

IF Student Design Awards



UN Goal 6 – By 2030, achieve universal and equitable access to safe and affordable drinking water for all

Autonomous River-Cleaning Drones:

Innovative Solutions for Pollution Management and Water Quality Restoration

Global Context / Problem

River pollution is currently on the rise with currently according to the United Nations Programme more than ⁱ‘40% of our freshwater systems are polluted with rubbish and harmful chemicals that are deposited into ecosystems.’ Water Chemistry is one of the key problems with aquatic pollution for example poor water quality caused more than ⁱⁱ‘80% of the worlds diseases.’ According to The World Health Organisation (WHO) it is estimated that ⁱⁱⁱ‘Some 1 million people are estimated to die each year from unsafe drinking waters.’ Water chemistry doesn’t just affect humans though because marine life is affected by the fact that even little exposure to low levels of harmful chemicals can impact the longevity and lifespan of water-based animals. This can be shown in the case study of when scientist did some research on seal pups on the ^{iv}‘coast of Scotland between 2015-2017, they found that 18-day old seal pups have already accumulated high enough levels of harmful chemicals in their blubber to impact function, which may negatively impact their ability to survive their first year of life at sea.’ This research shows that even of the coast of Scotland which in ^v‘2024 98% of its water met or exceeded he sufficient classification of water cleanliness’ still gets affected by very minute levels of chemicals and PH imbalances in their water and is still enough to harmfully affect and in danger animal species.

Objectives Of Product

The main goal of my product (the drone) will be waste collection whether that be plastic, organic pollution (algae, logs, aquatic weeds) or metals. It will be able to sort these items using multiple methods; for example, a magnetic conveyor-belt which will run horizontally parallel to separate and store metal objects, for the other objects they will pass through a small shredder to minimise the size of the organic and inorganic objects, since the shredder then reduced all of the waste into identical sizes they can then be organised by density, this will be done by using automated air separation to help separate the plastics from organic materials, the air separation is done using a constant flow of air to push the lighter waste away from the heavier. Due to these processes, there are then three separated waste collection points one for metals, one for organic materials and one for plastic materials. These can then be stored in separate containers until they can get deposited into the docking station for the product. This docking station will serve as a central command for the drone where it can send and receive long distance communications that can be monitored by an external operator. The docking station will be able to pick up the separate bins from the drone and either hold them until they need to be collected or used to help run a small generator to keep the entire system off the grid and therefore can be used almost anywhere around the world.

The secondary job of the drone will be to measure and control the PH levels it will be able to do this using a multitude of Sondes that will be positioned at the base of the drone's hull. A Sonde is a piece of equipment that can monitor several parameters to do with water quality all at the same time which will be perfect for mounting on the drone because then there would be real time information of the water where the drone is. For example, Sondes' can monitor water temperature, PH conductivity, dissolved oxygen levels and even salinity of the water. This will all be useful information for both the Docking Station and the Drone because the Drone can then relay this information back to the Docking station where its onboard AI system will then make a decision on what to do, The decisions that it will make is to either help reduce or increase the PH levels to help keep the river in a neutral state. This is so that the animal and plant life under the water can stay healthy and not be in constant danger of being damaged and or harmed whilst living in this specific area. To help keeps these neutral levels of between 6.5-8.5 with neutral being a 7 the drone itself will hold Bicarbonates, Carbonates and Hydroxides to help increase the PH levels of the river. The drone will also hold Alum and a very minute amount of Sulfuric Acid because not a lot of this is needed because these will be used to decrease the PH levels in water, all of these chemicals are safe for Animal, Plant and human life when used in the appropriate amounts which is why every time that the AI system thinks that it needs to adjust the PH levels in the river a message will be sent to an external operator and they can confirm or deny the use of these chemicals once they are presented with the real time information that will also be given to the operator via the Docking Station. Once the operator confirms the use of the specific chemicals the drone can be deployed to the area in question that needs the Ph levels adjusted, and it can deploy the necessary amounts needed by itself without the need of a trained operator/user being on site.

