Summer 2018

The Dose Makes The Poison

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The Dose Makes The Poison

by

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A written essay submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

Major: Graphic Design

Program of Study Committee:
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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this written essay. The Graduate College will ensure this written essay is globally accessible and will not permit alterations after a degree is conferred.

Iowa State University
Ames, Iowa
2018

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Abstract

Nutrient pollution is an ongoing problem in the Midwest, the repercussions of which stretch far and wide. However, the seriousness of this topic may have been explained so many times that it has begun to lose its affect on people. The goal of this project was to take this significant problem we face and present it in a way that re-emphasizes its significance. Sampling from previous works laid the foundation for the beginning of this creative component, giving me insight into the way water behaves with light and motion, how to tell a story, and how to incorporate data and science into the mix to create a compelling narrative. Through researching the effects of nutrient run-off on human health my hope was to bring this issue closer to home, rather than talk about the Dead Zone far away in the Gulf of Mexico. By giving examples of statistical information regarding drinking water contamination, images of clean drink water juxtaposed with toxic algae, and bringing in an expert on the issue of drinking water contamination, I was able to create a narrative that would hopefully re-capture the attention of the public. Further manipulating this story by projecting it into a tank of water, using a motor to disturb the water, pushed the boundaries of an otherwise simple video. By adding this physical element into the mix it brought the very issue being discussed, drinking water, and put in right on the front lines of the story and all of the issues surrounding it.

Introduction

I have lived in the Midwest my entire life; I even grew up twenty minutes from the world headquarters of John Deere. However it wasn’t until my undergraduate experience that I learned about the issue concerning nutrient pollution and its affects on the environment. What I found so perplexing is that ecologists and biologists have collected a plethora of data connecting Midwest nutrient runoff to the dead zone in the Gulf of Mexico, and in many other places as well, but not much has been done to address the issue. Furthermore, there have been many conservation studies conducted that have come to consensus on how to limit and prevent nutrient runoff. However, even with all this data available, the information seems to remain confined to scientists and those who intentionally seek this information out.

Coming from a background in science and swimming, many of my projects have focused around these topics, ranging from antibiotic resistance to a product review for goggles (figure 1). It has been intriguing and challenging to blend the two in a unique way that offers a product rooted in design principles that effectively speaks on data driven topics. Science can be a foreign topic at times however, so good design can make a huge difference in its communication with people that know little of, or simply don’t fully comprehend a particular issue. Trying to represent global warming through the use of ice (figure 2), detailing the amount of work that goes in to producing clean water (figure 2), and designing a kinetic sculpture focused on nutrient pollution and the resulting dead zone in the Gulf of Mexico (figure 3), gave me valuable experience with designing these kinds of interactions.
Research

Nutrient Runoff

Early on in the project I began researching about the affects nutrient runoff has on local bodies of water, examining the impact on algal blooms and overall water quality in Iowa. The Iowa DNR draft 2016 Integrated Report of Impaired Waters contained 750 water-bodies, with 608 at Category 5 (waterbody is impaired or threatened and a Total Maximum Daily Load [TMDL] is needed) and 142 waters in Category 4 (waterbody is impaired or threatened and a TMDL is not needed). Between Category 4 and 5 waters, there are a combined total of 1,096 impairments, the most common causes coming from E.coli and fish kills (1, 3). It is due in large part to a lack of conservation practices and an excessive use of fertilization that this problem has continued to get worse despite systems to help prevent it. Plans such as the Iowa Nutrient Reduction Strategy have established a goal of reducing total nitrogen and phosphorus levels by 45 percent. Non-point sources, largely agriculture, make up more 93 percent of the target load reduction for nitrogen, and about two-thirds of the total phosphorous load that end up in Iowa streams and rivers (Conrad et. al., 3). Corn and soybean crops account for over half (52 percent) of nitrogen that winds up in the Gulf of Mexico:

“In Iowa, nitrogen is applied to corn crops at the average annual rate of just under 130 pounds per acre, for a total of 1.6 billion pounds of nitrogen applied to Iowa-grown corn. Of this, little more than half is ever used by the corn plants, as their nitrogen use efficiency (NUE) typically hovers around 50 percent, with the other half lost to other natural processes. Assuming a 50 percent NUE means that over 800 million pounds of nitrogen fertilizer were applied to Iowa cornfields that were never used by the crop. Soybeans do not require any nitrogen application, but producers will apply some in order to boost yields. Soybean fields average 29 pounds per acre per year, for a total of 36.7 million pounds of nitrogen applied to Iowa soybeans. (Heffernan et. al., 3).”

