**TEAM PROJECT REPORT**

**Membrane Bioreactor System for Wastewater Recycling and Recovery of Phosphorus from Wastewater**

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**ABSTRACT**

Phosphorus (P) is a contaminant in wastewater that accumulates from a variety of sources including factories, households and farms, but P is also a valuable nutrient for optimal plant growth in agriculture. By evaluating membrane bioreactor and magnesium carbonate pellet technologies for the removal and sequestering of P, the merit of pursuing these technologies for more efficient removal of P from wastewater and/or sequestering P for later commercial use was explored. By monitoring P concentrations before and after the secondary aeration tanks in the Mill Creek Wastewater Treatment Plant, plus removing, digesting, and testing the biomass from the post-secondary aeration samples, the efficiency of P sequestration by the biomass was determined. By measuring P concentrations at equilibrium with magnesium carbonate pellets, the efficiency of the adsorption process for P recovery from municipal wastewater on a small-scale was evaluated. The hypothesis that the biomass sequestered significant and potentially recyclable P in the aeration basin solids prior to separation with a microfiltration membrane was tested. The hypothesis that magnesium carbonate pellets adsorb significant P was also tested. The efficiencies of the biomass sequestration and magnesium carbonate pellet adsorption suggest that these strategies may be useful to implement on a larger scale to improve P removal from wastewater and the addition of potentially feasible methods of recycling P from wastewater. These results will be disseminated through traditional scientific forums but also to students in middle school and first-year college through teaching units based on aspects of this research.

**KEY WORDS:** Phosphorus, wastewater, membrane bioreactor, magnesium carbonate adsorption, agriculture

1. **INTRODUCTION**

Phosphorus (P) enters wastewater from farms, factories, and housing (Parsons and Smith, 2008). Without wastewater treatment protocols, approximately 75% of this P would end up in rivers (Parsons and Smith, 2008). When P reaches significant concentrations, it leads to eutrophication in lakes and rivers (Parsons and Smith, 2008) by supporting algal blooms that disrupt the balanced ecosystem in rivers, lakes, and oceans (Paerl, 2013).

Traditional treatment plants use screening methods in the first part of the wastewater treatment process to remove large solid trash particles and various types of grit. The wastewater then typically enters an area of primary treatment where heavier solids are removed by gravity and are disposed of. The wastewater, which now contains tiny suspended solids as well as various dissolved chemical pollutants, typically enters secondary aeration tanks containing active colonies of bacteria and other beneficial microbes. These tanks are supplied with a high volume of air *via* compressors and piping to support the actions of the bacteria, which are actively digesting many of the waste particles and dissolved pollutants still left in the water at this point. During this stage of the treatment process, pollutants are pulled from the water and used as nutrients to build the biological molecules needed by the bacteria as they grow and reproduce. As the bacteria feed and grow in numbers, matter accumulates in the bottom of the tank: it consists of bacterial colonies, their wastes, and some yet-undigested solid material. A significant amount of activated sludge is retained for sustaining the bacterial colonies at this stage of treatment, while the excess sludge is pumped elsewhere for disposal. The effluent from the secondary aeration stage enters the secondary clarifier units where any remaining solids have a chance to settle out and microbes have even more time to process pollutants contained in the water. As microbes build up in the secondary clarifier, they are collected and returned to the secondary aeration tanks *via* pumps and pipes. This matter is collectively called activated sludge. The final stage of the treatment process typically involves the effluent from the secondary clarifier moving to the disinfection area, where chlorine or other chemicals are added to kill microbes remaining in the water before the water is released into the aquatic environments. As excess sludge is disposed of *via* incinerators or other means, the nutrients that have been sequestered inside its bacterial cells are included in this step, resulting in a large quantity of the P and other nutrients eventually going to the landfill. Because the water is continuously moving through the wastewater treatment plants (WWTPs), there is a hydraulic retention time (HRT) that can be calculated to determine how long any fraction of water is held during each step in the process (Monti, 2007). Similarly, the solids retention time (SRT) can be calculated, and the SRT differs from HRT in that the suspended solids and biomass are retained and recycled while the water moved through to effluent (Monti, 2007).

In the traditional ways that WWTPs deal with wastewater, much of the P is removed, but it gets disposed of in a landfill and is therefore lost to humans as a potentially useful nutrient. Recovery of that P in a way that makes it readily available for humans to use instead of sending it to a landfill is desirable if it is feasible. While advanced wastewater treatment typically involves biological nutrient removal (BNR) processes, one option that may add efficiency is a membrane bioreactor (Monti, 2007). Essentially the secondary clarifier is replaced with membrane filtration to more efficiently separate solids and microbes from treated wastewater (Monti, 2007). Retaining higher concentrations of mixed liquor suspended solids (MLSS) in the bioreactor results in an effluent without suspended solids and higher rates of removal of pollutants (Monti, 2007). Another method of recovering P is to use adsorbent pellets of magnesium carbonate inside of a water column as part of the wastewater treatment process. Both membrane bioreactor and magnesium carbonate adsorption strategies were explored here.

**2. LITERATURE REVIEW**

*2.1 Detection of P by Spectroscopy*

To detect P by spectrophotometry, colorimetric tests are used that react with phosphates and change color in proportion to the level of P present. P that responds in colorimetric tests is termed “reactive” and is primarily orthophosphate, and there are both dissolved and suspended forms of reactive P (APHA-AWWA-WEF, 1998). “Acid-hydrolyzable” P includes dissolved and particulate condensed phosphates converted to detectable dissolved orthophosphate (APHA-AWWA-WEF, 1998). Finally, “organic P” is released from organic matter only by oxidation destruction (APHA-AWWA-WEF, 1998) and so generally is not detected by colorimetric analysis. As per the Hach Company, the commercially available Hach TNT Vial Chemistries for P use the ascorbic acid method to detect orthophosphate forms by colorimetric conversion to a blue color detectable by spectroscopy (DR6000, HACH). In short, ammonium molybdate and antimony potassium tartrate react with dissolved P to form antimony-phospho-molybdate complexes that are reduced to a blue color by ascorbic acid (APHA-AWWA-WEF, 1998).

*2.2 Membrane Bioreactors*

In membrane bioreactors, aeration basins are typically coupled with microfiltration or ultrafiltration membranes to separate activated sludge from water (Water Environment Federation, 2007).. One advantage of membrane bioreactors is that the resulting effluent meets water reuse standards, which is one step above typical treatment protocols without membrane filtration (Water Environment Federation, 2007).

*2.3 P Removal in a Membrane Bioreactor System*

Membrane enhanced biological P removal has been studied to increase the removal of P from effluent (Monti, 2007). Microorganisms can take up soluble P and sequester this P by producing new biomass as they build their biological molecules. According to the Water Environment Federation (2007), traditional activated sludge systems reduce P by about 1 - 2 mg/L. Some systems termed “enhanced biological P removal” (EBPR) systems are designed to specifically select for a higher percentage of *Acinetobacter* organisms as these microbes can remove up to 3 - 6 mg/L of P (Water Environment Federation, 2007).

*2.4 P Removal using Magnesium Carbonate Pellets*

Once properly installed, plumbed, and setup with ideal flow rates, the magnesium carbonate pellets inside the water column theoretically have the potential to adsorb P from the wastewater instead of allowing that same P to be sequestered in bacteria or released into the watershed (Martin et al, 2018). The chemical attraction between magnesium carbonate and P allows the pellet to adsorb the P. The manufacturing process used for making the pellets from analytical grade magnesium carbonate powders gives the pellets a greatly increased surface area (Martin, 2018) which greatly surpasses those found in other adsorbents (Kose, 2011). This large surface area to volume ratio allows the pellet to adsorb a greater amount of P from the wastewater, and the loaded pellets could then be removed from the water column and placed in agricultural settings where the P could be reused as a slow-release fertilizer for crops. Similar results have been obtained and used in agricultural trials using recovered P in the form of struvite (Parsons and Smith, 2008), so the potential for the pellets in this study to be used as slow-release fertilizers is an option for future study.

**3. GOALS AND OBJECTIVES**

The strategy of this research project was to collect samples from the Mill Creek WWTP (Metropolitan Sewer District, Cincinnati, Ohio) and use them in a series of tests. These tests had three main objectives: (i) to investigate the amounts of P contained in the wastewater at various stages to establish a concentration profile, (ii) to evaluate the P concentrations that were sequestered inside bacterial cells using digestion techniques, and (iii) to measure the amount of P that was adsorbed onto magnesium carbonate pellets *via* a batch kinetic study. The goals in this project were accomplished in an iterative process to achieve accurate results.

1. **RESEARCH STUDY DETAILS**
   1. **Sample Collection at Wastewater Treatment Plant**
      1. *Wastewater Sample Collection Protocol*

Samples were collected using standard wastewater sampling techniques. In brief, a sample collection device was used to obtain a larger sample from the open surface of the treatment stage being sampled. The device was used to pour a sample into a clean collection vial (~ 125 mL) which was labeled and secured prior to transport to the laboratory for testing. Selected samples had aliquots added to Hach tubes prior to leaving the facility (see below for methodology).

* 1. **P Detection**

*2.2.1* *Principles of UV-VIS Spectroscopy*

The principle behind spectrophotometry is that molecules of solute in a solution will block transmittance of light through the solution by absorbing light over a particular range of wavelengths. UV-VIS spectrophotometers detect the wavelengths of visible or UV light transmitted through each sample. The Beer-Lambert Law states that if a beam of monochromatic light is transmitted through a solution with a substance that can absorb that light, the decrease in light intensity along the length of the sample is proportional to the concentration of the solution. By comparing the absorbance of light by a solution to that absorbed by the blank, the amount of solute in a solution can be determined.

*2.2.2 Detection of Total P by UV-VIS Spectroscopy*

Hach TNT Vial Chemistries for Low (0.05 to 1.5 mg/L), High (0.5 to 5.0 mg/L)and Ultra-High (2.0 to 20. 0 mg/L) Range P were prepared as per manufacturer’s instructions (Hach.com, 2018). In brief, the specified volumes of sample or distilled water negative control were added to each tube with the Dosi cap inverted and replaced, samples shaken vertically two to three times, followed by incubation at 100°C for 60 minutes in a Hach DRB200 incubator. After cooling to 18-20°C, reagent B was added as per manufacturer’s instructions, followed by mixing by inversion and a 10-minute incubation at room temperature. Samples were mixed again by inversion, vials were wiped with Kimwipes, and spectrophotometry using the appropriate barcode program in the Hach DR 6000 UV-VIS Spectrophotometer was performed with the results reported in mg/L PO43--P for total P.

*2.2.3 P Profile of the Mill Creek Wastewater Treatment Plant*

Wastewater samples were collected from four different stages of the plant for the purpose of establishing a profile of P levels at those areas. On six different dates, a sample was collected from each of the following areas:

1. Beginning of primary settling tanks
2. End of primary settling tanks (Fig.1), just before entering secondary aeration tanks
3. End of secondary aeration tanks, just before entering secondary clarifier
4. Effluent from secondary clarifier, just before the disinfection stage

These samples were each tested with the appropriate range of Hach vials, and the results were averaged.

*2.2.4 Acid Hydrolysis by Persulfate Digestion*

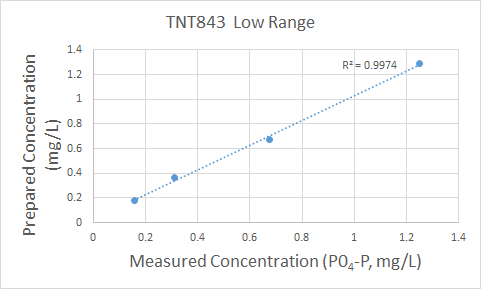
Samples were digested using the persulfate digestion method as per APHA-AWWA-WEF (pp.4-143-144, 1998). Briefly, for each digestion, 50 mL of sample was added to glassware rinsed with dilute hydrochloric acid (HCl) then with distilled water (dH2O). If filtered, then 50 mL of sample was added to a membrane filtration system which included either 0.45 m pore PVDF or nitrocellulose membrane, and vacuum was applied up to 8.2 lb/in2 until supernatant was separated from the sludge remaining on the filter. One drop (50 µL) of phenolphthalein was added to either 50 mL of sample 50 mL of dH2O containing the membrane filter plus sludge. If a red color developed, H2SO4 solution was added dropwise to just discharge color. One mL of H2SO4 solution and 0.5 g solid potassium persulfate (K2S2O8) were added to each sample, followed by gentle boiling on preheated hot plates until approximately 10 mL remained. After cooling, 20 mL dH2O and 50 µL of phenolphthalein were added, followed by neutralizing each diluted sample to a faint pink color with 1N sodium hydroxide (NaOH). Samples were then diluted with dH2O to a final volume of 100 mL and P mg/L determined as described previously.