Benchmarking

In this market there are a number of products which can do something similar to my product but other products do not provide all the functions that mine does for example ^{vi}“ClearBot Neo (pictured below) is an AI integrated drone” which has a simple conveyor belt which goes around a harbour collecting trash and putting it all into a big net to then later be organised by other people,. This causes a number of problems like cross contamination, and it all the trash then needs to be reorganised by a waste disposable operative. This can take up time that isn’t needed. Another flaw with this product is that it can only operate on flat still waters like an enclosed harbour and or in a very slow flowing water situation. On the other hand, there are some good points about the ClearBot Neo like the fact that it does photograph all the trash going into the net and then relays what is deposited back to an operator who then can calculate the percentage of different types of trash over time.



Another product which provides this function is from the business of ‘The Ocean CLEANUP’ and is called ^{vii}‘The Interceptor’ (pictured below). The product is a large barge like building that is positioned in the middle of the river and then has a barrier which runs from its nose to a river bank collecting every item which is flowing down the river on the surface however there are many different types of plastic which are flowing down river and around half of them will be submerged therefore with the interceptor only having a floating barrier to collect floating plastics it misses half of the plastic which will go under ‘The Interceptor’.

A further problem with 'The Interceptor' is that it is a stationary object. One of the main problems of this is that ^{viii} More the 1000 rivers account for 80% of global riverine plastic emissions into the ocean" this means that yes 'The Interceptor' could theoretically collect up to 80% of pollution but the other 20% that is stuck on the riverbanks or in the river basin sediment just stays there untouched for years affecting the biodiversity and environment. On the other hand, a good point about 'The Interceptor' is that it can operate in shallow waters like estuaries just before rivers reach the oceans creating the maximum amount of efficiency it can create collecting trash from all rivers joining just before the ocean. So for example this product can be very good when many rivers join into one large river just before reaching the sea however it is not the best when a river splits off into several smaller rivers before entering the ocean because it cannot cover all of the rivers unless it is positioned up stream but at that point it goes into the problem of missing sunken plastics and not be efficient enough to be feasible to put into place with all the time and money it would take to position.



Challenges and Limitations

Technical

The main challenges that my product will try and overcome is trash organization and separation in an efficient and environmentally friendly way for example reusing some biproducts of organic waste to be used as a fuel for the main Docking Station. Another part of this will be to organise these differentiated products into easily collectable sizes so that when they need collecting because the storage of them is full an operator can simply drive up to the main Docking Station collect the necessary items and drive off with the specific items which can then be disposed of in the required ways.

Some other problems that my Product will experience is large debris like trees that have been downed and are now flowing down the river, these could be a danger to property (i.e. yachts, Pontoons, Docks) and people downstream, the large debris could collide into these different types of property damaging them and in a worst case damaging beyond repair. This could even be harmful towards the marine life because for example if a shopping cart is left in a river and a rush of current makes the cart start to move downstream it could destroy marine life habitats by crashing into them. Once again this can cause further damage because once the debris has crashed into different habitats those habitats can then become larger debris parts that will also be traveling downstream causing a downward spiral in environmental damage.

Another problem I might encounter is that the sensors and cameras of the drone itself may become unreliable due to the pollution and contamination of the river that my product is situated in. This will need to be solved so that it can continue to do its job in the most effective and efficient way possible, it can be solved by either covering the cameras in a clear material that will bead off items like thicker mud and or debris and if needed the clear covering could have some sort of wiper system to help clear extra larger items if needed.

Environmental

Some of the environmental problems my product will try to solve will be potential ecological disruptions, This is because whilst the use of the Drone and Docking Station may be beneficial to the environment and surround area, its presence may disrupt the bio life and cause further problems, some of the ways these problems can be prevented is by not having exposed and open propellers and have them enclosed within the body of the drone as to not endanger any wildlife.

Another environmental problem I could encounter is that even though the release of the chemicals will be heavily controlled the release of the chemicals will have to be consistently monitored by a trained professional because if not there could be severe impacts on the natural environment and the biodiversity of the river and or seabed. For example, there is a river in the South of Wales called the Palenna river, this river has been heavily polluted with iron due to the abandoned mines. Their iron ore contaminating into the river has caused significant damage to the surround wetlands fauna and animal life.