These large quantities of fertilizer that end up in local streams and rivers eventually find themselves in the Mississippi River and come to rest in the Gulf of Mexico. From there the surplus of nutrients support the growth of massive algal blooms, which eventually die off and are decomposed by bacteria at the bottom of the Gulf. Through decomposition processes the levels of oxygen in the water is nearly eradicated, forcing fish and wildlife to leave or die. The Midwest
The agricultural industry is the largest contributor to the Dead Zone in the Gulf of Mexico. The impact of the Dead Zone has had a severe effect on the surrounding areas, including a 9 billion dollar industry. The National Oceanic and Atmospheric Administration estimates that the dead zone “costs the US seafood and tourism industries 82 million dollars annually” (Tercek).

The excess fertilization being dumped on Midwest crops produces large quantities of organic matter and is a waste element with a finite supply. In 2009 the US Geological Survey predicted that peak phosphorous production would land somewhere around the year 2033, meaning production would fall sharply downward after that (Duffin, Smith). The Iowa Nutrient Reduction Strategy executive summary for 2016 – 2017 reports that in 2016 there had been 600 thousand total acres of cover crop planted and an additional 250 thousand acres have gone towards prevention of soil and phosphorous loss. However this is just a small sample of Iowa's 26.7 million acres of cropland, nearly three fourths (74.2 percent) of the state (Major Land Uses). Phosphorous is a huge part of producing the amount of food we need to produce to sustain our current way of life, however our current use of phosphorous is rather unsustainable.

A major contributor to phosphorous runoff is livestock. Pasture and range animals account for up to 37 percent of phosphorous that is delivered into the Gulf of Mexico (Conrad et. al., 4). In a review of The Explosion of CAFOs in Iowa and Its Impact on Water Quality and Public Health, professors James Merchant, Professor Emeritus of Public Health and Medicine at the University of Iowa, and David Osterberg, Professor Emeritus in the Department of Occupational and Environmental Health at the University of Iowa, discuss how Concentrated Animal Feeding Operations (CAFOs) impact the quality of life in Iowa, as well as Iowa waters. In addition to the abundance of fertilizers that farmers use on their crops, the effects of concentrated animal feeding operations greatly impact runoff and water quality as well. In Iowa 97 percent of requested CAFO permits are approved (even in areas of fragile topography) and between 2001 and 2017 the number of CAFOs in Iowa has increased from 722 to over 10,000. Many of these CAFOs are not even recorded in the DNR’s database, as up to 5000 new CAFOs were documented in 2016 via satellite imaging (Merchant and Osterberg, i). These CAFOs have the potential to do serious harm to Iowa water-bodies as livestock production can contribute a considerable amount to water quality degradation. “The state has documented more than 800 manure releases to surface water, groundwater, and land due to improper waste handling, excessive waste application, mechanical failures, and other problems associated with CAFOs since 2000 (Merchant and Osterberg, 14).” These spills can do serious harm, leading to nitrate and ammonia pollution, hormones, antibiotics, and algae blooms. The US Department of Agriculture's Economic Research Service estimates that up to 15 percent of the nitrogen load entering the Gulf of Mexico, is contributed by animal manure (Merchant and Osterberg, 14).

It should be noted that major Nitrogen and Phosphorous contributors in Iowa come from soil erosion and municipal wastewater treatment plants. These sources contribute not only to the growth of algal blooms, but also foster high levels of bacterial contamination. However, this project focused largely on run-off from agriculture and CAFOs.