*2.2.5 Adsorption Studies*

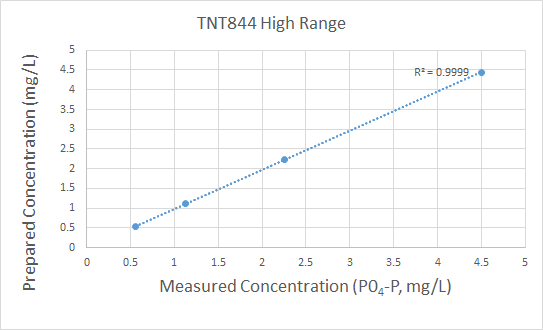
Batch kinetic trials were used to test the ability of magnesium carbonate (MgCO3) pellets to adsorb P from wastewater. For these trials, water samples were taken from the end of the primary settling tank (see Fig.1); at this stage the P was at its maximum level, as it had not yet been exposed to the digesting processes of the bacteria. For these trials, three 250 mL conical flasks were set up in the following way: (a) control flask A - contained 100 mL deionized water and an average of 4.706g of MgCO3 pellets, (b) control flask B - contained 100 mL wastewater only, and (c) experimental flask C - contained 100 mL wastewater and an average of 4.683g MgCO3 pellets. The pellets used in these trials were produced using the MZL Flat Die Pellet Mill (Xuzhou Orient Industry) using analytical grade MgCO3 powder with a constant moisture content of 45% water to MgCO3 weight ratio (Martin 2018). The pellets were then calcined at 300 oC for 17 hours, resulting in pellets with a diameter of 6 mm and an average length of 17 mm (Martin 2018). All three flasks were sealed with Parafilm and incubated at 25 oC and shaken at a mixing speed of 100 rpm using the MaxQ HP Incubated Console Shaker (Thermo Fisher Scientific). P concentrations for all three groups were measured at the beginning and at the end of the two-hour process, with the experimental group also being tested at every 30 minutes for 2 hours.

1. **RESEARCH RESULTS**
   1. *Calibration of the Hach DR 6000 UV-VIS Spectrophotometer.*

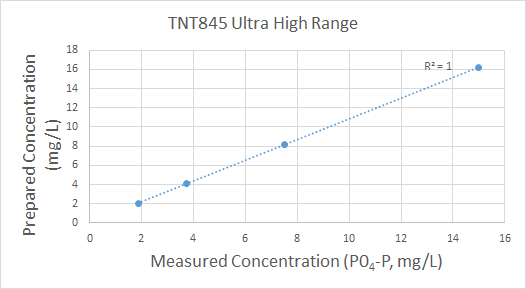
Serial two-fold dilutions were made with distilled water and P to provide four samples within the range of each of the three TNT Vial Chemistries Total P ranges and analyzed using the Hach DR 6000 UV-VIS Spectrophotometer. As presented in Figs. 2, 3 and 4, after plotting standard curves, results indicated that the instrument was calibrated and also that dilutions were accurately and precisely made as can be seen by the R2 values of 0.9974, 0.9999, and 1.0, respectively, from the low, high, and ultra-high range sets.



**Figure 2. Standard Curve for Low Range Total P**

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**Figure 3. Standard Curve for High Range Total P**

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**Figure 4. Standard Curve for Ultra High Range Total P**

*3.2 P Profile Plot of the Mill Creek Wastewater Treatment Plant.*

Samples from the influent, pre- and post-secondary aeration, and post-secondary clarifier were taken from the test site on five different occasions and tested for mg/L total P. Results in Table 1 indicate an average efficiency of 86.7% of P removal beginning with 2.3 mg/L total P in the influent and ending with 0.305 mg/L P after the secondary clarifier. Compared to reported typical results for activated sludge systems that typically remove 1-2 mg/L P, and EBPR systems that remove 3-6 mg/L P (Water

**Table1. Concentration of P (in mg/L) at four locations in Metropolitan Sewer District**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Date | Sample #1 (Primary influent) | Sample #2 (before aeration) | Sample #3 (after aeration) Supernatant | Sample #3 (after aeration) MLSS | Sample #4 (after secondary clarifier) |
| 6/29/2018 | 2.12 | 2.07 | 2.67 | 19.1 | 0.085 |
| 7/2/2018 | 0.878 | 1.09 | 0.647 | 18.5 | 0.115 |
| 7/6/2018 | 1.01 | 3.32 | 0.817 | 18 | 0.649 |
| 7/13/2018 | 2.85 | 3.06 | 0.389 | 19.8 | 0.259 |
| 7/13/2018 | 4.65 | 2.7 | 3.45 | 19.9 | 0.415 |
| Average | 2.3 | 2.57 | 1.59 | 19.06 | 0.305 |
| Standard Deviation |  |  |  |  |  |

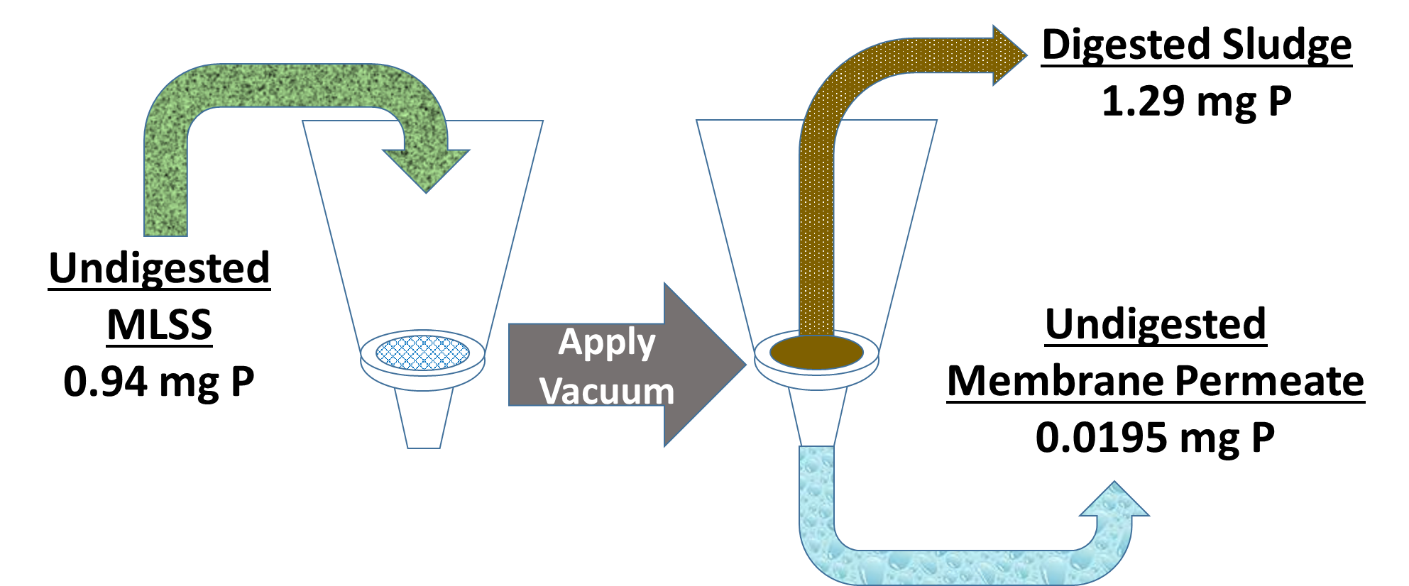
Environment Federation, 2007), the test site was within the range for typical results by removing an average of 1.995 mg/L P.

*3.3 Sludge Digestion Results*

To ensure that nitrocellulose and PVDF membrane filters were not contributing P to samples, distilled water was used as a negative control. As shown in Table 2, all distilled water samples had readings too low for accurate detection, indicating that the membrane materials used did not contribute P when used to filter supernatant or when present in digestion reactions. While both membranes retained approximately 13 mg/L P in the sludge obtained by filtering MLSS, the PVDF membrane allowed twice as much P into the supernatant as compared to nitrocellulose (0.777 vs. 0.389 mg/L) and took longer to filter the sludge so nitrocellulose results were selected for further mass balance analysis. Digested sludge plus undigested supernatant yielded 1.485 mg P while undigested input MLSS yielded 0.94 mg P in the same volume of input, a gain of 0.545 mg or an increase of 63.3% (Fig.5). The percentage of mg of P retained in the digested sludge was 1.49%.

**Table 2. Total P in mg/L Obtained by Nitrocellulose or PVDF Membrane Filtration Using Distilled Water or MLSS Containing 18.8 mg/L Input.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Total P in mg/L** | | | |
| **Sample** | **Nitrocellulose + dH2O** | **NItrocellulose + MLSS** | **PVDF + dH2O** | **PVDF + MLSS** |
| **Undigested Supernatant after Membrane** | 0.034  *(out of range - low)* | 0.389 | 0.028  *(out of range - low)* | 0.777 |
| **Digested Sludge with Membrane** | 0.014  *(out of range - low)* | 12.9 | 0.005  *(out of range - low)* | 13.1 |

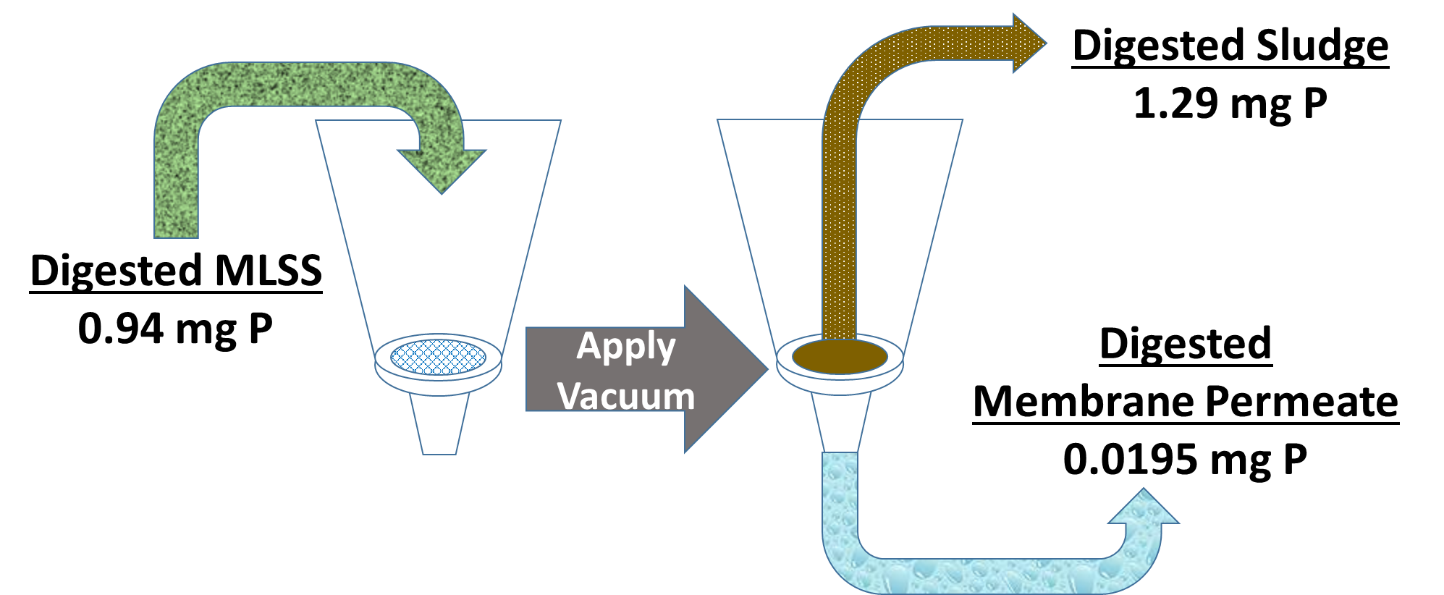
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**Figure 5. Mass Balance for Phosphorus through Membrane Filtration.**

To test the possibility that the discrepancy in the mass balance equation was due to the sludge being digested, a second set of samples was tested with digestion of samples prior to and following membrane filtration to ensure maximum detection of P present (Table 3). The mass balance analysis in Fig.6 showed digested sludge plus digested supernatant yielded 2.371 mg versus 2.1 mg of input, a gain of 0.271 mg or 11.4%, suggesting that the previous gain of 63.3% was due to missing undetectable forms of P in the input MLSS that were subsequently released through persulfate digestion (APHA-AWWA-WEF, 1998). The overall retention of P in the sludge versus the supernatant was 94.1% by using nitrocellulose membrane filtration and releasing detectable P by persulfate digestion.