However, this was then treated using a specific blend of chemicals. These include Limestone, Quicklime, Caustic Soda and Soda Ash, these chemicals were used to help increase the alkalinity of the water which in turn made the PH levels more neutral and slowly helped to increase the biodiversity and the flower and fauna levels. This was shown when later in the study they went back to the same location that these chemicals were released and there was a noticeable difference in the wildlife in the area. Also, it was noted that different unique amounts of these Neutralisation chemicals can target different metals. Therefore, when a specific metal was detected, and curtain chemical mix was made and there was an increased amount of metal reduction in the water levels. An example of this is using Hydroxides for manganese removal in the most efficient way possible. Another way that chemicals helped to increase water PH levels is by increase decomposition of organic matter because when sewage/sludge is decomposed faster it increases PH levels, this decreases metal toxicity and therefore enhances vegetation growth and over all marine life.

Economical

One of the main problems of my solution is the economic cost to Manufacture, Build, and deploy these Drones and Docking Stations. The goal of my product in its final form will be around £30,000 per unit, this will be because the other products that are of a similar size and effectiveness of mine are around that price depending on several variables like: Fully Autonomous, Remote Controlled, ext. Some of the products that are already on the market are prices cheaper at around £20,000 however they only do one of the many functions that mine will accomplish. At this price it would be more beneficial to buy 24 units of mine to create a swarm then it will be to buy and position one of the larger barge style cleaning solutions (e.g. The Interceptor).

To also help with cost of operating my solution is the fact that only one operator is needed to run several of the drones compared to some other similar style drones where each individual unit needs its own trained operator to run it efficiently. This will reduce the overall operation costs of my solution drastically.

On the other hand, there are downsides to running multiple drones 24/7 and that is the maintenance on them because this will need to be done by weekly to make sure that all of them are running in perfect condition to make sure they are as efficient as they can be. This will cost an increasing amount depending on if any of the individual units needs repairing.

Financial

The main source of income to produce these Drones and Docking stations will come from government subsidies like the “Water Restoration Fund” this grant program is specifically for funding products that improve the water environments rivers, lakes and bodies of water. They get their money from giving penalties and fines that are issued to water companies for polluting in bodies of water. Another main source of the income to

help run and operate my products will be from private and public institutions for example organisations like the United Nations could fund part of the money needed. Other organisations like Shell could also help to fund these products since they might want to have a better public image in the eyes of their consumers, or they could even need to use one/a few of them themselves because of things like an oil spill or contamination into a water source.

This leads me to the second source of income for the operation of the drones is that once the drones and docking stations are produced, they can be rented out to anyone willing. This is because sometimes the drones will not be needed 24/7 hours 365 days a year so with this it means you could rent the Drones and Docking stations and all the necessary maintenance needed for a few months just to clean up oil spillages. Another benefit of being able to just hire the Drones and Docking Stations is that business and organisations which do not have a large amount of funding can still make a difference in cleaning the marine life and surrounding area without having to come up with a large sum of money.

Future Development / Scalability

My solution will have a multi-drone system this is so that my product cannot be limited by the size of a river, this will be because the multi-drone system will interlink several drones together so that different drones do not end up patrolling the same parts of a river and therefore can cover a much larger area all at the same time. This will be perfect for adaptability due to the fact that my solution can then be used all around the world without struggle.

Future development of my product could even include AI integration with smart city links for example it could track different areas that are being polluted monitoring where the most plastic waste is being found in the river and then sending this information back to the Docking Station and then the internal computer system can update its patrol routes so that it covers the more polluted areas more than the less polluted areas where it is not needed.

