STARTS Residency Public Report
Orbital River Station

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Abstract The paper discusses the project Orbital River Station (O.R.S) a floating sculpture that rotates with the water current which also acts as platform for artistic and scientific experimentation to investigate water quality. The deployment on O.R.S led to the artistic reinterpretation of two scientific experiments to monitor water quality using nano materials. The methodology during the collaboration was based on artists observing how scientists work and then redesigning the experiments by conceiving new forms and shapes. The art-science relationship and the co-creation process was based on clear boundaries between the roles of the artist and the scientist from the outset, and the fact that we shared goals and motivations created a mutual trust and easy exchange. In terms of impact, the collaboration brought some of the rigor of science into the artwork, so that scientifically valid data was collected, and likewise for the scientists it opened a window onto the possibilities offered by artistic interpretation of scientific protocols. The future direction is to continue the experiments begun during the residency and exhibit the work in situ and in a gallery setting.

Index terms: art, nanogold, COF, perception, ethics, water contamination.

I.INTRODUCTION

ORS STARTS residency enabled a collaboration between artist duo HeHe (Helen Evans & Heiko Hansen) and marine biologist Begoña Espiña, group leader of the Water Quality Research group within the Department of Life Sciences at International Iberian Nanotechnology Laboratory (INL). The duo HeHe create large scale installations in public spaces that look at the paradoxes of ecological problems, they often engage with scientific processes in the production of their artworks. Dr. Espiña focuses her research on developing portable and remote biosensors and devices based on nanomaterials for the selective capture of water chemical contaminants, as well as developing methods for nanomaterials' fate, bioaccumulation and toxicity with special emphasis in implementing the safety-by-design concept.

II.ARTWORK

O.R.S is an abbreviation for Orbital River Station which is a floating sculpture. It is an inflatable object, bright orange and white, that takes the form of a giant lifesaving ring. It was installed in summer 2019 on the river in Avignon, where it was anchored to the riverbed and the formidable current of the Rhône made it rotate. The sculpture is inspired by utopian concepts for space habitation which take the form of a slowly turning giant torus that simulates the sensation of gravity. O.R.S is a earth bound river station that turns around its axis and could be developed to harness the current of the river to generate energy.

Our intention in this work is to create a vehicle that, once installed in the riverscape, investigates and reveals what is going on inside the ecosystem of the river. The speed of rotation of the O.R.S renders the speed and force of the river current immediately perceptible for contemplation. Going beyond the limits of sculpture, design and site-specific installation, O.R.S is a project that seeks to become an open-air laboratory for the practice of environmental science. It aims to develop into a form of utopian environmental water-based architecture: a liveable 'machine for living' for researchers and activists.

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To realise the rotational movement of O.R.S, we experimented with the difficult problem of how to make the O.R.S turn with the force of the current. We made many 1:20 models of various forms which were tested in an 10m long aquarium equipped with a current simulator at the Laboratoire Ondes et Milieux Complexes of the Université du Havre. This aquarium allowed us to scale the experiment to the estimated current flow (between 400 m^3/sec and 1000 m^3/sec) found in the Rhone. After several failures using fixed blade prototypes, these early experiments in the laboratory led us to conceive a a dynamic form of blade – a textile pocket that has the ability to change shape during the rotation of the object. Unlike a complex mechanical system for generating dynamic thrust - like the cyclorotor or the Voith Schneider turbine which works by modifying the angle of attack of the blades of the rotor over time - ORS works with compartments which are fixed on the underside of the ring but through their shape and material they remain flexible. The compartments open and close under the water, as needed, creating a dynamic play of shapes. It is a simple, innovative solution, closer to the fluid and poetic organic movement of a jellyfish drawn by Ernst Haeckel or sea animals in glass by Leopold Blaschka.

The goal of the START residency was to find ways of incorporating research prototypes under development at the Water Quality group at INL into the the Orbital River Station. The outcomes are the following.