**Table 3. Total P and Mass Balance Analysis of Digested Versus Undigested Samples**

|  |  |  |
| --- | --- | --- |
| **Sample** | **Total P (mg/L)** | **Total P (mg)** |
| **Undigested Influent Before Aeration (#2)** | 2.7 | 0.135 |
| **Digested Influent Before Aeration (#2)** | 3.28 | 0.328 |
| **Undigested MLSS** | 19.4 | 0.995 |
| **Digested Input MLSS** | 21.0  *(out of range - high)* | 2.1  *(out of range - high)* |
| **Digested Sludge with Nitrocellulose Membrane** | 22.3  *(out of range - high)* | 2.23  *(out of range - high)* |
| **Digested Supernatant after Nitrocellulose Membrane** | 1.41 | 0.141 |

****

**Fig. 6 Mass Balance Equation for Nitrocellulose Membrane Filtration of MLSS.**

**Table 4. Phosphorus Concentrations Measured Immediately After Collection Versus After One Hour Storage.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Location of test (Immediately at plant or 1 hour later at lab) | Sample #1 (Primary influent) | Sample #2 (before aeration) | Sample #3 (after aeration) Supernatant | Sample #3 (after aeration) MLSS | Sample #4 (after secondary clarifier) |
| Plant | 4.57 | 3.08 | 1.01 | 19.4 | 0.404 |
| Lab | 4.65 | 2.70 | 3.45 | 19.9 | 0.415 |

Possible explanations for the 11.4% discrepancy include the following. The mg/L measurements used to calculate mg P yield for digested input MLSS and digested sludge were out of range for the Ultra High Range Hach Kit and no higher range kit was available during the time frame of this study. Acid hydrolysis of the Digested Input MLSS was started immediately after samples were obtained in the laboratory while there was a delay due to the membrane filtration time, leading to an increased time of sludge in contact with supernatant in the Digested Sludge sample. Retention time differences were documented below (see the changes in P concentration between samples added to test vials at the water treatment plant versus at the laboratory in Table 4) supporting this possible explanation. Alternatively, the supernatant mixed with suspended solids in the Digested Input MLSS sample could have led to some of the acid hydrolysis in the sample being performed on non-P-containing solids, leading to reduced detection as compared to the separated sludge and supernatant following nitrocellulose membrane filtration.

*3.4 Adsorption Studies With Magnesium Carbonate Pellets*

Data was collected from three separate batch kinetic trials as shown in Table 5. A plot showing that the adsorption of P over time in the presence of pellets did not follow a linear pattern and leveled off as time progressed is shown in Fig. 7. The final point at 2 h was assumed to approximate the final equilibrium concentration, Ce. Next, the Langmuir isotherm model was applied to these data using the following equation:

**Ce/qe=(1/qmax)Ce+(1/KLqmax)**

where qe is the amount of adsorbed adsorbate per unit mass of adsorbent (milligrams of P per milligram of pellets), Ce is the equilibrium concentration of unadsorbed P in solution, and qmax and KL are system constants. The graph resulting from this model is shown in Fig. 8. This equation yielded a qmax value of -0.0061 and a KL value of -0.612. These data are unexpected since the qmax value would normally be expected to be positive because it represents the maximum mg P per g pellet that can be adsorbed. However, the control sample of supernatant only data for the second and third kinetic studies showed something interesting; there was a loss of P when no pellets were present. This loss due to mechanisms other than adsorption to the pellets may have skewed the isotherm data. This issue should be investigated further to determine the mechanisms. Likely sources of additional P loss may have been either adsorption to the glassware and/or biological uptake for any small amounts of biomass in the samples (even 10 mg/L of biosolids could have made a difference since a 3-5% P incorporation in the solids is typical).

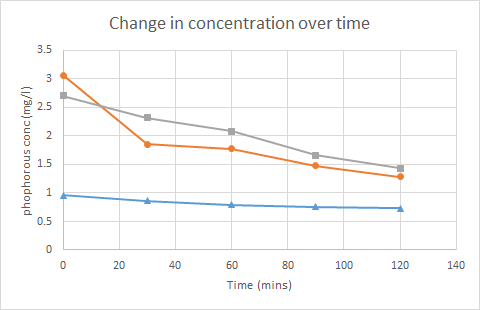
These data were also used in the Freundlich isotherm model using the following equation:

**log qe=log Kf+ (1/n)log Ce**

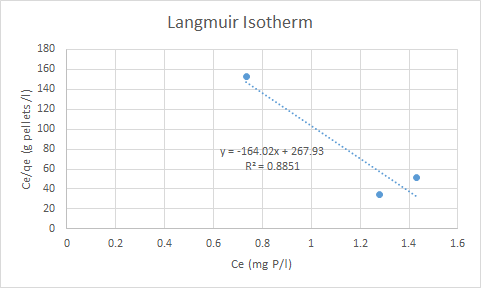
where Kf and n are system constants. In this equation, Kf had a value of 0.0127 and n had a value of 0.337. The graph is shown in Fig. 9. For further reference, all of the values used in these models are shown in Table 6. With its slightly higher R2 value of 0.9156, the Freundlich isotherm model was found to be the better fit for the data collected in this experiment.

**Table 5: P Concentration Data From Batch Kinetic Trials**

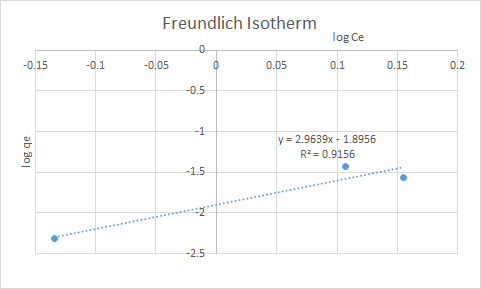
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Time stirred | Distilled water + Pellets (mass in g) | Supernatant only | Supernatant + Pellets  (mass in g) |
|  |  | DI +Pellets (4.642) |  | Supernatant + Pellets (4.668) |
| 7/12/2018  (Run 1) | 0 min. | 0.017 | 0.960 | 0.960 |
| 30 min. | X | X | 0.864 |
| 60 min | X | X | 0.796 |
| 90 min. | X | X | 0.0759 |
| 120 min. | 0.004 | 0.997 | 0.0735 |
|  |  | DI +Pellets (4.7692) | Supernatant only | Supernatant + Pellets (4.7655) |
| 7/13/2018  (Run 2) | 0 min. | 0.005 | 3.06 | 3.06 |
| 30 min. | X | X | 1.85 |
| 60 min | X | X | 1.77 |
| 90 min. | X | X | 1.48 |
| 120 min. | 0 | 1.62 | 1.28 |
|  |  |  | Supernatant only | Supernatant + Pellets (4.6153g) |
| 7/18/2018  (Run 3) | 0 min. |  | 2.7 | 2.7 |
| 30 min. |  | X | 2.32 |
| 60 min. |  | X | 2.08 |
| 90 min. |  | X | 1.66 |
| 120 min. |  | 1.88 | 1.43 |

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**Fig. 7: Change in P Concentration for Adsorbance Experiment**



**Figure 8: Linearized Langmuir Model Applied to Adsorbance Experiment With Pellets**



**Figure 9: Linearized Freundlich Model Applied to Adsorbance Experiment with Pellets**

**Table 6: Values Used In Langmuir and Freundlich isotherm models**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Run | C0  (mg P/ l) | Ce  (mg P/l) | M  (g pellets) | qe  (mg P/g pellets) | (g pellets/l) | log Ce | log qe |
| 1 | 0.96 | 0.735 | 4.668 | 0.00482 | 152.488 | -0.13371 | -2.31695 |
| 2 | 3.06 | 1.28 | 4.7655 | 0.037352 | 34.26876 | 0.10721 | -1.42769 |
| 3 | 2.7 | 1.43 | 4.6153 | 0.027517 | 51.96755 | 0.155336 | -1.5604 |

1. **RESEARCH CONCLUSIONS**

In the portion of this experiment dealing with the plant profile, it was found that a considerable amount of P is being removed from the wastewater by the bacteria and other microbes living in the sludge. On average, the P concentration dropped from 2.3 mg/L to 0.305 mg/L (see Table 4), a decrease by 86.7%. This decrease is substantial, but that P is destined for landfills rather than being reused.

Next, in the sludge digestion portion of this experiment, controls with distilled water showed that the nitrocellulose membrane did not contribute detectable P. Nitrocellulose membrane filtration of input MLSS resulted in 94.1% retention of detectable P following persulfate digestion of samples to release the maximum reactive P for detection by colorimetric spectroscopy. These results suggest that recovering biomass using membrane filtration can result in the retention of significant levels of P. However, recovering the P from the biomass/sludge for re-use was not explored and may result in this methodology not being cost-effective.

Finally, the adsorbance experiments using magnesium carbonate pellets demonstrated that the P in wastewater can be removed in a way that allows the P to be recovered for future use if desired. This experiment also showed that the wastewater with pellets added saw a decrease of 11% more P in two hours than the wastewater without pellets added; this means that even though P is already being removed from the water by some other process(es), the addition of magnesium carbonate pellets will increase the removal of P.

1. **RECOMMENDATIONS FOR FUTURE RESEARCH**

The mass balance for the simulated membrane bioreactor showed increases in detectable P following membrane filtration. The increases in detectable P could be due to several possibilities. To further characterize the mass balance equation of MLSS to sludge and supernatant, a time course of digestions to minimize inadvertent release of organic P and/or different digestion protocols could be explored. Other future research could explore the cost analysis of using membrane separation of sludge from supernatant, as 94% retention of P is beneficial as it is removed from effluent but it is unknown if the process is cost-effective for commercial use to recover P for fertilizer. Additionally, studies could determine if membrane filtration followed by magnesium carbonate pellet adsorption of P from the supernatant would provide more P recovery.

The adsorbancy experiment was performed using small batches of pellets in conical flasks with 2-hour incubation times. For the purposes of a large wastewater treatment plant, it might be advisable for similar experiments to be tested in bench-scale apparatus resembling designs which might actually be installed in a plant, such as a water column design. Since wastewater treatment plants already have certain systems in place, they might also conduct testing to see how much time the water must spend in contact with the pellets in order to feasibly adsorb the maximum amount of P. Another consideration for future research is the cost recovering the P as compared to costs of mining P and any profit that is earned by reusing the P (Parsons, 2008).

1. **CLASSROOM IMPLEMENTATION PLAN**

**8.1.1 Jennifer’s Unit:**

Jennifer’s unit will incorporate concepts from this project by replicating aspects of membrane bioreactors in a community college teaching lab. After exploring biological organisms naturally found in pond water, students will be asked to consider pollutants and other compounds in water and to propose a way to use living organisms to remove or add a detectable substance from or to water. Students will learn to use a visible light spectrophotometer, construct a standard curve based on known samples, and use a standard curve to determine the concentration of a provided unknown sample. Students will perform library research to explore possible ways to change the concentration of pollutants or other compounds in water, and then propose a possible bioreactor design that can be set up and run for up to a week. Samples will be taken before and after the bioreactor runs and samples will be tested for the presence of the substance to be detected (i.e. P). Students will collect and analyze their data, present it to their peers in an advertisement presentation format, and propose refinements to their design to improve bioreactor efficiency.

**8.1.2 Paul’s Unit:**

Paul’s unit will incorporate concepts from this project by focusing on the methods by which P enters the water through weathering and erosion of land. After his students have learned about how P from farms and other areas ends up in the watershed during rainstorms, they will be tasked with designing a solution that prevents or decreases the amount of P that leaves a farm. Solutions will be built as a small model of a farm in a plastic box, and simulated rain will be added to measure the effectiveness of each design. The effluent from each model will be measured and inspected to see how much soil was lost, as well as how much fertilizer went with the soil. Sand will be used as the “soil” and will sink to the bottom of the effluent for easy quantification, while tiny foam pellets will represent the fertilizer and will float on top of the effluent for equally easy quantification. After testing their first design, student groups will have two more chances to improve the farm’s ability to resist erosion.

1. **ACKNOWLEDGEMENTS**

The authors of this report would like to thank the following people for helping in various ways during the steps of this project: Dr. Margaret Kupferle, Dr. Soryong Chae, Ms. Mohini Nemade, Ms. Brindha Murugesan at UC, Mr. Achal Garg at MSD. This project would not have been possible without their assistance in the form of guidance, advice, sample collections, and training in lab procedures and data analysis. The authors would also like to thank Mrs. Debbie Liberi, Ms. Kristin Barnes, and Dr. Anant Kukreti for extending the RET 2018 opportunity to Cincinnati-area educators. Finally, they would like to recognize the National Science Foundation Grant ID No. EEC-1710826 “Challenge-Based Learning and Engineering Design Process Enhanced Research Experiences for Secondary School and 2 and 4 Year Teachers” for providing the funding necessary to make this opportunity happen.

1. **BIBLIOGRAPHY**

Chan, Y.-H. M. and Boxer, S.G. (2007). “Model membrane systems and their applications,” *Current Opinion in Chemical Biology*, Vol. 111, pp. 581-587.

Hach.com. (2018). *Water Quality Testing and Analytical Instruments | Hach*. [online] Available at: https://www.hach.com/ [Accessed 4 Jul. 2018].

Kose, T.E., Kivanc, B.(2011). “Adsorption of phosphate from aqueous solutions using calcined waste eggshell,” *Chemical Engineering Journal* 178, pp. 34-39.

Judd, S. (2008). “The status of membrane bioreactor technology,” *Trends in Biotechnology*, Vol. 26, No. 2, pp.109-116.

Paerl, H.W., Otten, T.G. (2013). “Harmful cyanobacterial blooms: causes, consequences, and controls,” Microbiological Ecology 65, pp.995-1010.