All of this excess fertilization, in conjunction with eroding soil from constant plowing, more severe and unpredictable weather patterns due to climate change, and a lack of public involvement equates to a long up hill battle. These large quantities of nutrients that increase yields and help crops to flourish do the same thing for aquatic plants after they runoff fields and into rivers and streams. Algae and protozoa growth explodes creates toxic algal blooms that create unsafe conditions for activities such as swimming, fishing, and present an overall unpleasant aesthetic to look at. Water-bodies, rivers, lakes, streams and the like are features of our landscape that can be profoundly beautiful to look at.
The way light reflects and interacts with the surface of a moving river, or the sound of a “babbling brook,” or even the cool breeze we enjoy blowing off a body of water on a hot day are things we normally take for granted. However the problem of nutrient runoff jeopardizes the quality of those water-bodies. In his book Blue Mind, Wallace J. Nichols describes how a quarry pool, known as Blue Lagoon, “attracted dozens of swimmers to its beautiful turquoise waters (87),” despite warnings of toxicity levels resembling that of bleach. It wasn’t until government officials dyed the water black that people quit jumping into the lagoon. Isn’t this is exactly what our nutrient runoff problem is doing?

Health Risks

At this point in my research I was beginning to feel that this is an issue that has been around for some time now. People know about nutrient pollution, especially in the Midwest, so how could I present this topic in a way that would create a more visceral reaction, or call to action. It was at this point I started exploring the relationship between the nutrients, affecting Iowa’s waters, specifically nitrogen and phosphorous, and how they directly impact peoples’ health. Publications, such as Nitrate, Bacteria and Human Health in the Nature Reviews Journal, describe the possible negative impacts nitrates can have on the human body. Methaemoglobinemia for example, otherwise known as blue baby syndrome, is a condition that mostly affects infants by causing the “oxidation, by nitrite or nitric oxide, of hemoglobin in red blood cells to an abnormal form known as methaemoglobin that cannot bind or transport oxygen” (Lundberg 2004, 596). In adults “studies have shown increased risks of colon, kidney, and stomach cancer among people with higher ingestion of water nitrate and higher meat intake” (Cancer). Nitrate in the oral cavity is reduced to nitrite by bacteria residing there, leading to a “1,000 fold increase saliva compared to plasma” (Lundberg 2009, 867). As we swallow all that saliva (1.5 liters per day) it generates a number of nitrogen oxides, including nitric oxide (NO). NO has the potential to diffuse into the tissue near the gastro-esophageal junction where it forms nitrosating species (similar to reactive oxygen species), which could lead to DNA damage and promote carcinogenesis (Lundberg 2009, 867). Phosphorous and phosphate toxicity is associated with cardiovascular calcification, significant decrease in serum calcium levels, impaired renal function, and can speed up the aging process (Razzaque, 4,5). Additionally, phosphate runoff can promote cyanobacterial algal blooms, some species of which can produce toxins that can compromise drinking water and lead to complications such as “acute hepatoxicity (liver damage), neurotoxicity, gastrointestinal problems, and a wide range of allergic reactions” (Merchant and Osterberg, 15). Some of these studies looking at nitrate and phosphate toxicity looked at at much higher concentrations that what is normal for drinking water, however being exposed to elevated levels, thanks to nutrient runoff, over a long period of time could lead to complications such as those previously mentioned.