During its deployment in the River Rhone, we attached and immersed a new material, called COF TpBD-$(CH_3)_2$, prepared at the laboratory at INL and designed to capture lipophilic organic pollutants from water. COFs (Covalent organic frameworks) are a new class of material made from molecular building blocks and can be tuned and functionalized as needed. This porous material, in powder form, has nanoscale pores which are tuned in size and shape to adsorb a specific range of molecules. The design of the material allows the powder to be pressed into a shape with good mechanical stability. TpBD-$(CH_3)_2$, has been tested at INL under laboratory conditions to capture pharmaceuticals such as ibuprofen and pesticides such as chlorpyrifos from water. This is exciting material for O.R.S as it does more than simply monitor the situation by providing data – it physically captures and potentially removes contamination from environments, in some cases after only one hour of immersion.

Pharmaceuticals – such as analgesics, antibiotics, anti-platelet agents, hormones, psychiatric drugs, anti-histamines – are increasingly present in large rivers and are therefore highly relevant to O.R.S. These common drugs are consumed, directly be people or through industrially farmed meat, and after ingestion are ejected into the waste water system. The expansion of sewage systems in large urban areas means that effluent, even after filtering, ends up in freshwater rivers where the dispersion of molecules has a detrimental effect on aquatic ecosystems. Ibuprofen, for example, has been proven to have an immunosuppressive effect on fresh water fish, even in environmentally low doses. The dispersal of pharmaceutical waste into the natural environment is also one of the factors driving the evolution of drug-resistant bacteria and viruses.

On the other hand, atrazine and chlorpyrifos were commonly used herbicide and insecticide, respectively. Both pesticides act as endocrine disruptors with strong potential to bind to androgen receptors, interfering in natural hormone binding and thus altering the normal functioning of the endocrine system.[1] Since 2004, atrazine use in agriculture is highly restricted in the EU by the directive 2004/248/EC. Chlorpyrifos was introduced in 1965 as an alternative insecticide to dichlorodiphenyltrichloroethane (DDT). Although EPA banned the residential use of chlorpyrifos in 2000, this pesticide is still the most widely used broad-spectrum insecticide for crops worldwide [2]. In the EU, eight countries had already banned chlorpyrifos for all its uses and since December 2019 its use is prohibited across the whole EU.

Securely tethered to the O.R.S in a small bag by rope and chain, and immersed in the river Rhône for 2 weeks, the COF material was then returned to INL for analysis. In the lab we photographed the samples using the Scanning Electron Microscope (SEM) which produced a series of digital images where the fragments of dead diatoms, the fossils from ancient single cell algae, are visible among a landscape of micro debris. The COF material then underwent a process of washing in ethanol to extract the contaminants and HPLC (High-performance liquid chromatography), a technique in analytical chemistry used to separate, identify, and quantify each component in a mixture for analysis. We found significant (quantifiable) amounts of ibuprofen, diclofenac and topiramate; three of the most used pharmaceuticals. Carbamazepine and atrazine were not found in significant amounts. Chlorpyrifos was present in relatively high quantities.

After experimenting with the COF on the ORS in the Rhône HeHe designed a new form for the COF material. The COF material was then pressed at INL into the form of a miniature ORS, that can be worn on your finger while swimming. The little O.R.S wearable ring is a concept, a small artistic gesture, to counteract and manifest the contaminating effects of big pharma on the aquatic environment.

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1 W. Mnif, A.I.H. Hassine, A. Bouaziz, A. Bartegi, O. Thomas, B. Roig, Effect of endocrine disruptor pesticides: A review, Int. J. Environ. Res. Public Health. 8 (2011) 2265–2303. doi:10.3390/ijerph8062265.

2 E.M. John, J.M. Shaike, Chlorpyrifos: pollution and remediation, Environ. Chem. Lett. 13 (2015) 269–291. doi:10.1007/s10311-015-0513-7

A second avenue of research focused on a portable paper base sensor developed at INL that uses synthesized gold nanodots to detect sulphide ions, a dissolved form of sulphur, a contaminant caused by industrial activities for example mining, metallurgy petrochemical industries and pesticide runoff. The paper-based sulphide sensor was designed to be used in the field, when collecting water samples. The gold nanodots are capped with 6-mercaptostriazolo(4,3-b)-s-tetrazine (MTT) to provide them with stability in aqueous solution and selectivity against sulphide and fluoresce under UV light (360nm) more or less depending upon the level of sulphide. A matrix of water-soluble white dots was made by printing a negative form in solid wax ink and by heating the paper so that the wax ink soaks from the surface into the paper. The MTT nanogold solution is applied to each white dot. The sensor is then ready to be deployed in the field, and a drop of river water sample can be placed onto the white nanogold dot. If sulphide is present, it is attracted to the gold and is retained on the dots, reducing the fluorescence. In the laboratory, the precise fluorescence of the dot can be analysed with an optical spectral device to determine the precise quantity of sulphide present in the water sample.