Monti, A., Hall, A.R., Koch, F.A., Dawson, R.N., Husain, H., Kelly, H.G. (2007). “Toward a high-rate enhanced biological P removal process in a membrane-assisted bioreactor,” *Water Environment Research,* Vol.79, No.6, pp.675-686.

Parsons, S.A, Smith, J.A. (2008). “P removal and recovery from municipal wastewaters,” *Elements*, Vol. 4, pp. 109-112.

Water Environment Federation. (2007). *Operation of Municipal Wastewater Treatment Plants: WEF Manual of Practice No.11*. WEF Press, New York, NY. pp. 22-1:22-6.

Martin, E., Lalley, J., Wang, W., Nadagouda, M., Sahle-Demessie, E., Chae, S. (2018). “Phosphate recovery from water using cellulose enhanced magnesium carbonate pellets: Kinetics, isotherms, and desorption.” Accepted by *Chemical Engineering Journal* 28 June 2018.

APHA-AWWA-WEF. (1998). *Standard Methods for the Examination of Waste and Wastewater, 20th edition.* American Public Health Association, Washington, DC.

1. **APPENDIX I: NOMENCLATURE USED**

ADSORBATE = particles or materials that are adsorbed onto the surface of another particle or material

ADSORBENT = particles or materials that adsorb other particles or molecules onto their surfaces, usually by a chemical or physical process

AERATION = process by which air bubbles are introduced into a tank of wastewater with bacteria so that the bacteria can work in aerobic conditions

Ce = final equilibrium concentration in the Langmuir isotherm model

EFFLUENT = the water that leaves an area after the necessary processes of that area have acted upon that water

EUTROPHICATION = excessive richness of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life from lack of oxygen

INFLUENT = water coming into an area from a previous location, before it has had time to undergo the processes happening in the new area

KL = a system constant in the Langmuir isotherm model

MLSS = Mixed Liquor Suspended Solids - concentration of suspended solids, which is mostly microorganisms and non-biodegradable suspended matter in an aeration tank during the activated sludge process that occurs during the treatment of wastewater

P = phosphorus

qe = amount of adsorbed adsorbate per unit mass of adsorbent in the Langmuir isotherm model

qmax = a system constant in the Langmuir isotherm model

SLUDGE = a thick, soft, wet mixture of solids and water, typically bacterial colonies and non-biodegradable matter

SUPERNATANT = liquid remaining at the surface after solid particles have settled to the bottom

1. **APPENDIX II: LAB EQUIPMENT USED**

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MaxQ HP Incubated Console Shaker (Thermo Fisher Scientific)

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HACH DRB 200 Incubator

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HACH DB 6000 UV-VIS Spectrophotometer

1. **APPENDIX III: UNIT TEMPLATE OF JENNIFER LEIGH MYKA**

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| --- | --- | --- |
| **Name: Jennifer Leigh Myka** | **Contact Info: jennifer.myka@kctcs.edu** | **Date: 07/16/2018** |

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| **Unit Number and Title: Unit 1 Membrane Bioreactor – What Can Biological Organisms Do for You? OR**  **Unit 1: Membrane Bioreactors – What Can Biological Organisms Do To and For Your Water? – Design and Implement a Biological System to Modify Water Samples** |

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| **Grade Level:** | **College 1** |

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| **Subject Area:** | **Biological Sciences** |

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| **Total Estimated Duration of Entire Unit:** | **2-3 weeks** |

**Part 1: Designing the Unit**

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| **1. Unit Academic Standards (Identify which standards: NGSS, OLS and/or CCSS. Cut and paste from NGSS, OLS and/or CCSS and be sure to include letter and/or number identifiers.):** |

**COURSE DESCRIPTION: BIO116**: Examines basic biological concepts such as ecology, biologic diversity (to include the Kingdoms of life), reproduction, growth, and development, with emphasis placed on multicellular systems. **BIO117:** A two-hour laboratory to be offered concurrently with BIO 116. Designed to acquaint the student with the use of analytical techniques in biology, theory, and methods involved in experimentation in order to facilitate a greater understanding of concepts presented in lecture and the way in which information is gathered in science.

**KCTCS Natural Sciences Outcomes**

1. Demonstrate an understanding of the methods of science inquiry

2. Explain basic concepts and principles in one or more of the sciences

3. Apply scientific principles to interpret and make predictions in one or more of the sciences

4. Explain how scientific principles relate to issues of personal and/or public importance

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| **2. Unit Summary** |

**The Big Idea (including global relevance):**

Water quality is a universal issue as every living organism requires water for life. What can you do if the water treatment process used to provide you with fresh water has broken down?

**The (anticipated) Essential Questions:** List 3 or more questions your students are likely to generate on their own. (Highlight in yellow the one selected to define the Challenge):

* What could be detected in drinking water that needs to be removed for safe water?
* How do we know if water is safe to drink or for organisms to live in?
* What are the criteria for safe drinking water?
* Are certain levels of pollution acceptable in water?
* Can bodies of water clean themselves without human intervention?
* What do biological organisms do to water?

**Possible Guiding Questions:**

* What types of organisms could help remove pollutants?
* What organisms are found in or around water bodies in the natural environment?
* What factors contribute to clean water in nature?

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| **3. Unit Context** |

Justification for Selection of Content– Check all that apply:

☐ Students previously scored poorly on standardized tests, end-of term test or any other test given in the school or district on this content.

☐ Misconceptions regarding this content are prevalent.

☐ Content is suited well for teaching via CBL and EDP pedagogies.

☐ The selected content follows the pacing guide for when this content is scheduled to be taught during the school year. (Unit 1 covers atomic structure because it is taught in October when I should be conducting my first unit.)

☐ Other reason(s) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**The Hook:**  (Describe in a few sentences how you will use a “hook” to introduce the Big Idea in a compelling way that draws students into the topic.)

The Hook will utilize a lab based on observations of living microorganisms in pond water. In this lab, students observe multiple types of microbes using a microscope and working on identifying those microbes to the Kingdom and possibly Phylum. Once students observe and identify microorganisms, then the discussion can easily lead towards asking students to answer the question “What do microorganisms do to water?” They will definitely see some living microorganisms including protozoans and green algae, and the movements and behaviors of these creatures under the light microscope always intrigue students. The discussion can also include references to ecology, metabolism, biological molecules, and biodiversity that are part of the curriculum to ask students about inputs and outputs from biological systems.

In addition, videos on pollution and cleanup in the Great Lakes will add the concept of bodies of water being polluted and renewing themselves to some level when left alone. This can lead to the question “How can organisms alter water pollution?” which will further lead students toward the Challenge.

The Challenge and Constraints:

☐ Product **or** ☐ Process (Check one)

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| --- | --- |
| Description of Challenge (Either Product or Process is clearly explained below): | List the Constraints Applied |
| **Design and test a water treatment protocol involving biological organisms to remove some quantity of an identified pollutant from the water.** | **Must be able to be set up and running during one lab period and tested within one week.**  **Must remove some pollutant that can be detected in testing protocols in our laboratory (based on equipment and reagents that can be obtained prior to the unit’s implementation). A list of possible testing protocols, equipment, and reagents will be provided.**  **Must collect a minimum of before and after sample(s) by removing biological organisms using 0.2um filtration to test the resulting clarified sample(s) for levels of their identified pollutant remaining after treatment.**  **Must fit within equipment and supplies that are already available or can be obtained within the project’s timeframe – list provided by the instructor.**  **Must fit the potential organisms list provided by the instructor.** |

Teacher’s Anticipated Guiding Questions (that apply to the Challenge and may change with student input.):

**How can biological organisms be used to remove a pollutant from water?**

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| **4. EDP: Use the diagram below to help you complete this section.** |

How will students test or implement the solution? What is the evidence that the solution worked? Describe how the iterative process from the EDP applies to your Challenge.

**Students will need to implement their solution by first testing the input water for the identified pollutant, setting up the biological system they choose and letting it run for up to one week, collecting sample(s) and removing biological organisms using 0.2um filtration, then testing the resulting clarified sample(s) for levels of their identified pollutant remaining after treatment. Once initial results are obtained and analyzed, students can propose changes to their system and re-test. Students can decide whether iterations should start with the same samples that they started with or if they should start by making adjustments to the system already in place.**

How will students present or defend the solution? Describe if any formal training or resource guides will be provided to the students for best practices (e.g., poster, flyer, video, advertisement, etc.) used to present work.

**Students will present their solution in an advertisement format to either city planners or to venture capitalists that could produce the solution as a commercially available product. The advertisement presentation will include details about the challenge, their logic for their solution, testing results with appropriate data analysis, and their conclusions based on their testing of the solution. This will allow the course content and data analysis to be assessed, but add another element linking this project to the real world by emphasizing that different solutions to clean water are proposed and implemented commercially. The rubric will include criteria related to career exploration related to the project or extensions.**

What academic content is being taught through this Challenge?

Biodiversity and Ecology: Ecology with regard to the impact of pollution on water and also on the relationships between diverse organisms and their environment, including human impacts by using the organisms to solve societal problems.

Assessment and EDP:

Using the diagram above, identify any places in the EDP where assessments should take place, as it applies to your Challenge. Describe below what kinds of assessment are most appropriate.

|  |  |
| --- | --- |
| What EDP Processes are ideal for conducting an Assessment? (List ones that apply.) | List the type of Assessment (Rubric, Diagram, Checklist, Model, Q/A etc.) Check box to indicate whether it is formative or summative. |
| Gather information  Construct standard curve    Identify & select alternatives      Implement solution    Evaluate solution    Communicate Solution    Refine    Communicate | Rubric to assess resources and citations ☐ formative ☐ summative  Rubric to assess graph ☐ formative ☐ summative    Student-assessed decision matrix ☐ formative ☐ summative      Method description including scientific method application ☐ formative ☐ summative  Data analysis and presentation (graph) ☐ formative ☐ summative    Advertisement presentation ☐ formative ☐ summative    Rubric to assess refinement ☐ formative ☐ summative    Student group checklists and updates throughout ☐ formative ☐ summative |

Check below which characteristic(s) of this Challenge will be incorporated in its implementation using EDP. (Check all that apply.)

☐ Has clear constraints that limit the solutions

☐ Will produce than one possible solution that works

☐ Includes the ability to refine or optimize solutions

☐ Assesses science or math content

☐ Includes Math applications

☐ Involves use of graphs

☐ Requires analysis of data

☐ Includes student led communication of findings

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| **5. ACS (Real world applications; career connections; societal impact):** |

Place an X on the continuum to indicate where this Challenge belongs in the context of real world applications:

|  |  |  |
| --- | --- | --- |
| **Abstract or Loosely Applies to the Real World** | **|--------------------------------------|----------------------------------X----|** | **Strongly Applies to the Real World** |

Provide a brief rationale for where you placed the X:**­­­­­­­­­­­­­­\_All living organisms, including humans, require clean water for life.**

What activities in this Unit apply to real world context? Gathering information and communicating results with impacts and relevance to the real world.

Place an X on the continuum to indicate where this Challenge belongs in the context of societal impact:

|  |  |  |
| --- | --- | --- |
| **Shows Little or No Societal Impact** | **|-------------------------------------|-----------------------------------X----|** | **Strongly Shows Societal Impact** |

Provide a brief rationale for where you placed the X: ­­­­­­­­­­­­­­\_**Finding alternatives related to water quality and water treatment could potentially become real products or processes for use locally, regionally, or even globally.**

What activities in this Unit apply to societal impact? **\_Understanding more about pollutants and how they are monitored in water plus seeing the potential commercial impacts of designing water treatment processes that could be used in the real world. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

Careers: What careers will you introduce (and how) to the students that are related to the Challenge? (Examples: career research assignment, guest speakers, fieldtrips, Skype with a professional, etc.)

**Chemical engineer, agricultural engineer, microbiologist, etc. The Advertisement will include presentation of relevant careers associated either with the project or logical extensions thereof.**

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| **6. Misconceptions:** |

To be completed post-implementation.

