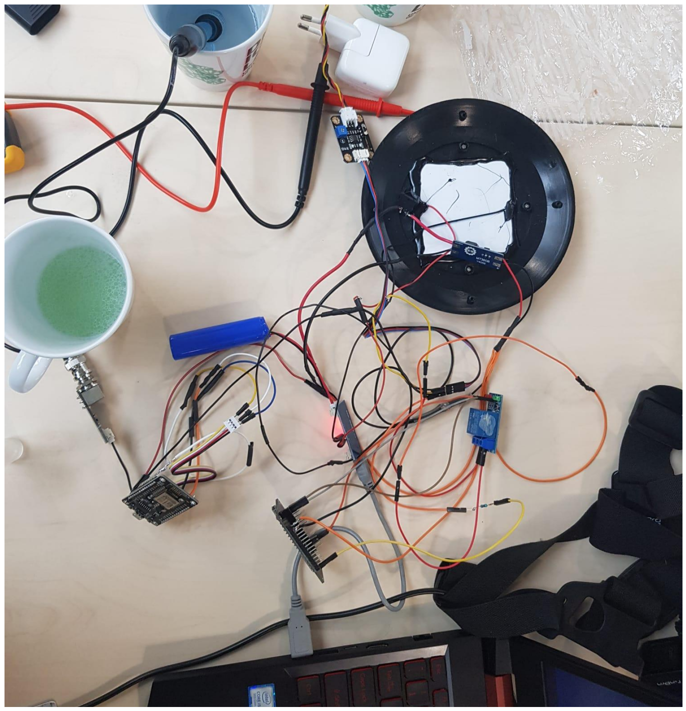

Figure 6. Finished circuitry

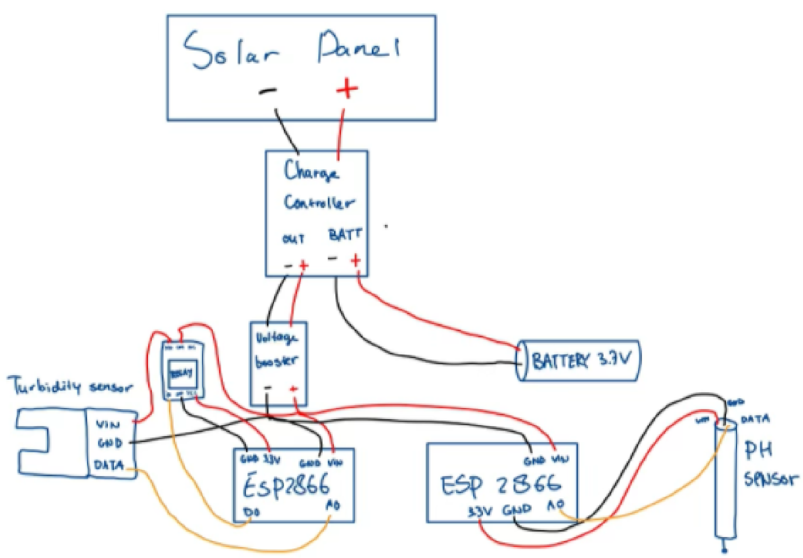

Figure 7: Sketched circuit

Although all aspects functioned well individually, errors started to come up when combining these objects. We wanted to use the arduino wifi shield, but it was a bit old and there wasn't a lot of documentation for this. We didn't get it to do post requests. So we used the NodeMCU, which unfortunately only has 1 analog input which does not suit our situation of 2 sensors using analog input. We decided to build a circuit using diodes and some clever programming to iterate between reading 2 sensory inputs. This worked fine for 2 potentiometers, but when we hooked up the Turbidity and Ph sensors the readings weren't accurate. After pondering on what to do we decided to use 2 NodeMCU's and send the data to 2 different databases. This has the advantage that if one microcontroller fails the other one can still send data and that the readings are more accurate. In the future we could connect these 2 and implement accompanying troubleshooting applications.

Another issue we faced is power, when testing with our microUSB directly to a computer it gave a stable 5 volt and the PH sensor worked fine. However when hooking it up to the battery and solar controller it only supplies around 3.1 volt. When measuring the voltage on the pins we concluded it was too low in order to get accurate readings. So we obtained a voltage booster which boosts the voltage to 5v. This made the PH sensor function properly. Since voltage doesn't get divided when using parallel circuits we could connect 2 microcontrollers requiring little current quite easily. However the next issue was on our path; the turbidity sensor needed 5 volts to function and the microcontroller we were using only supplied 3.3. Hooking the turbidity sensor directly to the power supply would measure the data constantly which isn't necessary and power inefficient, we hence made a circuit with a relay.

The relay is triggered by the microcontroller and if on supplies the turbidity sensor 5 volt from the battery. We use a resistor on the analog pin so the higher voltage from the turbidity sensor doesn't break the microcontroller. We tested it out on a local network and the final circuitry (Visual Figure 6, functionality Figure 7) worked properly. A group member did some last magical, extremely fast calculations ensuring that the PH sensor was accurate and the turbidity was also fine tuned.

While this was happening some other members prepared the actual case for the buoy. They made rubber sheets for protection against water, drilled holes for the sensors, painted it with waterproofing material and attached the floating ring.

Unfortunately, the pH sensor was broken when inserted into the buoy for the first time, resulting in an anticlimactic failure. Even so, we did not allow that to discourage us and continued working. At the time this documentation is written, we only have Figure 8, which was a functional prototype, to present. It was capable of reading water purity values and sending them to the server to present. Even so, there is not a doubt in our minds that we will be able to complete the BayWatch after this document is submitted, so Figure 8 is meant to serve as a preview of what is soon to come.