We remade this experiment in the INL lab and designed a new graphic form for the sensor that takes the form of a cartography of the River Seine. The paper map has been printed and is ready to be activated with the water samples along the 350 km stretch known as 'Les boucles de la Seine', a major waterway that connects Paris to the seaport of Le Havre. The water samples will be completed in summer respecting the established scientific protocol for collecting environmental data: date, GPS position, pH level and atmospheric temperature and all the samples must be taken on the same day under the exact same conditions. Thus, once the samples have been placed on the nanogold dot maps, the representation of the riverscape actually carries real water of the Seine and the river is visible through the absence-presence of its sulphide contamination.

III.METHODOLOGY

The collaboration began with an introduction to the laboratory and presentation of the recent and ongoing scientific experiments. Dr. Espina and her team demonstrated and explained their work, HeHe observed, asked questions, took notes and reflected upon their observations. We then tried to imagine what could be done with these experiments, asking ourselves how could we give them an additional meaning by rethinking them, to preserve their function, but redevelop either a three-dimensional form or a two-dimensional image. We made a series of project proposals, preliminary concepts expressed in the form of images and short text, which were a direct response to seeing the scientific experiments in the laboratory. These ideas were then discussed with Dr.Espina and together we made choices based on the scientific relevancy as well as time and resource constraints. Several ideas were then experimented with in mixed media, in a process of trial and error, to explore the potential of the idea in an intuitive, 'hands on' way. In the process some avenues were explored and then abandoned, due to technical complexity, artistic interest and scientific relevancy. This is a normal part of any creative process, where multiple projects are initiated and choices have to be made.

IV. CO-CREATION PROCESS

The artist and scientist roles were clearly defined. The artist worked on forms and images, integrating the scientific experiments and protocols into the artworks. The scientists brought in their expertise and substantial resources of INL into the project.
From the synthesizing of capped nanogold and COF nanomaterials to supplying solid ink printers, chromographic paper, to cutting moulds with CNC or printing in 3D as well as offering the means to observe and analyse the experiments through SEM and HPLC technology. The artworks could not exist without the generous support of INL.

For both scientists and artists, seeing something with your eyes counts as proof that it is there, that it exists. In this project the artists have strived to be scientific, to follow scientific protocols, even as we give new forms and shapes to them. By redesigning them, we extended their usage into the realm of narrative, a way of understanding the possibilities of the science in a subjective realm. Although they are scientific experiments, the results matter less than the process and their manifestations. We already know that these rivers are polluted. Our imaginations are primed to project a mental image of that contamination. So, what can the data tell us? That significant levels of sulphide, pharmaceuticals or pesticides are present in

the river during a period of time, but not if they appear in particular places, on a specific day. There are always limits to scientific knowledge. We cannot know the names of all the contaminants in the river, only those that we are looking for. The unknown knowns. These experiments validate our suspicions: to see is to know. But by seeing it expressed as a form or as image, you start to know it in a more subjective way and then you start to perceive the implied meaning beyond what is visible.

V.IMPACT

A. Research Impact

The integration of an artist in the daily routine of a research group is always an enriching experience as both share their interest in understanding the world, but with very different perspectives. In this particular case, the artist had already an approach that implied obtaining scientifically relevant results, which enabled an efficient interaction from the beginning.

The concept of a moving station in the river that could provide water monitoring over a large area allowed the use of passive sampling systems based on COFs to check their performance in a real water scenario far from the lab. We were able to test the presence and richness in several lipophilic organic pollutants in the Rhône River. Despite of the limited information that can be extracted in terms of localization of particular spills or particular events in time, if used in a continuous and consistent way, this methodology could help to understand temporal trends that would allow to understand the massive use of pharmaceuticals and the efficiency of the wastewater treatment to remove them or verify the implementation of a pesticide ban.