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| **7. Unit Lessons and Activities:** (Provide a tentative timeline with a breakdown for Lessons 1 and 2. Provide the Lesson #’s and Activity #’s for when the Challenge Based Learning (CBL) and Engineering Design Process (EDP) are embedded in the unit.) |

**Unit 1: Membrane Bioreactors – What Can Biological Organisms Do To and For Your Water? – Design and Implement a Biological System to Modify Water Samples**

Lesson 1: Membrane Bioreactors – Explorations of the Biodiversity of Organisms and Their Effects on Water Quality (2 days)

*Lesson 1 will focus on introducing the concept of membrane bioreactors and recognition that biological organisms can affect water quality. Students will learn about biodiversity with a focus on aquatic organisms and will be introduced to the used of spectrophotometry learn to detect several contaminants/nutrients in water.*

Activity 1: Introduction of the Big Idea, Generating the Essential Question, Challenge, and Guiding Questions (1 day plus outside research)

Activity 2: Standard Curves and Spectrophotometry (1 lab plus outside graph preparation)

**Lesson 2: Membrane Bioreactors – Planning a Bioreactor and Testing Its Effectiveness in Removing (or Adding) a Specified Compound from (to) Water (3 days in class, including the week between lab periods)**

*Lesson 2 enables students to take what they have been learning, including their group research, and plan a bioreactor protocol. The idea is that they choose which compound to detect and propose a testable hypothesis about the effect that the biological system they choose will have on that compound’s presence in water before and after treatment. They will then test their solutions and analyze their results. Finally, they will communicate their results to their peers and propose a refinement.*

Activity 3. Design a Bioreactor, Plan Implementation Strategy, Implement and Collect Data, Analyze Data (1 week)

Activity 4: Present Bioreactor Solution with Proposed Refinement as an Advertisement (1 day)

**CBL:** Lesson 1, Activity 1, Lesson 2 Activity 3, Lesson 2, Activity 4

**EDP:** Lesson 1, Activity 1, Lesson 2 Activity 3, Lesson 2 Activity 4

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| **8. Keywords:** |

**Water quality, pollution, ecology, bioreactor, membrane filtration, spectrophotometry, indicators**

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| **9. Additional Resources:** |

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| **10. Pre-Unit and Post-Unit Assessment Instruments:** |

KEY:

1) Which of the following is FALSE about the evolution of metabolic pathways? All organisms:

a. use aerobic metabolic pathways due to atmospheric oxygen.

b. use enzymes to catalyze metabolic pathways.

c. do not use the same metabolic pathways.

d. perform glycolysis.

2) A cell that can use energy from the sun, and CO2 as a carbon source is a:

a. Chemoautotroph

b. Chemoheterotroph

c. Photoautotroph

d. Photoheterotroph

3) Plants cannot fix nitrogen, yet some plants do NOT need nitrogen from the soil. This is because:

a. These plants are the exceptions that can fix nitrogen.

b. They have been infected by a parasitic virus that can fix nitrogen.

c. They are able to obtain nitrogen from the air.

d. They have a symbiotic association with a bacterium that can fix nitrogen.

4) Which of the statements about groundwater is NOT accurate?

a. In the United States, groundwater provides 50% of the population with drinking water.

b. Groundwaters are being depleted faster than they can be recharged.

c. Groundwaters are becoming increasingly polluted.

d. Removal of pollutants from groundwaters is easily achieved.

5) Which of the following statements about the phosphorus cycle is correct?

a. Phosphorus is fixed by plants and algae.

b. Most phosphorus released from rocks is carried to the oceans by rivers.

c. Animals cannot get their phosphorus from eating plants and algae.

d. Fertilizer use has not affected the global phosphorus budget.

6) Biological magnification occurs when

a. Pollutants increase in concentration in tissues at higher trophic levels.

b. The effect of a pollutant is magnified by chemical interactions within organisms.

c. An organism is placed under a dissecting scope.

d. A pollutant has a greater than expected effect once ingested by an organism.

7) Oligotrophic lakes can be turned into eutrophic lakes as a result of human activities such as:

a. Overfishing of sensitive species, which disrupts fish communities.

b. Introducing nutrients into the water, which stimulates plant and algal growth.

c. Disrupting terrestrial vegetation near the shore, which causes soil to run into the lake.

d. Spraying pesticides into the water to control aquatic insect populations.

8) How do you think water get cleaned at a sewage treatment plant?

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| **11. Poster** | **12. Video (Link here.)** |

**If you are a science teacher, check the boxes below that apply:**

|  |  |
| --- | --- |
| **Next Generation Science Standards (NGSS)** | |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☐ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☐ Developing and using models | ☐ Cause and effect |
| ☐ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☐ Systems and system models |
| ☐ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☐ Engaging in argument from evidence | ☐ Stability and change. |
| ☐ Obtaining, evaluating, and communicating information |  |

**If you are a science teacher, check the boxes below that apply:**

|  |
| --- |
| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☐ Demonstrating Science Knowledge (D) |
| ☐ Interpreting and Communicating Science Concepts (C) |
| ☐ Recalling Accurate Science (R) |

**If you are a math teacher, check the boxes below that apply:**

|  |  |
| --- | --- |
| **Ohio’s Learning Standards for Math (OLS) or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

**Part 2: Post Implementation- Reflection on the Unit**

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| **Results:** Evidence of Growth in Student Learning - After the Unit has been taught and the Post-Unit Assessment Instrument has been used to assess student growth in learning, the teacher must analyze the data and determine whether or not student growth in learning occurred. Present all documents used to collect and organize Post- Unit evaluation data such as graphs or charts. Provide a written analysis in sentence or paragraph form which provides the evidence that student growth in learning took place. Please present results and, if applicable, student work (as a hyperlink) used as evidence after the Unit has been taught.    **Please include:**   * Any documents used to collect and organize post unit evaluation data. (charts, graphs and /or tables etc.) * An analysis of data used to measure growth in student learning providing evidence that student learning occurred. (Sentence or paragraph form.) * Other forms of assessment that demonstrate evidence of learning. * Anecdotal information from student feedback. |

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| **Reflection: Reflections: Reflect upon the successes of teaching in this Unit in 5 or more sentences in the form of a narrative. Consider the following questions:**  **1)** Why did you select this content for the Unit?  2) Was the purpose for selecting the Unit met? If yes, provide student learning related evidence. If not, provide possible reasons.  3) Did the students find a solution or solutions that resulted in concrete meaningful action for the Unit’s Challenge? Hyperlink examples of student solutions as evidence.  4) What does the data indicate about growth in student learning?  5) What would you change if you re-taught this Unit?  6) Would you teach this Unit again? Why or why not? |

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| --- | --- | --- |
| **Name: Jennifer Leigh Myka** | **Contact Info: jennifer.myka@kctcs.edu** | **Date: 07/16/2018** |

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| **Lesson Title : Membrane Bioreactors – Explorations of the Biodiversity of Organisms & Their Effects on Water Quality** | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **1** |
| **Activity Title: Introduction of the Big Idea, Generating the Essential Question, Challenge, & Guiding Questions** |

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| **Estimated Lesson Duration:** | **1 day, 1 lab, plus outside research and graph preparation** |
| **Estimated Activity Duration:** | **1 day plus outside research** |

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| **Setting:** | **Active learning laboratory classroom** |

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| **Activity Objectives:** |

1) Given the Concept of Membrane Bioreactors, Students will be able to generate an Essential Question.

2) Given the Essential Question, Students will generate appropriate Guiding Questions.

3) After outside research using the Essential and Guiding Questions as guides, Students will contribute ideas about a possible Challenge.

4) The Student will be able to explain the concept of a bioreactor and recognize ways that biological organisms can affect water quality, including the contributions of aquatic organisms, plus recognize how the membrane component filters out the biological organisms leaving water with molecular components and contaminants.

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| **Activity Guiding Questions:** |

1) Given a Topic and Big Idea, what are some good Essential Questions?

2) What would be a good Challenge considering the Essential Question selected?

3) What are the functions of a membrane?

4) What organisms are found in or around water bodies in the natural environment?

5) What factors contribute to clean water in nature?

6) What types of organisms could help remove pollutants?

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| --- | --- |
| **Next Generation Science Standards (NGSS)** | |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☐ Developing and using models | ☒ Cause and effect |
| ☒ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☐ Systems and system models |
| ☐ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☐ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☒ Demonstrating Science Knowledge (D) |
| ☒ Interpreting and Communicating Science Concepts (C) |
| ☒ Recalling Accurate Science (R) |

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| --- | --- |
| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

**COURSE DESCRIPTION: BIO116:** Examines basic biological concepts such as ecology, biologic diversity (to include the Kingdoms of life), reproduction, growth, and development, with emphasis placed on multicellular systems. **BIO117:** A two-hour laboratory to be offered concurrently with BIO 116. Designed to acquaint the student with the use of analytical techniques in biology, theory, and methods involved in experimentation in order to facilitate a greater understanding of concepts presented in lecture and the way in which information is gathered in science.

**KCTCS Natural Sciences Outcomes**

1. Demonstrate an understanding of the methods of science inquiry

2. Explain basic concepts and principles in one or more of the sciences

3. Apply scientific principles to interpret and make predictions in one or more of the sciences

4. Explain how scientific principles relate to issues of personal and/or public importance

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| **Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)** |

1) Pond water samples, microscopes, slides, coverslips, Protoslo, disposable transfer pipets

2) Pre-Assessment Handout

3) Pond Water Microorganism Lab Handout

4) YouTube Video on Great Lakes Cleanup | National Geographic :<https://youtu.be/6LbZz8vyMqw>

5) YouTube Video on Saving the Great Lakes from Toxic Algae:<https://youtu.be/b6JzL4NG26k>

6) Essential Question & Proposed Challenge Handout

7) Guiding Question Handout

8) Challenge Handout

9) Gather Information Handout

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| **Teacher Advance Preparation:** |

1) Make sure the links to YouTube are accessible on the internet.

2) Have activity materials and handouts available.

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| **Activity Procedures:** |

Activity 1: Day 1

1) Introduction to Topic and Big Idea with Pond Water Microorganism Lab.

2) Students generate some Essential Questions and propose a Challenge, using Essential Question & Proposed Challenge Handout. Instructor will collect Challenge proposals for next class.

Activity 1: Day 2

1) Challenge is shared with students. Students generate guiding questions for Challenge using the Guiding Question Handout.

2) Students research properties of water, microorganisms and their effects on water, and common water pollutants using the Gather Information Handout.

* Topic exploration
* Short lecture/just-in-time teaching as needed by the Instructor

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| **Formative Assessments: Link the items in the Activities that will be used as formative assessments.** |

1) Gathering Information – rubric to assess resources and citations

2) Identify & Select Alternatives – student-assessed decision matrix

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| **Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.** |

N/A in this Activity

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| **Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.**  **Refer to Activity Template for details.** |

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| **Reflection: Reflect upon the successes and shortcomings of the lesson.** |

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| **Name: Jennifer Leigh Myka** | **Contact Info: jennifer.myka@kctcs.edu** | **Date: 07/16/2018** |

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| **Lesson Title : Membrane Bioreactors – Explorations of the Biodiversity of Organisms & Their Effects on Water Quality** | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **2** |
| **Activity Title: Standard Curves and Spectrophotometry** |

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| **Estimated Lesson Duration:** | **1 day, 1 lab, plus outside research and graph preparation** |
| **Estimated Activity Duration:** | **1 lab plus outside graph preparation** |

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| **Setting:** | **Active learning laboratory classroom** |

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| **Activity Objectives:** |

The student will be able to:

1) Explain the basic principles of spectrophotometry.

2) Set up and test sample dilutions and blanks for visible light spectrophotometry.

3) Analyze spectrophotometry data by constructing a standard curve graph.

4) Understand the principle behind using an indicator dye to detect water contaminants.

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| **Activity Guiding Questions:** |

1) How can water components or pollutants be detected?

2) How does spectrophotometry use visible light to detect and determine concentrations of specific compounds?

3) Why are samples diluted before spectrophotometry?

4) What is the purpose of constructing a standard curve? What information can be gained from a standard curve graph?

5) What is the range of accurate results? Why is there a range that is accurate?

6) Why is an indicator dye used to detect water contaminants? How does this allow analysis of results by spectrophotometry?

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| **Next Generation Science Standards (NGSS)** | |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☒ Patterns |
| ☐ Developing and using models | ☒ Cause and effect |
| ☒ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☒ Analyzing and interpreting data | ☐ Systems and system models |
| ☒ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☐ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☒ Demonstrating Science Knowledge (D) |
| ☒ Interpreting and Communicating Science Concepts (C) |
| ☒ Recalling Accurate Science (R) |

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| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

**COURSE DESCRIPTION: BIO116:** Examines basic biological concepts such as ecology, biologic diversity (to include the Kingdoms of life), reproduction, growth, and development, with emphasis placed on multicellular systems. **BIO117: A two-ho**ur laboratory to be offered concurrently with BIO 116. Designed to acquaint the student with the use of analytical techniques in biology, theory, and methods involved in experimentation in order to facilitate a greater understanding of concepts presented in lecture and the way in which information is gathered in science.

**KCTCS Natural Sciences Outcomes**

**1. Demonstrate an understanding of the methods of science inquiry**

**2. Explain basic concepts and principles in one or more of the sciences**

**3. Apply scientific principles to interpret and make predictions in one or more of the sciences**

**4. Explain how scientific principles relate to issues of personal and/or public importance**

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| **Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)** |

1) Spec20 spectrophotometers, cuvettes, prepared standard solutions, distilled water, micropipettors, pipet tips for micropipettors, indicator dye solutions, Sharpie markers, lab tape, Parafilm, incubators, unknown solutions for each group.

2) Videos from lab manual on spectrophotometry and standard curve preparation.

3) Spectrophotometry and Standard Curve Lab Handout.

4) Construct Standard Curve – Graph Rubric Handout

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| **Teacher Advance Preparation:** |

1) Make sure video files are available.

2) Have materials and handouts for spectrophotometry lab available.

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| **Activity Procedures:** |

Activity 2: Day 1

1) Students introduced to spectrophotometry, using Spectrophotometry and Standard Curve Lab Handout.

* Short lecture/just-in-time teaching by the Instructor as necessary.