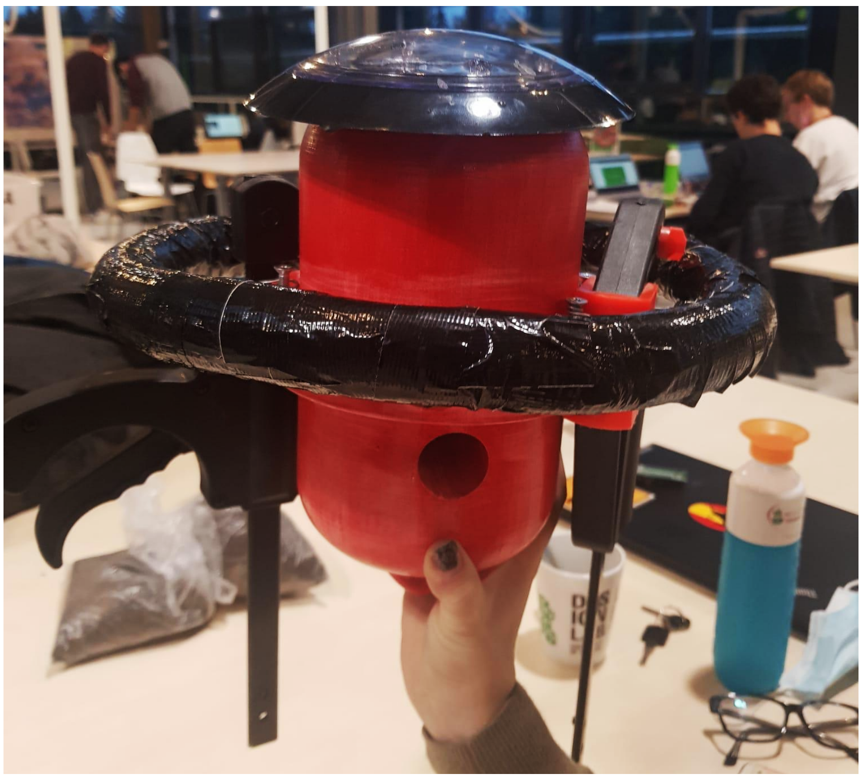

Figure 8: The BayWatch, final state

The setup for the webserver demanded quite some time. It is built by one of our programmers on the popular NodeJS using Express to serve web pages. The webpage which is served automatically sends a GET request to the server to check if any new data was added to the database. The database is a simple NeDB database, which is a watered down version of

MongoDB. Although quaint, it fits the purpose of our project since we are just storing values. The data is displayed with the popular open source ChartJS. You can zoom and pan around the graph, making the data visual shows the live health of a river, which is also important for awareness. Incoming data is sent in JSON by http POST request protocol (by the microcontroller) and is put into the database. The web server adds a timestamp to the received data. Furthermore we set up an email account and used nodeMailer to send mails when PH or turbidity levels are too high.

Real-life feasibility

As already elucidated, water pollution remains prominent as the delayed reaction time of salvage teams enables it to be done anonymously. It is also this delay in reaction time that renders pollution so caustic, since much damage may have already been done to the environment before the filth is removed from the river or ocean. We therefore believe that the BayWatch may indeed be a realistic solution, as rapid detection of waste will increase reaction time and enable authorities to protect the water purity of rivers.
In fact, variants of our buoy monitoring station have already been used in the field recently. [33] For instance, we discussed this matter with founder of “Drinkable Rivers” Li An Phoa, who is currently also working on a creative, biological measuring network which employs clams' reaction to dissolved particles in water bodies to determine the amount of pollution. The fact that many others have taken similar approaches as we did confirms that our solution is not baseless.

However, this plan does come with considerable restrictions. For instance, as it stands during the time when this is written, the laws of pollution are still not sufficient to deter large corporations from ceasing pollution, essentially rendering a policing device rather obsolete [34]. Although this fine is no small sum, it often is merely a fraction of what it would cost the company to properly dispose of their waste. Such companies are simply not deterred to alter their procedures so long as it is not profitable to do so. Having said this, there is evidence that coming laws will grow more constricting on such corporations, so perhaps this obsoletion is only temporary.
Furthermore, there is a concern regarding the material we will employ, as it will be counter-productive to employ BayWatches that will ironically in the long run only further harm

the environment by breaking down and heightening the garbage pile [35]. This may prove difficult, as oceans are biospheres most susceptible to sudden meteorological change and may grow violent, or destruction may even come from a passing cruise ship splitting the buoy carelessly in two, for instance.

Future outlook

In its current state, the BayWatch is a simplified prototype and could continue to be enhanced. Now it only possesses turbidity sensors and a pH sensor, but alternate methods of analysing water bodies exist, such as with biological contaminants or spectroscopic readings. The buoy could be increased in size so that it may utilise more sensors so that its data supply may be interpreted more clearly.

As of now, the BayWatch is a singular prototype, however, it is designed to be one node in a large ad hoc wireless network. In other words, the true BayWatch would be a large network of buoys that through intercommunication relay swift and accurate readings. This would come with many improvements, for example, one prototype is set to send data through polling each 10 minutes, but if multiple nodes are set to pole at different intervals, then there is a constant stream of data. Furthermore, a network may continue to function even if a device ceases to operate, this is of course not possible with an individual prototype.

All in all, this prototype is meant to showcase what the BayWatch's functionality would be on a basic level, but it by no means represents it's full potential. As an ad hoc network, it would certainly make pollution more challenging to do anonymously and no longer allow it to be done unnoticed.

Figure 9: A render of a possible future buoy

Figure 10: An additional render of a possible future buoy

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