On the other hand, having the artist perspective in the Nano2Water project for the paper-based detection system for sulphide in water, based on gold nanodots, allowed the integration of a new dimension; geolocalization. By developing the tests over a map of the sampled area, a visual understanding of the local impact is incorporated in the tests. Something that could be very useful in the future for decision support systems, above all, if other information layers are added, such as the presence of infrastructures such as waste water treatment plants, industries or cities.

B. Artistic Impact

When making work, the artists are engaged in a multiplicity of techniques and the immersion in the INL lab led to experiments with new materials and techniques which extended their art practice into new mediums. The residency enabled artists to work on developing objects and images that use nanotechnology research to measure and investigate water quality. The work led to a better understanding by the artists about the chemical processes used to tune nanomaterials and appreciate the sometimes utopian nature of working in the nanoscale. The residency led us to ask ourselves many questions about the possibilities and limits of nanotechnologies.

Beyond the actual projects developed, being at INL facilitated many fascinating conversations about the potential of nanomaterials and their possible risks as they become dispersed in our bodies and in the environment. These conversations lay the seeds for new artworks that the artists hope to develop in collaboration with biologists in the near future. The time spent at INL enabled us to develop a more nuanced understanding of the field of research about water contamination and to gain a practical, albeit rudimentary, understanding of how scientists are designing and changing the environment in the nanoscale.

VI.ART-SCIENCE INTER-RELATIONSHIPS

A successful collaboration begins with a clear definition of the roles of each collaborator, whereby the artist and scientist draw on their own expertise and experience in a spirit of mutual trust and respect. Above all, a collaboration is a personal relationship, an exchange between individuals. It is not necessary to understand everything about each other's area of experience, and indeed this would be impossible, but being open to dialogue is fundamental. In this collaboration, the Art-Science team had lots of dialogue and shared the same aim – to use nanoscale technology to find solutions to monitor and reduce environmental contamination. The artists proposed new forms for ongoing scientific experiments.

The residency sparked many non-realised ideas for art-science projects, some were in response to INL's work investigating the impact of nanomaterials in health and environment, studying the toxicity of nanoparticles and COFs. One particular proposal by the artists entailed running experiments which would expose zebrafish embryos to cosmetics. Experiments with zebrafish embryos - under 72 hours - are used as an alternative to animal experiments as they are a non-invasive way of seeing and measuring toxicity. These proposals stimulated discussion about the overall ethics of conducting experiments on living organisms and whether such experiments can be morally justified if they lead to relevant scientific data and therefore not

justifiable if they lead to an artwork without scientific relevance.

The artists and scientist did not agree on this point, or at least we agreed respectfully to disagree. To be relevant to its time, art imitates real life and it may have to cross lines to reveal a moral problem. Art can be a transgressive activity, it often breaks with conventional codes of what is considered acceptable. The function of art and science are not the same: while science seeks objective knowledge about reality- that can be generalised and is based on logical relationships leading to indisputable facts - art seeks to represent a particular reality from a singular, subjective viewpoint. It might provide a radical, nuanced or qualitative reading of a situation, or kindle a sense of empathy or aversion, or bring a fresh perspective by re-interpreting an old problem from a new vantage point. Art is a form of empirical knowledge that provokes, we hope, an aesthetic, emotional or intellectual response to the world. For the artist, the same code of ethics applied for scientific experiments should be applied in equal measure to a process of art production, as art and science are equals. As for the final outcome, in both domains the result and impact of an experiment is only apparent after the event. For the researcher, despite being a non-invasive test, *in vivo* zebrafish embryo toxicity experiments use the exposure of living organisms and the same principles of 3R's (reduction, replacement and refinement) that guide animal experimentation should be considered. Taking this into account, these kinds of tests are only authorised in the laboratory when the results obtained can ensure gaining significantly better knowledge of the risks associated with tested materials/chemicals, consequently contributing to an increase in human and environment safety.