2) Students set up serial dilutions, add indicator dye, and read samples using a visible light spectrophotometer.

3) Students share data points within each lab group to set up individual standard curve graphs for online submission as homework using the “Construct Standard Curve” handout for the rubric.

Activity 2: Day 2

1) Brief discussion of resulting standard curves.

* Short lecture/just-in-time teaching by the Instructor as necessary.

2) Students resubmit standard curve graphs online with revisions, if desired.

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| **Formative Assessments: Link the items in the Activities that will be used as formative assessments.** |

1) Construct Standard Curve – rubric to assess graph first draft

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| **Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.** |

1) Construct Standard Curve – rubric to assess re-submitted graph

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| **Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.**  **Refer to Activity Template for details.** |

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| **Reflection: Reflect upon the successes and shortcomings of the lesson.** |

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| **Name: Jennifer Leigh Myka** | **Contact Info: jennifer.myka@kctcs.edu** | **Date: 07/16/2018** |

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| **Lesson Title : Membrane Bioreactors – Planning a Bioreactor & Testing Its Effectiveness in Removing (or Adding) a Specified Compound from (to) Water** | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **3** |
| **Activity Title: Design a Bioreactor, Plan Implementation Strategy, Implement and Collect Data, Analyze Data** |

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| **Estimated Lesson Duration:** | **3 days including lab time** |
| **Estimated Activity Duration:** | **1 week including lecture and lab time** |

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| **Setting:** | **Active learning laboratory classroom** |

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| **Activity Objectives:** |

The student will be able to:

1) Design a bioreactor as a member of a lab group, using their background research and the essential and guiding questions.

2) Plan an implementation strategy to implement their group solution.

3) Implement the bioreactor design and collect data for up to one week, as appropriate.

4) Analyze collected data and construct an appropriate graph to highlight results and conclusions.

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| **Activity Guiding Questions:** |

1) What is required for a bioreactor?

2) What organisms should be present?

3) What compound(s) will the selected organisms remove from the water?

4) What hypothesis will be tested when the bioreactor model is implemented and analyzed?

5) How and when will data be collected?

6) How will the water be analyzed for the presence of the compound of interest?

7) How can a conclusion be reached concerning the activity/efficiency of the bioreactor model?

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| Next Generation Science Standards (NGSS) | |
| Science and Engineering Practices (Check all that apply) | Crosscutting Concepts (Check all that apply) |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☒ Patterns |
| ☒ Developing and using models | ☒ Cause and effect |
| ☒ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☒ Analyzing and interpreting data | ☒ Systems and system models |
| ☒ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☒ Structure and function. |
| ☒ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☒ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☒ Demonstrating Science Knowledge (D) |
| ☒ Interpreting and Communicating Science Concepts (C) |
| ☒ Recalling Accurate Science (R) |

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| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

**COURSE DESCRIPTION: BIO116:** Examines basic biological concepts such as ecology, biologic diversity (to include the Kingdoms of life), reproduction, growth, and development, with emphasis placed on multicellular systems. **BIO117:** A two-hour laboratory to be offered concurrently with BIO 116. Designed to acquaint the student with the use of analytical techniques in biology, theory, and methods involved in experimentation in order to facilitate a greater understanding of concepts presented in lecture and the way in which information is gathered in science.

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1. Demonstrate an understanding of the methods of science inquiry

2. Explain basic concepts and principles in one or more of the sciences

3. Apply scientific principles to interpret and make predictions in one or more of the sciences

4. Explain how scientific principles relate to issues of personal and/or public importance

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| **Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)** |

1) Student-Assessed Decision Matrix

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| **Teacher Advance Preparation:** |

1) Provide a list of all materials and equipment currently available in the laboratory for the project, including available reagents, equipment such as spectrophotometers, organisms including microorganisms and plants, etc., as per approved student proposed challenges from the previous activity.

2) Print out handouts for formative assessments:

1. Identify & Select Alternatives – Student-Assessed Decision Matrix

3) Print out handouts for summative assessments:

1. Implement Solution – Method Description Including Hypothesis Tested and Engineering Design Process Steps

2. Evaluate Solution – Data Analysis and Presentation (Graph)

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| **Activity Procedures:** |

Activity 3: Day 1

1) Students will work together in groups to design a bioreactor and plan an implementation strategy, including a plan for data collection and analysis.

* Student groups will construct the Student-Assessed Decision Matrix using the provided handout as guidance.
* Short lecture/just-in-time teaching by the Instructor as necessary.
* Students will complete the Implement Solution handout as a Summative Assessment.
* Instructor will approve viable models and plan to obtain any additional materials as feasible.

Activity 3: Day 2

1) Students will construct and implement their bioreactor model. Initial data points will be obtained and recorded.

* Short lecture/just-in-time teaching by the Instructor as necessary.

Activity 3: Day 3

2) Students will continue data collection and begin data analysis of the data set.

3) Students will evaluate their bioreactor performance.

4) Students will begin discussions within groups on a possible refinement to the model they tested.

5) Students will be introduced to the Advertisement Summative Assessment.

* Students will complete the “Data Analysis and Graph Presentation” as a Summative Assessment to be turned in online in Blackboard.
* Students will receive the Advertisement Presentation handout for the next class.
* Students will also receive the Rubric to Assess Refinement Summative Assessment handout for the next class.
* Short lecture/just-in-time teaching by the Instructor as necessary.

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| **Formative Assessments: Link the items in the Activities that will be used as formative assessments.** |

1) Identify & Select Alternatives – Student-Assessed Decision Matrix

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| **Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.** |

1) Implement Solution – Method Description Including Scientific Method Application

2) Evaluate Solution – Data Analysis and Presentation (Graph)

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| **Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.**  **Refer to Activity Template for details.** |

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| **Reflection: Reflect upon the successes and shortcomings of the lesson.** |

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| **Name: Jennifer Leigh Myka** | **Contact Info: jennifer.myka@kctcs.edu** | **Date: 07/16/2018** |

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| **Lesson Title : Membrane Bioreactors – Planning a Bioreactor & Testing Its Effectiveness in Removing (or Adding) a Specified Compound from (to) Water** | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **4** |
| **Activity Title: Present Bioreactor Solution with Proposed Refinement as an Advertisement** |

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| **Estimated Lesson Duration:** | **4 days including lecture and lab time** |
| **Estimated Activity Duration:** | **1 day** |

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| **Setting:** | **Active learning laboratory classroom** |

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| **Activity Objectives:** |

**The student will be able to:**

**1) Present group analyzed data on the implementation of the group bioreactor as an advertisement.**

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| **Activity Guiding Questions:** |

**1) What conclusion(s) can be drawn from the data collected?**

**2) Was the hypothesis tested supported or refuted?**

**3) What was the activity/efficiency of the bioreactor model?**

**4) How could the implemented model be refined to improve performance?**

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| **Next Generation Science Standards (NGSS)** | |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☒ Patterns |
| ☒ Developing and using models | ☒ Cause and effect |
| ☒ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☒ Analyzing and interpreting data | ☒ Systems and system models |
| ☒ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☒ Structure and function. |
| ☒ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☒ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☒ Demonstrating Science Knowledge (D) |
| ☒ Interpreting and Communicating Science Concepts (C) |
| ☒ Recalling Accurate Science (R) |

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| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

**COURSE DESCRIPTION: BIO116:** Examines basic biological concepts such as ecology, biologic diversity (to include the Kingdoms of life), reproduction, growth, and development, with emphasis placed on multicellular systems. **BIO117:** A two-hour laboratory to be offered concurrently with BIO 116. Designed to acquaint the student with the use of analytical techniques in biology, theory, and methods involved in experimentation in order to facilitate a greater understanding of concepts presented in lecture and the way in which information is gathered in science.

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2. Explain basic concepts and principles in one or more of the sciences

3. Apply scientific principles to interpret and make predictions in one or more of the sciences

4. Explain how scientific principles relate to issues of personal and/or public importance

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| **Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)** |

1) Students already received the Advertisement Presentation Handout

2) Students already received the Rubric to Assess Refinement Summative Assessment Handout

3) Presentation equipment including projector and computer for presentation

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| **Teacher Advance Preparation:** |

1) Check presentation equipment to ensure smooth presentation flow.

2) Copies of Rubrics to evaluate each group.

1) Communicate Solution – Advertisement Presentation

2) Refine – Rubric to Assess Refinement

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| **Activity Procedures:** |

Activity 4: Day 1

1) Students will present their bioreactor solution with a proposed refinement as an advertisement.

* Students will be assessed on their group Advertisement Presentation.
* Students will be assessed using the Rubric to Assess Refinement Summative Assessment handout.

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| **Formative Assessments: Link the items in the Activities that will be used as formative assessments.** |

1) N/A

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| **Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.** |

1) Communicate Solution – Advertisement Presentation

2) Refine – Rubric to Assess Refinement

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| **Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.**  **Refer to Activity Template for details.** |

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| **Reflection: Reflect upon the successes and shortcomings of the lesson.** |

1. **APPENDIX IV: UNIT TEMPLATE OF PAUL SCHEMBER**

**Unit Plan:**

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| **Name: Paul Schember** | **Contact Info: schember.p@norwoodschools.org** | **Date: 7-11-18** |

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| **Unit Number and Title: Save the Soil!** |

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| **Grade Level:** | **8th** |
| **Subject Area:** | **Science** |

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| **Total Estimated Duration of Entire Unit:** | **11 days** |

**Part 1: Designing the Unit**

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| 1. **Unit Academic Standards (Identify which standards: NGSS, OLS and/or CCSS. Cut and paste from NGSS, OLS and/or CCSS and be sure to include letter and/or number identifiers.)** |

**OLS: ESS:** A combination of constructive and destructive geologic processes formed Earth’s surface.

**PS:** Forces have magnitude and direction.

**NGSS:** - Designing technological/engineering solutions using science concepts

- Demonstrating science knowledge

- Interpreting and communicating science concepts

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| 1. **Unit Summary** |

**The Big Idea (including global relevance):**

**Minimizing erosion:** Erosion is constantly changing Earth’s surface by moving sediments and soil to new places by the forces of wind, water and gravity. Erosion is a problem for people farming on land with a slope because their valuable topsoil gets eroded downhill. When the good soil with all of its nutrients is removed, this leaves poor soil that farmers must add fertilizers (usually in the form of chemical pellets) to the land in order to improve its ability to grow crops. As the erosion process continues each year, the fertilizers from the fields get washed into the watershed and can trigger eutrophication in bodies of water when nutrient levels reach critical levels. By minimizing erosion on farmland, the rich soil is kept in place, extra chemicals are not needed, and eutrophication is avoided.

**The (anticipated) Essential Questions: List 3 or more questions your students are likely to generate on their own. (Highlight in yellow the one selected to define the Challenge):**

What materials and methods can be used to prevent erosion?

How can eutrophication be prevented in our watersheds?

How can fertilizers be kept in the farmland where they are needed[WU1] [C2] ?

How can erosion be minimized?

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| 1. **Unit Context** |

**Justification for Selection of Content– Check all that apply:**

☐ Students previously scored poorly on standardized tests, end-of term test or any other test given in the school or district on this content.

☐ Misconceptions regarding this content are prevalent.

☐ Content is suited well for teaching via CBL and EDP pedagogies.

☐ The selected content follows the pacing guide for when this content is scheduled

to be taught during the school year. (Unit 1 covers atomic structure because it

is taught in October when I should be conducting my first unit.)

☐ Other reason(s) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**The Hook:** (Describe in a few sentences how you will use a “hook” to introduce the Big Idea in a compelling way that draws students into the topic.)

1. Students will complete a pretest containing questions about weathering, erosion, forces, and erosion control. Some concepts may have already been introduced by this point and others will be taught during the unit lessons.
2. Students will compete in a quick relay race at the beginning of class. Working in teams, students will need to carry water in a sponge over to a surface with a small pile of soil. The water in sponge will be squeezed out onto the soil in an attempt to wash the soil off of the surface. Sponge is returned to the next member and the process is continued until all of the soil has been washed off of the surface.
3. A Gallery Walk will be set up to have students observe images related to the Big Idea: of farmland, fertilizers, eroded areas, pond scum, algal blooms, fish kills, etc. Students will be asked to respond to the images in writing.

**The Challenge and Constraints:**

☐ Product **or** ☐ Process (Check one)

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| --- | --- |
| Description of Challenge (Either Product or Process is clearly explained below): | List the Constraints Applied |
| **A nearby community contains a lake that is fed by the watershed surrounding it. That lake is used by the residents for recreational activities such as swimming, boating and fishing. Lately, the water has been plagued by toxic algal blooms that prevent people from using the lake. Meanwhile, farmers who live near the lake have been complaining about the high prices of fertilizer pellets and how they keep losing some of their best topsoil every year. Your challenge is to help the farmers and the community by finding a way to keep the topsoil in the farms so that it doesn’t pollute the lake with chemicals that feed the algae. This will also help to make the lake useable again!** | **-Time is limited**  **- The same amounts of basic materials**  **will be used by each group**  **-Model built must not lose more than**  **\_\_\_\_ g of sand.**  **-Groups may only change their design**  **and retest it two times**  **- Soil level in model must be even with**  **the wall height on the downhill and**  **uphill sides of the model box**  **-30% of the farm model’s surface area**  **must be devoted to animals and**  **60% devoted to crops.**  **-Farm model must be topographically**  **accurate to the area chosen on the**  **map.** |

**Teacher’s Anticipated Guiding Questions (that apply to the Challenge and may change with student input.):**

How can I slow down erosion?