Another idea that my Drone could include could be further chemical treatments once more research is completed and further advancements are made the drone could then carry these mixes of chemicals to help deter other polluting materials like, algae and even plastic completely. This would be made easily possible because onboard the drone there will be contained and sealed compartments that can store various chemicals depending what contamination problem the drone is trying to solve. For example, if the drone is in iron ore contaminated waters it can release the alkaline chemicals to neutralise PH levels, however if not need these containers can be easily removed and stored in the Docking Station if not needed. This can be beneficial to the drone because it can help reduce its overall weight. This can mean that the Drone itself can continue patrolling for a longer time collecting more trash and decreasing total contamination in its specific location.

Furthermore, for future development is the educational benefits of the Drone, for example the Drone could hold water samples and bring them to an operator who could then take them around for example it can be taken to schools or environmental groups to promote water pollution awareness. This is a positive correlation spiral because the more people that know the fact about water pollution the more people will want to be involved in a positive solution, this can all mean that there is a higher chance for funding to take place for different environmental groups which can even expand production of these types of solutions for river contamination and pollution.

This leads me on to increasing public relations and exposure of pollution because my Docking Station and Drone can increase community engagement because the Drone itself takes the samples of the river which can then be tested elsewhere. But the actual Docking Station would also be informational to the public because rather than just being an eyesore on the riverbank it can have informational notice boards on the side of it that can show different goals and objectives that the Drone is achieving, and it can show how much pollution/contamination and trash it has collected during that day and in total. This is so that even though it will be a larger product it can still be used globally in all situations even in the more developed countries that don't have so much contamination, but the water levels need monitoring. To additionally help with public relations all the internal information can be sent to an app that citizens of the surrounding area or even all owners of the app. On this app it can show the locations of the pollution hot spots and other collection data that is gathered from the Drone. This would be so that it can increase awareness and also the interaction of people who are interested in helping the economy become a greener and more environmentally friendly place, Because then they can actively help-out using this app to find out what they could do, For example an area that might not be accessible for the drone to implement its pollution control initiatives could be handled by a concerned citizen, The trash that they collect on their own can still be deposited into the Docking Station so that it can get organized and dealt with accordingly. On the app it will also tell you where the nearest Docking Station will be so that it is easier for the external citizen to help. This also works as an additional way to convince people to help the overall objectives to reduced pollution because it will be easier to help rather than having to do it all yourself and then organize all of the trash collected yourself.

In addition, for the increase in public relations on the app there could also be a feature in which the user of the app could highlight an area in which the drone hasn't patrolled, A message can then be sent to the Drone to go to that location and increase patrolling and collecting from that area. This will increase the overall information knowledge that is gathered so that specific researchers can create a more accurate image of the total riverbed and its contamination. This once again create an increasing correlation spiral of more information results in decreased levels of contamination.

If all of this can happen it can result in a larger increase in development of products that decrease the contamination and pollution. This means if more people are trying to develop products/chemicals/other solutions then there will be a lot more information going round making the final goal of zero pollution and contamination in rivers and oceans a lot more achievable world-wide.

Product Specifications

The Docking Station would mainly run off solar powered energy however it would also have a miniature bio-fuel generator internally that would be powered using some of the organic matter that is collected and deposited from the drone into the sorting system. The drone itself will also have some smaller solar panels on the top surface of it so it can keep its batteries recharging throughout the day and therefore can last longer on the water cleaning, However as a back-up to the solar power when it is out collecting the waste on the river during its patrol routes it will also have a non-powered free spinning propeller which will act as a secondary hydro-electric power supply. Due to the flow of the current in which the drone will be in the propeller will naturally spin creating kinetic energy which can then be transferred into a miniature alternator which in turn can recharge and power the batteries on-board the Drone itself so it can stay out on the water for a longer amount of time. There are also some other beneficial advantages to have the secondary power supply on-board the Drone and the main one will be that the Drone will then be able to last longer in a stronger current. This is because even though the stronger current flow of the water requires a stronger output from the motors and propellers the stronger current also results in a faster free spinning secondary power-supply providing an increase in the power gained it-self. The Drone itself will be used to collect the various types of trash and pollution using its main function of a simple conveyer-belt mounted at the front in the middle of the Drones main body, to further help with collection of trash and debris there should also be an animatronic arm to grab larger objects like tree logs and metal objects. This arm will either be positioned on the side or the top of the Drone to maximise the functionality of the arm itself, this arm will be controlled using the Drones on-board AI system that is enabled using many different radars and Lidars that are positioned all over the Drones itself.