EWG

After doing all this research into nutrient runoff and potential health complications I realized that I still did not have a clear direction I wanted to take. I had all this information but was unsure of how to channel it into a meaningful project. It was at this time I was introduced to the work of the Environmental Working Group (EWG) and their tap water database. The database is a collection of water quality testing information form over 50 thousand water municipalities from all 50 states providing information on what kinds of contaminants have been detected in that respective water supply, and at what levels. What was interesting about the EWG was that they also compared these levels of contamination to the EPA’s legal limits, and also recommended health limits, established by scientists from the California Office of Environmental Health Hazard Assessment and the National Cancer Institute. Combing through this group’s website gave me valuable insight into the current state of drinking water in Iowa, as well as the
rest of the country. What I found to be most intriguing was the (usually) large discrepancies between the legal and recommended health limits for drinking water contaminants. For example, the legal limit on nitrogen is 10ppm, a limit that all water utilities in Iowa met, however the recommend limit is 5ppm, 71 utilities were above that limit (EWG). This is just one of the many incredibly surprising facts about drinking water standards that the EWG’s database touches on. One of the factors that really caught my attention was that of “disinfection byproducts,” or the resulting chemicals that form after disinfecting the drinking water that are extremely difficult to filter out. What I learned was that these chemicals are almost entirely the resulting consequence of nutrient runoff. As high levels of organic matter enter the treatment facility, resulting from high levels of runoff as discussed earlier, the disinfection process, which usually involves chlorine, interacts with this organic matter forming chemical byproducts known as Trihalomethane (THMs). “At elevated levels have been associated with negative health effects such as cancer and adverse reproductive outcomes” (Barrett, 474). According to Craig Cox, Senior Vice President for Agriculture and Natural Resources, the only way to really combat this is to invest in large tanks and filters to sort out the organic matter before it reaches the disinfection phase of treatment, which can cost a lot of money (which costs the community a lot of money). It was this connection to adverse health outcomes, as a direct result of nutrient runoff, that was exactly the sort of thing I thought could bring this worn topic into a new light. By depicting how nutrient runoff ties directly into the sort of contaminants entering your drinking water it would hopefully “hit closer to home” rather than being told of an “algal bloom” one thousand miles away (literally) in the Gulf of Mexico.

Creative Component

The “Fish Tank”

So began development of the very installation I would create to depict this cycle of runoff, disinfection, byproducts, drinking water. Much like the topic itself I was not looking to do this in a generic way with posters or an add campaign. I wanted to hopefully grab the viewer’s attention and present this message in a way that might stick with him or her for awhile. I went through many ideas but a core throughout was that I wanted to incorporate (physical) water into this project. During the research phase I had slowly been brainstorming ways in which to go about presenting and representing these concepts. I have recently been exposed to the concept of projection mapping, or taking an otherwise normal video projection, and mapping it to a surface other than a blank white screen. In addition, we have been discussing the concept of “The Medium Is The Message” from Marshall McLuhan, and how the delivery and reception of a message can be altered via the medium it uses to transcribe that message. Through a melding of these two concepts I arrived at the idea of projecting an information based projection into an actual body of water, such as a local river. The thought of an outdoor projection into a material actually being affected by what I was talking about in my project seemed especially powerful. However, I came to this decision in mid February, and due to the unpredictable nature of Iowa spring time river conditions, the logistics surrounding this proved difficult to plan for.

After some thought I transitioned to the concept of bringing the river indoors, so to speak, by constructing my own tank to fill with water and project my video into. While this compromise looses a bit of the “grandness” of an outdoor projection over a river, it does allow for a more controlled environment where I could account for variables and conduct testing more regularly without worrying about weather conditions. This tank would also allow for this to be a more accessible installation for people to attend, view, and potentially interact with. I designed a 5 ft long by 1.5 ft wide by 1 ft deep (54 gallon volume) acrylic box (what came to be referred to as the “fish tank”) supported by a white, wooden frame (to keep the acrylic from bending under the weight of the water) (figure4).
The video component that would be projected into the tank of water could’ve gone a multitude of directions, seeing as how broad this topic is. What I decided to do was create a narrative of how one element water contamination leads to another, while also addressing the differences in drinking water standards between federal regulations and those recommend by leading research and health experts. I had been making sketches about how I might depict the text, statistical information, and visual components of the video. I was mostly trying to figure out how juxtaposing a data point with a vivid real life image might really drive home the point I was trying to make. What eventually came to fruition was a video with three types of sections to it: heavy text and graphics (figure 5), interview and video footage (figure 6), and beginning and ending quotes that tie the video into a running loop (figure 7).