How can the surface of the land be changed to slow down water?

What materials will I be using for this simulation?

How can the chemicals be kept out of watersheds?

How can water be slowed down as it runs over land?

What forces cause erosion to happen[WU3] ?

Can other things be used as fertilizers?

How does the shape or slope of the land affect erosion?

What are the causes of erosion?

Which materials can be moved by erosion forces?

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| **4. EDP: Use the diagram below to help you complete this section.** |

How will students test or implement the solution? What is the evidence that the solution worked? Describe how the iterative process from the EDP applies to your Challenge.

**The students will work in groups to build a scale model of the plot where their farm is located on a topographical map. A plastic box (small clear tote) will serve as the container that sets the boundaries for the plot, and students will add rocks and packed clay soil to represent the subsoil layer and a mixture of 80% sand and 20% chopped sphagnum moss or plain sand to represent the topsoil layer. A farm model that has not been modified (the control) will be demonstrated with simulated rainfall to show students how much soil is eroded. Based on their observations and content learned from activities, the students will design a plan to modify their farm in a way that reduces soil loss. When students test their own solution, erosion can be assessed by measuring the final mass of the farm and by measuring the amount of soil that left the farm and landed in the overflow container. This data will be collected. The flow rate of water running off will also be measured and recorded. Before and after photos could also be taken for visual comparisons of erosion.**

**After testing their design, groups will have two more opportunities to make changes to their design and retest to see if better results are obtained. The new data will be collected and can be compared to the original data so that teams can make decisions based on the information that is collected. For each iteration that groups test, they need to document the steps that were taken in the EDP to produce those new results.**

How will students present or defend the solution? Describe if any formal training or resource guides will be provided to the students for best practices (e.g., poster, flyer, video, advertisement, etc.) used to present work.

**Students will present their solution to the class as a commercial or elevator pitch using either Powerpoint or a poster as their visual aid. In the commercial, each group will need to describe their design, explain how these changes reduced erosion, and present the data that supports their claims. As students are presenting, their classmates will complete evaluation forms.**

What academic content is being taught through this Challenge?

**This challenge will teach the concepts of weathering, erosion and deposition as well as forces and motion. Students will get to observe that constructive and destructive forces can change the shape of their land plot, and the speed of water movement can be calculated during each trial. The concept of topographical maps to show land elevation will also be used at the beginning of the challenge.**

Assessment and EDP:

Using the diagram above, identify any places in the EDP where assessments should take place, as it applies to your Challenge. Describe below what kinds of assessment are most appropriate.

|  |  |
| --- | --- |
| What EDP Processes are ideal for conducting an Assessment? (List ones that apply.) | List the type of Assessment (Rubric, Diagram, Checklist, Model, Q/A etc.) Check box to indicate whether it is formative or summative. |
| Identify & define  Gather information  Implement solution  Communicate solution | Q/A, checklist\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ☐ formative ☐ summative    Worksheet \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ☐ formative ☐ summative  Model, Data table, Worksheets\_\_\_\_\_\_\_ ☐ formative ☐ summative  Presentation\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ☐ formative ☐ summative |

**Check below which characteristic(s) of this Challenge will be incorporated in its implementation using EDP. (Check all that apply.)**

☐ Has clear constraints that limit the solutions

☐ Will produce more than one possible solution that works

☐ Includes the ability to refine or optimize solutions

☐ Assesses science or math content

☐ Includes Math applications

☐ Involves use of graphs

☐ Requires analysis of data

☐ Includes student led communication of findings

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| **5. ACS (Real world applications; career connections; societal impact):** |

**Place an X on the continuum to indicate where this Challenge belongs in the context of real world applications:**

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| --- | --- | --- |
| **Abstract or Loosely Applies to the Real World** | **|--------------------------------------|--------------------------------------X|** | **Strongly Applies to the Real World** |

Provide a brief rationale for where you placed the X:

**This challenge strongly applies to the real world because erosion due to runoff on sloped land happens anywhere in the world where rainfall and watersheds exist.**

What activities in this Unit apply to real world context?

**1. Research: students will find existing options to solve a real-world problem.**

**2. Brainstorming and working cooperatively: these are skills required in many areas in the real-world setting.**

**3. Building a model: this simulates an actual plot of land that requires careful planning on how to subdivide it for different uses.**

**4. Gallery walk: becoming aware of the real-world problems associated with erosion**

Place an X on the continuum to indicate where this Challenge belongs in the context of societal impact:

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| **Shows Little or No Societal Impact** | **|----------------------------|------------------------------------X---|** | **Strongly Shows Societal Impact** |

Provide a brief rationale for where you placed the X:

**Societal impact will be emphasized during the testing phase of this challenge as students see how much erosion happens to a plot of land that is inhabited by people. The implications of that erosion (groundwater pollution, crop failure, habitat loss, structural failure of houses and other buildings, etc.) will be discussed and learned.**

What activities in this Unit apply to societal impact?

**1. Gallery walk: many pictures will include resources that students can recognize as being useful to themselves or other humans**

**2.Testing phase of challenge: students will witness the destructive forces of erosion on their model farm during and after a simulated rainfall.**

Careers: What careers will you introduce (and how) to the students that are related to the Challenge? (Examples: career research assignment, guest speakers, fieldtrips, Skype with a professional, etc.)

1. **Environmental engineers- students will be introduced to this career during the challenge as they conduct and investigation and work as “junior engineers” who are finding and modeling solutions for a client**
2. **Farmers- this career will be explored briefly as the client needing the engineers’ help; students will learn about practices farmers can use to prevent erosion.**
3. **The erosion control practices mentioned above might also apply to careers such as excavators, land developers, and forestry/wildlife management personnel.**

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| **6. Misconceptions:** |

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| **7. Unit Lessons and Activities:** (Provide a tentative timeline with a breakdown for Lessons 1 and 2. Provide the Lesson #’s and Activity #’s for when the Challenge Based Learning (CBL) and Engineering Design Process (EDP) are embedded in the unit.) |

*Lesson 1: This lesson will focus on getting students interested in the content related to erosion, generating essential questions and a challenge question, and then providing experiences that teach students about erosion so that they can use the information to succeed in the challenge.*

Activity 1: Introducing the Unit: A Gallery Walk, Erosion Relay race, Video clip, Generating the Essential Question, Challenge and Guiding questions (2 days)

Activity 2: Stream Lab, Interactive lab investigation website for erosion on a hill (2-3 days)

*Lesson 2: This lesson will focus on learning more content about erosion and then researching for specific practices that can be used to prevent or reduce erosion. Students will then use information learned to build a model that makes use of their findings to satisfy the challenge requirements. After three iterations, student groups will communicate results to their classmates.*

Activity 3: Notes and/or video with supporting questions to add content for weathering, erosion, and deposition (1 day)

Activity 4: EDP, Research erosion mitigation techniques, Brainstorming and planning activity, Building and testing models, Presenting best solution and data to class, Posttest (4-5 days)

**CBL:** Lesson 1, Activity 1 and Lesson 2, Activity 4

**EDP:** Lesson 2, Activity 4

**Content standards:** Lesson 1, Activity 2 and Lesson 2, Activity 3

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| **8. Keywords:** |

science, middle school, 8th grade, earth science, ESS, erosion, weathering, topography

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| **9. Additional Resources:** |

**Materials used in Challenge:**

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| **10. Pre-Unit and Post-Unit Assessment Instruments:** |

**Pretest/Posttest:**

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| --- | --- |
| **11. Poster** | **12. Video (Link here.)** |

**Coming soon: Coming soon:**

**If you are a science teacher, check the boxes below that apply:**

|  |  |
| --- | --- |
| **Next Generation Science Standards (NGSS)** | |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☐ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☐ Developing and using models | ☐ Cause and effect |
| ☐ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☐ Systems and system models |
| ☐ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☐ Engaging in argument from evidence | ☐ Stability and change. |
| ☐ Obtaining, evaluating, and communicating information |  |

**If you are a science teacher, check the boxes below that apply:**

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| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| **☐ Designing Technological/Engineering Solutions Using Science concepts (T)** |
| **☐ Demonstrating Science Knowledge (D)** |
| **☐ Interpreting and Communicating Science Concepts (C)** |
| **☐ Recalling Accurate Science (R)** |

**If you are a math teacher, check the boxes below that apply:**

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| **Ohio’s Learning Standards for Math (OLS) or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

**Part 2: Post Implementation- Reflection on the Unit**

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| **Results: Evidence of Growth in Student Learning -** After the Unit has been taught and the Post-Unit Assessment Instrument has been used to assess student growth in learning, the teacher must analyze the data and determine whether or not student growth in learning occurred. Present all documents used to collect and organize Post- Unit evaluation data such as graphs or charts. Provide a written analysis in sentence or paragraph form which provides the evidence that student growth in learning took place. Please present results and, if applicable, student work (as a hyperlink) used as evidence after the Unit has been taught.    **Please include:**  ● Any documents used to collect and organize post unit evaluation data. (charts, graphs and /or tables etc.)  ● An analysis of data used to measure growth in student learning providing evidence that student learning occurred. (Sentence or paragraph form.)  ● Other forms of assessment that demonstrate evidence of learning.  ● Anecdotal information from student feedback. |
| **Reflection: Reflections: Reflect upon the successes of teaching in this Unit in 5 or more sentences in the form of a narrative. Consider the following questions:**  1) Why did you select this content for the Unit?  2) Was the purpose for selecting the Unit met? If yes, provide student learning related  evidence. If not, provide possible reasons.  3) Did the students find a solution or solutions that resulted in concrete meaningful  action for the Unit’s Challenge? Hyperlink examples of student solutions as evidence.  4) What does the data indicate about growth in student learning?  5) What would you change if you re-taught this Unit?  6) Would you teach this Unit again? Why or why not? |

**Lesson 1:**

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| **Name: Paul Schember** | **Contact Info: schember.p@norwoodschools.org** | **Date: 7-3-18** |

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| **Lesson Title : Intro to Destructive Earth processes** | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **1** |
| **Activity Title: The Hook and Essential Questions** |

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| **Estimated Lesson Duration:** | **4-5 Days (50 minute periods)** |
| **Estimated Activity Duration:** | **2 days (50 minute periods)** |

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| **Setting:** | **Classroom and possibly outside for the relay race** |

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| **Activity Objectives:** |

1. Students will be able to recognize and describe destructive Earth processes that they

observe: weathering, flooding, erosion, soil movement, water pollution.

2. Students will be able to describe some problems that these destructive processes cause for humans.

3. Given the Topic (Farm erosion and eutrophication) and Big Idea (Minimizing erosion), students will contribute to forming some essential questions.

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| **Activity Guiding Questions:** |

1. Which destructive Earth processes have you seen?

2. Why are these processes considered destructive?

3. What are some problems that these processes can cause for humans living in that area?

4. Given this Big Idea of minimizing erosion and the Topic of Farm erosion and eutrophication, what are some good Essential Questions?

5. What might be a good Challenge related to the Essential Question that we selected?

6. How strong is the force of moving water when it is eroding soil on a sloped surface?

7. Which materials are eroded easily?

8. ­­­­­What other problems are related to the erosion of farmland?

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| **Next Generation Science Standards (NGSS)** | |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☐ Developing and using models | ☒ Cause and effect |
| ☐ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☐ Systems and system models |
| ☐ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☐ Engaging in argument from evidence | ☒ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☐ Demonstrating Science Knowledge (D) |
| ☒ Interpreting and Communicating Science Concepts (C) |
| ☒ Recalling Accurate Science (R) |

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| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

**OLS:** ESS: A combination of constructive and destructive geologic processes formed

Earth’s surface.

**NGSS:**  - Demonstrating science knowledge

- Interpreting and communicating science concepts

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| **Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)** |

1. Printed photos for the Gallery Walk

2. Answer sheet for Gallery Walk

3. Supplies for the Erosion Relay race: Per group- Basin, Dixie cup or syringe (no

needle), board with sand castle, bucket or other large container to draw water from,

water

4. Video clip from YouTube

5. Worksheet for Big Idea/ Essential Questions/ Challenge

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| **Teacher Advance Preparation:** |

Day 1: Hang up Gallery Walk photos, make copies of Answer sheets, set up materials for

Erosion Relay race.

Day 2: Make sure link to YouTube video is working, make copies of Big Idea/ Essential

Question/ Challenge worksheets

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| **Activity Procedures:** |

Day 1: -Have students circulate through all of the photos in the gallery walk and record

their responses on the provided sheets.

-Collect the sheets for daily grade (formative assessment).