The locations of the cameras and sensors will be the main large Lidar camera positioned on the front and rear of the drone these will be used to map out the surface objects (E.I. Boats, People, Docks). The Lidar cameras can also be used for exact positioning of when the Drone needs to return to the Docking Station for re-charging and trash depositing. There will also be in the range of between 12-20 other sensors positioned around the drone itself these will serve as navigational sensors to make sure it stays on the intended path, to help with that there will also be on-board GPS and radar for a number of reasons the main ones are for the Drone to avoid boat traffic and the other boats to know its positioning. The GPS will also be needed for the summoning feature of the Drone to the app user. This can mean the Drone can have a much more accurate pin pointing technique so that when a user of the app calls the drone it will get there safely and efficiently.

The Drone will be propelled using two propellers that will either be positioned at the centre swivel point so that that can the most agile it could be, Or the propellers will be positioned at the stern of the Drone in a regular position likes it competitors. These

propellers will be electric powered so that they won't have to be consistently filled up with fuel every day.

The Drone itself will be around 1.5-2.5 square metres big this will be so that there is plenty of space on-board for all the trash itself and all the necessary equipment. The Drone cannot be too large itself otherwise it will become too much of a hassle to be able to move around and store.

Some other components of the Drone will be the sealed and removable/refillable storage containers for the chemicals needed for neutralizing the acidity and alkalinity of the waters. These containers will be stored within the hull/keels of the Drone so that they have the most structural integrity without having to compromise on exterior space. The containers however will need to be refillable from the Docking Station so that an operator is not always needed to refill the containers/tanks on the Drone. The larger secondary tank can be stored in the Docking Station will only need to be filled once every few months. Which aligns with maintenance so when the overall product is getting its maintenance checked it can also be refilled and emptied of all the trash and debris that has been stored in it.

On-board the Drone there will also be a smaller secondary drone which will be designed to go under the water scanning the riverbed and notifying the Drone of any large debris or contamination that will need resolving. The Secondary miniature drone will also be powered using solar energy and hydro kinetic energy like its larger counterpart. This underwater drone will be attached to the main Drone using magnets and claws positing near the rear of the Drone as to not damage it from any unexpected head on collisions with debris. This miniature drone can then be easily deployed if the Drone thinks is necessary, because this smaller drone can also be used to lift plastics that are hidden in the sediment of the riverbed to then be collected and organised by the Docking Station later.

The Docking station will be a larger object that can be position on riverbanks and can serve as a mobile central hub for the Drone, this will mean that the Docking Stations will need to have anchoring systems built into its automatic levelling hight adjustable legs so that it can always be at an optimal height for the Drone even if the waters are tidal.

On-board the Docking Station will be the several waste organisation systems internally so it can process all the waste itself. It will then have easily accessible hatches on the side in which the operator can go up to them and simply remove and empty the compartments of their waste and dispose of them in the proper ways. The Docking Station itself will have a large entrance facing the river so that the Drone can return and deposit its waste, The drone will be held into an exact place in the Docking Station using guide rails and magnets so that there is limited space for error when it returns to recharge and offload. At this point the Drone will start to push all the waste it collected into the Docking Station to get sorted using its on-board nematic piston. After the waste is offloaded and the Drone is sufficiently charged it can continue patrolling the waters collecting its waste. There will also be a secondary waste shoot so that any passers-by can

also put their rubbish and trash into the Docking Station, it is then guaranteed to be organised and disposed of in the right way rather than it just being put into a landfill polluting the land even more then before.

The entire system itself including the Drones and Docking System will be designed as to either fit on a standardized trailer so that the entire product can be easily transported from place to place without having to worry about if you need any specialised products to help move the System, Or it will be designed to be a physical trailer in itself saving on the user having to own or rent a trailer to move the entire system itself. This is so that in struggling countries it can be used with ease and with minimal funding for specialized components.

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