The graphics used to depict the number of utilities and people affected by these contaminants are represented to the number. I used Processing to code for the exact number of people and/or utilities that the data set called for (figures 5). This hopefully emphasized the scale with which these contaminants have an affect, as well as offer an accurate representation of just how greatly the legal and recommended limits for drinking water contaminants differ.

The EWG has a regional office here in Ames and their Senior Vice President Craig Cox, of whom I mentioned previously, was kind enough to meet with me for an interview. He provided me with valuable information regarding their organization’s data collection on drinking water. I thought that the image of a real person (with credentials) narrating the story of how all of these components affecting drinking water are connected. During his narration I spliced in clips of the Ames Water Treatment Plant, farms and livestock, and a montage of algae, dead fish, chemicals, and drinking water. The narration of someone who has spent years working to fight this prevalent issue coupled with strong imagery would hopefully generate a genuine reaction from the spectator.
When most Americans drink a glass of tap water, they're also getting a dose of industrial or agricultural contaminants...
- EWG on the state of American drinking water
Audio

The audio accompanied with the visuals consisted of speech from the interview as well as sound bites from nature and from audio tracks of musicians. The first audio we hear is from an acoustic ecology assignment from a previous sustainability course, made up of bird calls, rustling winds, and of course the sounds of water sloshing around in a lake. These sounds help the viewer to truly encapsulate the experience of being near a body of water. In addition to these natural sounds I used a track called The River by Jeanette Lindström. The song uses chimes and soft dull tones to convey the feelings associated with a flowing river, and I thought it paired quite nicely with the text and graphics to give those somewhat “dry” moments some added emotional connection. When the song is played backwards (as it is during the last graphic showing the number of people in Iowa exposed to any contaminants over the recommended health guidelines) it creates an eerie and unnervingly familiar tune that helps to convey the magnitude that the graphic is visually representing. Lastly I used the intro to another song (Under The Water by Aurora) that crescendos from a soft tone to a louder “awakening” (for lack of a better word). This in conjuncture with an ever faster cycling of clips of runoff, algae, treatment, and drinking water, amounted to what I felt was a strong climax to the narrative. The silence that follows gives way to the natural sounds of the acoustic ecology audio, along with a quote urging a call to action.

Movement

This element of motion is what helped add a portion of the natural feel of a river back into this controlled setting. The motion of the water was able to help create striking refractions of light, cast shadows across the images displayed on the bottom of the tank, and establish an overall more striking aesthetic for the viewer to engage with. Without this motion of the water there would have been little differentiating the projection form being displaced in a tank of water and a blank white screen. That added layer of depth, of motion, of skewing the information, of making it a challenge to decipher the message, is what drew me using a “live” element like a river originally. During a prototype set up (figure 8) with a bucket and projector in hand, I was able to get a feel for the possibilities that a relationship between this disturbance of the water, partnered with light from the video projection, could have.
Installation

The installation itself used two tripods on either end of the tank that held up a crossbar, from which a mirror was hung. The mirror allowed me to create an acceptable amount of distance between the tank and the projector’s throw, in half the space, to match exactly with the dimensions of the tank. (Figure 9).

Figure 9.

Conclusion

The creation of this project pulled from many aspects of previous works and passions of mine. It was entirely rewarding to be able to successfully blend them into a type of installation that could potentially bring new light to an old topic. The combination of environmental impact via nutrient runoff, various health risks associated with that, the authority and resources of an agency devoted to examining the contaminants and chemicals we are exposed to on a daily basis, a video implementing a compelling narrative that should appeal to our better nature, and the element of physical water being at the center of it, all allowed me to present something as essential to us as drinking water, in great need of attention.

Some future directions for this project could come in the form of mobilizing the projection by taking it out to actual creeks and streams like I had originally intended. Documentation of this in various places of runoff as well could help spark some discourse. I also only gave a brief overview of the everything involved with a topic as large as nutrient pollution. With so many possible directions additional videos and graphics could be produced in order to further the discussion.
Work Cited