-Organize students into teams, explain the goal of the relay race (completely wash

all of the sand castle off of a board using a small amount of water carried in a

Dixie cup or syringe) and begin the race.

-Dismiss class or (if time remains) discuss the purposes of that day’s activities.

Day 2: - Show the YouTube video clip.

- Pass back responses from yesterday’s Gallery Walk and quickly discuss

reactions to photos.

- Distribute Big Idea/ Essential Question/ Challenge worksheets and work through

as a class and in pairs (think/pair/share or similar method)

- Collect their work, tell students that all ideas will be reviewed so that Challenge

can be determined.

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| **Formative Assessments: Link the items in the Activities that will be used as formative assessments.** |

1. Gallery Walk response sheet will be collected for review and a daily grade. On the following day, it will be passed back and briefly discussed; participation during the discussion could be recorded for a grade.

2. Big Idea/ Essential Questions/ Challenge worksheet will also be collected for review and a daily grade.

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| **Differentiation:** |

Students may be paired with a suitable partner during the Gallery Walk. Number of answers needed on worksheets will be modified/ reduced as needed for individual cases. Groups for the relay race will be formed heterogeneously. Students will be paired with a suitable partner during the think/pair/ share section of the Big Idea/ Essential Questions/ Challenge activity. Pairing with a suitable partner is easily accomplished by carefully making a classroom seating chart based on student attributes earlier in the year; then students can pair up with their immediate neighbors.

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| **Summative Assessments:** |

None in this activity

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| **Reflection: Reflect upon the successes and shortcomings of the lesson.** |

**Lesson 2:**

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| **Name: Paul Schember** | **Contact Info: schember.p@norwoodschools.org** | **Date: 7-16-18** |

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| **Lesson Title : Intro to Destructive Earth processes** | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **2** |
| **Activity Title: Erosion Factors** |

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| **Estimated Lesson Duration:** | **4-5 days (50 minute classes)** |
| **Estimated Activity Duration:** | **2-3 days (50 minute classes)** |

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| **Setting:** | **Classroom** |

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| **Activity Objectives:** |

1. Students will be able to identify several factors that affect erosion and describe the affect

that they have.

2. Given a combination of erosion factors, students will predict the level of erosion that will

occur.

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| **Activity Guiding Questions:** |

1. Which factors can expedite the erosion process?

2. Which factors can reduce or slow down erosion?

3. How does slope angle affect erosion by water?

4. How does vegetation affect erosion by water?

5. How is erosion affected by the presence of vegetation?

6. How is erosion affected by obstacles (fence posts, boulders, etc.)?

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| **Next Generation Science Standards (NGSS)** | |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☐ Asking questions (for science) and defining problems (for engineering) | ☒ Patterns |
| ☒ Developing and using models | ☒ Cause and effect |
| ☐ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☒ Analyzing and interpreting data | ☐ Systems and system models |
| ☐ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☒ Structure and function. |
| ☐ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| **☐ Designing Technological/Engineering Solutions Using Science concepts (T)** |
| **☐ Demonstrating Science Knowledge (D)** |
| **☒ Interpreting and Communicating Science Concepts (C)** |
| **☐ Recalling Accurate Science (R)** |

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| --- | --- |
| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

OLS: ESS: A combination of constructive and destructive geologic processes formed

Earth’s surface.

PS: Forces have magnitude and direction.

NGSS: - Demonstrating science knowledge

- Interpreting and communicating science concepts

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| **Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)** |

1. Materials for the Stream Lab (see attachment)

2. Computers or computer lab for the interactive activity[WU1] : I found an interactive simulation that allows the students to change several parameters (amount of rainfall, slope angle, vegetation or no vegetation). After the simulation, results are given in the form of amount of soil that eroded.

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| **Teacher Advance Preparation:** |

**Stream Lab: -** Make student copies of directions and worksheets

- Gather all materials needed for the lab

**Interactive lab activity: -**Make student copies of answer sheets

- Make sure laptops are charged or that computer lab is reserved

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| **Activity Procedures:** |

Days 1&2: Students work in groups to complete the Stream Lab . This lab consists of

a rain splash block filled with moist sand into which the students can carve a

stream bed. The stream bed is then elevated at one end, where a tube supplies

a stream of water at a constant flow for a prescribed amount of time. During

this time, students will observe the amount of erosion via sand runoff from the

splash block. Variables to be investigated in further trials include steeper

slope, obstacles in the stream bed, meandering stream path, and higher water

flow. The lab instructions can be found in the attachments. On Day 1, students

will learn how to set up the stream bed and will complete a few variable trials.

On Day 2, students will finish any remaining variable trials and make

conclusions about their findings.

Day 3: Students will work individually or in pairs to complete all parts of the

interactive simulation activity at the website. Results should be recorded on

the accompanying worksheet. This program simulates a hillside that receives a

rainstorm, and it allows the student to adjust several variables before starting the

storm. After the simulated storm, this program measures the amount of soil that

was eroded and gives the student a visual representation of the damage done to

the hill.

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| **Formative Assessments: Link the items in the Activities that will be used as formative assessments.** |

1. Stream Lab: lab results and conclusions can be collected for review and a daily grade based on completion; results can also be discussed in class and grade can be taken for participation in the discussion.

2. Interactive activity: Student results can be treated in the same way as the Stream Lab results described above. A review of some type will be used to gauge level of student awareness and as a second chance to expose students to the content as a way to make sure all students received the concept.

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| **Summative Assessments: None at this point.** |

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| **Differentiation:** |

Student grouping will be done in a way that maximizes student success. Lab questions may also be modified and/or reduced as needed by individual students. During discussion times in class, students will be set up for success by asking struggling students a question that they are sure to answer successfully.

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| **Reflection: Reflect upon the successes and shortcomings of the lesson.** |

**Lesson 3:**

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| **Name: Paul Schember** | **Contact Info: schember.p@norwoodschools.org** | **Date: 7-5-18** |

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| **Lesson Title : Minimizing Erosion** | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **3** |
| **Activity Title: Erosion methods and problems** |

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| **Estimated Lesson Duration:** | **5-6 days (50-minute periods)** |
| **Estimated Activity Duration:** | **1 day (50-minutes periods)** |

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| **Setting:** | **Classroom** |

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| **Activity Objectives:** |

1. Students will be able to describe several methods by which erosion takes place.

2. Students will be able to recall and describe various problems that are caused by various

forms of erosion.

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| **Activity Guiding Questions:** |

1. Which forces are involved in erosion?

2. Which substances are displaced during erosion?

3. What problems are created when these substances are removed from their original

sites?

4. What problems are created when these substances are deposited at their new

sites?

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| **Next Generation Science Standards (NGSS)** | |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☐ Asking questions (for science) and defining problems (for engineering) | ☒ Patterns |
| ☐ Developing and using models | ☒ Cause and effect |
| ☐ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☐ Systems and system models |
| ☐ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☐ Engaging in argument from evidence | ☒ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☒ Demonstrating Science Knowledge (D) |
| ☒ Interpreting and Communicating Science Concepts (C) |
| ☒ Recalling Accurate Science (R) |

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| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

OLS: ESS: A combination of constructive and destructive geologic processes formed Earth’s

surface.

PS: Forces have magnitude and direction.

NGSS: - Demonstrating science knowledge

- Interpreting and communicating science concepts

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| **Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)** |

1. PowerPoint presentation with notes and images of erosion

2. Textbook pages related to erosion methods and problems

3. Video clip(s) depicting various erosion types and problems

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| **Teacher Advance Preparation:** |

1. Run the PowerPoint slides to check that all function well and contain no errors.

2. Locate textbook pages related to the topic and generate questions to use in

discussion.

3. Check to make sure all videos play without issues.

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| **Activity Procedures:** |

1. View video clip(s) at the beginning of class. Students should write down key ideas and interesting things that they observe.

2. Briefly discuss the video clips using what students have jotted down; students should add to their notes as needed.

3. Show PowerPoint slides to the class; students should be taking notes or otherwise be attaining this information, according to their best learning style. These PowerPoint slides will present new vocabulary terms related to weathering and erosion and will provide examples with pictures. They will also provide a chance for discussion of any misconceptions at this point (my students often confuse the topics of weathering, erosion, and deposition). Slideshow will be in attachments.

4. Textbook pages with erosion information will be assigned as independent reading assignment, coupled with a form to be filled out (homework assignment) to be discussed and/or collected the following day.

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| **Formative Assessments: Link the items in the Activities that will be used as formative assessments.** |

1. Student participation in the video discussion can be recorded as points. Their notes can be collected after the video and discussion as a daily grade, too.

2. On the following day, the homework can be collected for a daily grade or checked for completion and discussed in class.

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| **Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.** |

None at this point in the unit.

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| **Differentiation:** |

All of the assignments in this activity can be modified in length and/or complexity according to individual student requirements. In some cases, the assignments might be read aloud, completed in a pullout small group, or allowed extended time for completion.

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| **Reflection: Reflect upon the successes and shortcomings of the lesson.** |

**Lesson 4:**

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| **Name: Paul Schember** | **Contact Info: schember.p@norwoodschools.org** | **Date: 7-5-18** |

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| **Lesson Title : Minimizing Erosion** | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **4** |
| **Activity Title: EDP Challenge-Save the Soil!** |

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| **Estimated Lesson Duration:** | **5-6 days (50-minute periods)** |
| **Estimated Activity Duration:** | **4-5 days (50-minute periods)** |

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| **Setting:** | **Classroom** |

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| **Activity Objectives:**    1. Students will work together in teams to design a solution for an erosion problem on a  sloped surface.  2. Students will identify erosion control techniques via research activities.  3. Students will apply research findings to build an effective model that minimizes  erosion.  4. Students will communicate their solution to classmates in an effec**tive way.** |

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| **Activity Guiding Questions:**    1. What methods are effective for reducing erosion on a slope?  2. Which materials can help to control erosion?  3. How will success be measured in this challenge?  4. How many techniques should be used in the model?  5. How can erosion be mitigated on a sloped surface?  6. How can our results be communicated effectively?  7. What data can be collected to indicate success? |

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| **Next Generation Science Standards (NGSS)** | |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☒ Patterns |
| ☒ Developing and using models | ☒ Cause and effect |
| ☐ Planning and carrying out investigations | ☒ Scale, proportion, and quantity |
| ☒ Analyzing and interpreting data | ☒ Systems and system models |
| ☒ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☒ Structure and function. |
| ☒ Engaging in argument from evidence | ☒ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| **Ohio’s Learning Standards for Science (OLS)** |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☒ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☒ Demonstrating Science Knowledge (D) |
| ☒ Interpreting and Communicating Science Concepts (C) |
| ☒ Recalling Accurate Science (R) |

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| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Use appropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attend to precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

**OLS: ESS:** A combination of constructive and destructive geologic processes formed

Earth’s surface.

**PS:** Forces have magnitude and direction.

**NGSS:** - Designing technological/engineering solutions using science concepts

- Demonstrating science knowledge

- Interpreting and communicating science concepts

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| **Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)** |

1. Student copies of EDP flowchart, Research worksheet, Brainstorm & Planning

sheet, Challenge packets per team, and Posttests (see attachments)

2. Materials for the challenge (see attachment)

3. PowerPoint slides or Poster paper for presentation

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| **Teacher Advance Preparation:** |

- Make copies of all papers

- Gather all materials and verify quantities

-Check functions of all measuring equipment

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| **Activity Procedures:** |

Day 1: -Introduce the challenge and generate guiding questions

-Show topographical map and choose a plot from options

-Show students the control farm (normal, nothing changed) and measure the runoff

water and sand.

-Review the EDP process

-Begin research in class, finish for homework if needed

Day 2: -Teacher assigns student[WU2] groups and each group then assigns roles

-Teams put research results together and use them to brainstorm

-Teams use brainstorming to plan on paper what they will build; provide

labeled sketch with pros and cons listed

-Choose best plan and have it approved by teacher

Days 3-4: -Each student group will build a model according to the plan and have it

checked by teacher

-Test the model and record results

-Redesign plan to improve it; get new plan approved, then build and test it, collect

data

-Redesign for one more time, get approval, test it and collect data

Day 5: -Groups present their results to the class with one poster or two PowerPoint

slides

-Students fill out a rubric/questionnaire for classmates’ presentations

-Each student takes the Posttest

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| **Formative Assessments:** |

1. Teamwork can be evaluated as a formative assessment grade if desired. (see attachment)

2. The results from research, brainstorming, and planning can be used to assess daily

grade(s).

3. Model-testing results can be used as formative results on the first two trials.(see

attachment)

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| **Summative Assessments:** |

1. The final model test can be used as a summative assessment. (rubric attachment)

2. The presentation can also be used here (rubric)

3. The posttest can also be used here.(see attachment)

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| **Differentiation:** |

To maximize success for all students in this stage of the unit, groups will be chosen carefully to ensure that each is as heterogeneous and harmonious as possible. Worksheets can be reduced or modified when needed, and roles should be chosen so that they cater to each student’s strengths. For the posttest, the usual accommodations will be given for students who receive them.

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| **Reflection: Reflect upon the successes and shortcomings of the lesson.** |