VII.FUTURE DIRECTION AND ACTIONS

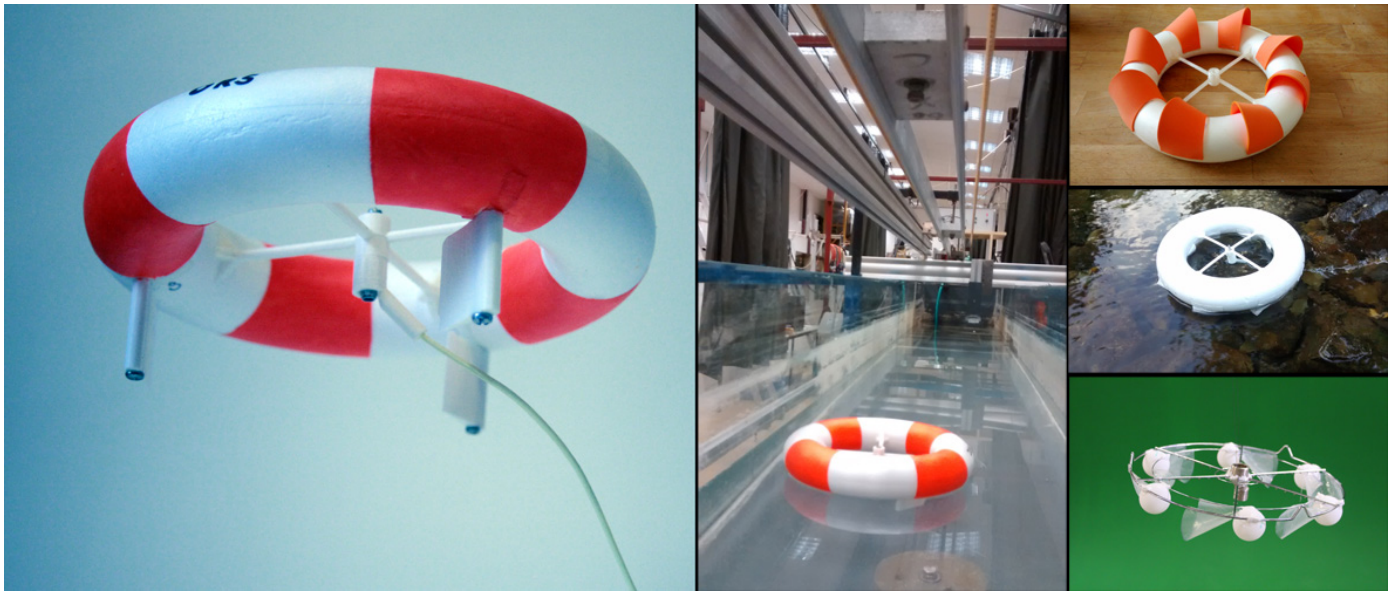
The next step is to diffuse the artworks, both the sculpture and the objects of scientific experiment. The Seine maps will be completed with water sample this summer. They need to be framed or mounted so they can be exhibited. The wearable O.R.S ring of COF also needs to have a formal solution for how to exhibit it in a gallery environment. We are actively seeking opportunities to deploy the ORS in the Seine, Danube and Thames rivers.

VIII.CONCLUSION

A. Concluding Remarks

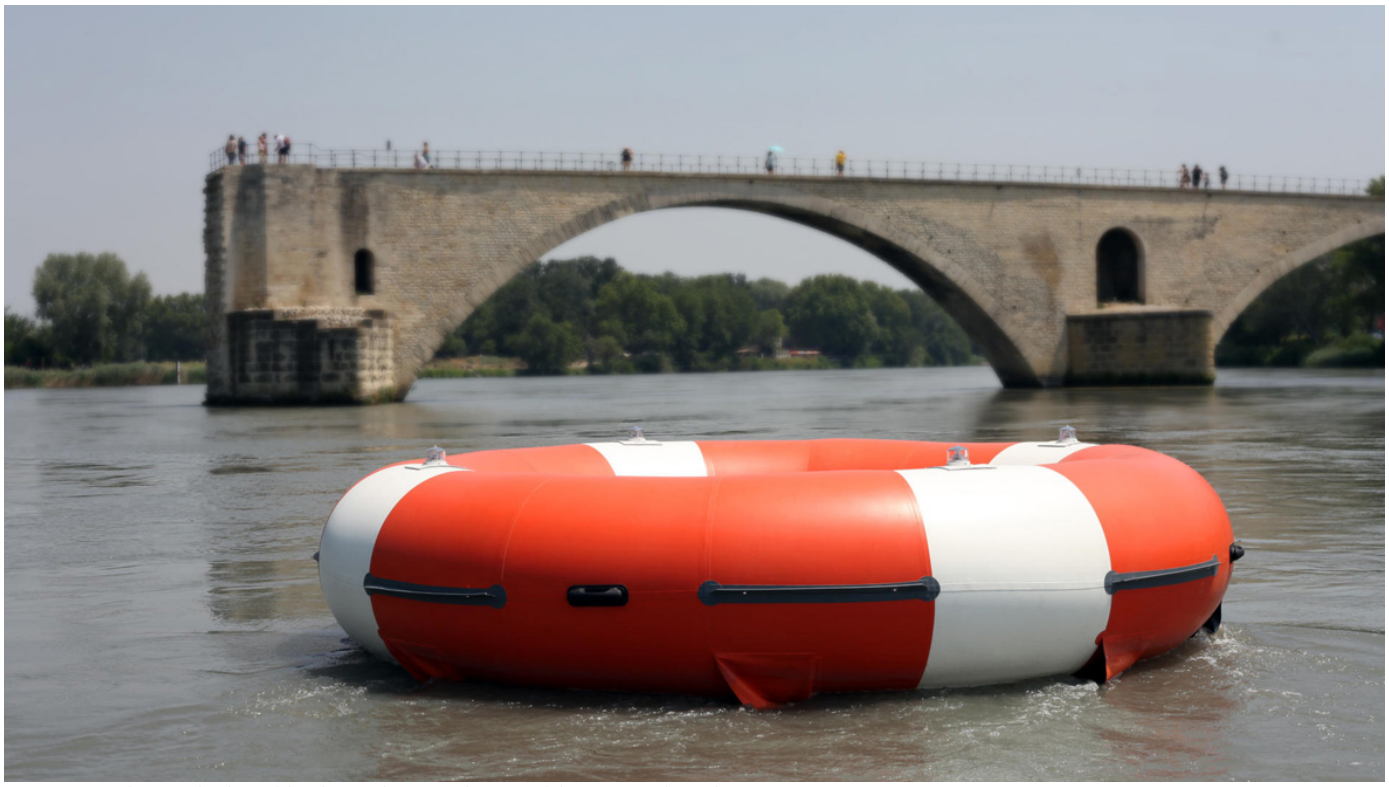
The first prototype of Orbital River Station, in collaboration with the International Iberian Nanotechnology Laboratory, is a step onto an unknown terrain: the deep and dark water of the river. The major rivers - such as the Seine or the Rhône - have become open-air laboratories where the chemical excesses of our urban life styles are ejected. It is the task of science to produce knowledge and tools to understand the changing conditions of our rivers and so there is also a place to make art that create experiences to access these new realities. The O.R.S is a hybrid platform, a project where art and science intersect and exchange. It is an artistic research project that is always in movement, ready to be reinvented, to test, to understand and to alter our ways of seeing. More than simply bringing visibility to the work of scientists, or offering new materials and techniques to artists, this collaboration lead to the production of artworks that represent the river through the particular qualities of the water. It puts both art and science practices in a different space. The chemical composition of the riverscapes and the impact of their ecosystems are complex and so are the art science endeavours that attempt to untangle them. In times of viral pandemic, the first findings of the collaboration with INL are evidence for the need for original, immersive, theatrical art processes that create narratives around the reality of the ecosystems of our rivers.

APPENDIX



1. Early models of O.R.S, with fixed and flexible rudders, tested in the current simulator at LOMC University du Havre and in natural streams.

2. SEM images of COF, the ring of COF and a nanogold map of the Port of Le Havre



3. O.R.S sculpture deployed in river Rhône Avignon with COFs onboard.

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