American Eagle Paper Mill Waste Management

Project Description

American Eagle Paper Mill is a paper plant which produces paper from 100% recycled content. During the paper-making process, a waste sludge is produced as a by-product. This sludge, which is primarily carbonaceous paper material, is currently used as a soil amendment for nearby reclaimed mining areas but will soon no longer have that application due to land constraints. As a result, the paper sludge will build up on site or require landfilling if no alternatives are proposed, leading to challenges at the facility and an unsustainable future for their plant operations. To determine a reasonable plan, American Eagle Paper Mill requested input on potential disposal methods for the paper waste sludge.

For this project, the students were tasked with determining a viable solution for the presented challenge. To appropriately determine a solution, the project was defined by a set of constraints and criteria, listed below:

Constraints

- Feasibility - Integration into current site operations is a crucial design consideration.
- Risk - Risk to people, the environment, and the company need to be minimized through design.
- Uncertainty - Ensure confidence, reliability, and consistency in the final design proposal.
- Life Cycle - Limit the production of additional life cycles. The design should be the end of the paper's life cycle
- Environmental Impact - Reduce the damage inflicted on the environment. Limit transportation, emissions, and landfilling of the material.

Criteria

- Repurpose of Reclaimed Fiber Material - Identify a beneficial and repurposed end use for the paper sludge.
- Reduce Transportation – Reduce or eliminate transportation of the material and associated costs and risks.
- Integrate with Current Operations - The design should be easily integrated into current operations
- Keep Costs Reasonable- Solve the problem at a cost that is within the scope of what American Eagle can afford. The design should reduce the long-term cost of operation.

Proposed Alternative Concepts and Selection

After research and analysis, the students identified three potential solutions to the challenges facing American Eagle: composting, use as a daily landfill cover, and combustion with energy extraction. For this project, all proposed designs aimed to ensure the health, safety, and welfare of humans and the environment. The following criteria were considered for the proposed designs:

- Reuse of the paper sludge material to avoid landfilling, promoting a healthier environment

- Beneficial reuse of the paper sludge in a way that integrates into the plant processes, thus limiting the transportation of the material, decreasing the risk to human life.

Benefits of the three proposed alternatives are as follows:

Composting

- Creates a soil amendment that can be used by farmers and local people to enhance crop output
- Reuse of nutrients and paper waste that would generally be landfilled.
- Promotes a sustainability society and helps to inspire composting projects across communities.

Daily Landfill Cover

- Supports legally required BMP for landfill operations - helps the public and the surrounding wildlife to remain safe from contamination
- Provides additional use for the material which conserves space in the landfill for addition human waste

Combustion

- In-house energy production reduces natural gas usage, allowing for increased efficiency on-site
- Less damage to the environment as there is less reliance on natural gas
- Reduces risk to human lives as reliance on transportation is decreased
- Emissions are controlled which limits any environmental impacts
- Beneficial reuse of paper waste and LPDE. This removes two waste streams from landfilling

Initially, the paper sludge was quantified and sent to various labs for chemical analysis. Both the composting option and the daily landfill cover required compliance with the Environmental Protection Agency's Bureau of Waste Management's General Permit WMGR04. After chemical composition analysis, the sludge composition was found to be well below the required standards, allowing either use. Subsequent compost pilot-testing showed that the sludge can be composted if there is an additional high-nitrogen source of material (such as food waste) added to the sludge. With the gathered results, the students determined that composting and the daily landfill cover were viable options.

Similarly, permitting standards are required for alternative fuel sources. For combustion of paper sludge as fuel, compliance with the DEP WMGR130 alternative fuel sources permit was required. BTU testing, proximate analysis, and ultimate analysis were conducted on the paper sludge. An additional material, a low-density polyethylene (LDPE) waste product at the paper mill, was also tested as a possible fuel source. The results showed sufficient combustion potential for the combined LDPE and paper sludge waste, indicating a feasible process.

After initial testing and analysis, all three options met the required permitting standards. To determine the most appropriate process, all three options were evaluated based on the initial constraints and criteria of the project. The criteria were ranked, and the proposed solutions were all

analyzed based on their alignment with the criteria. After communication among the students, advisors, and clients, combustion was determined to be the most beneficial and efficient process for using the waste sludge. Both composting and daily landfill cover require continuous transportation costs, with additional expenses associated specifically with composting, and thus, from an economic perspective, combustion offers the greatest advantages. The combustion process occurs directly on site, which limits transportation costs. The combustion process effectively meets the remaining constraints and criteria. For both the composting and daily landfill cover, other essential criteria were not resolved. For example, the composting process fails to integrate efficiently into the current plant operations (*Figure 1*). The daily landfill cover application requires excessive transportation as well.

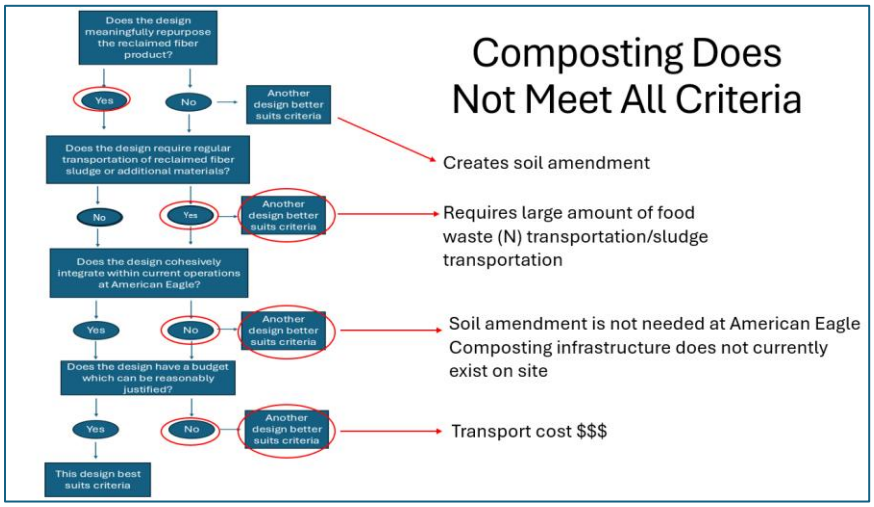

Figure 1. Strategy for evaluation criteria for each proposed alternative. This example shows the failings of a composting process for sludge disposal.

Design Development

With the combustion process selected, the team proceeded to further design a combustion process, ensuring efficiency, reliability, and sustainability. Additional outsourced lab testing was conducted to verify the combustion capabilities of the paper sludge and the LDPE, confirming that the two combined alternative fuel streams are an effective fuel source. The emissions from the combustion process are similar to natural gas combustion. Notably, the carbon dioxide released from both fuel sources is nearly identical.

There are two major components of the combustion system: the dryer and the boiler, which operate in series. Initially, the wet sludge, directly from the plant, enters the dryer. An initial energy source is required to dry the first batch of sludge. The dried paper sludge is moved to the boiler for combustion. The LDPE is sent directly to the boiler, as it is produced in sufficiently dry form during paper-making operations. The boiler produces 800 million BTU/day when the paper sludge and LDPE are combusted (*Figure 2*). Some of this energy, 341 MBTU, is used to dry incoming batches of wet paper sludge. Additional heat (not required for drying) is redirected for use within the plant as a supplemental energy source (*Figure 2*).

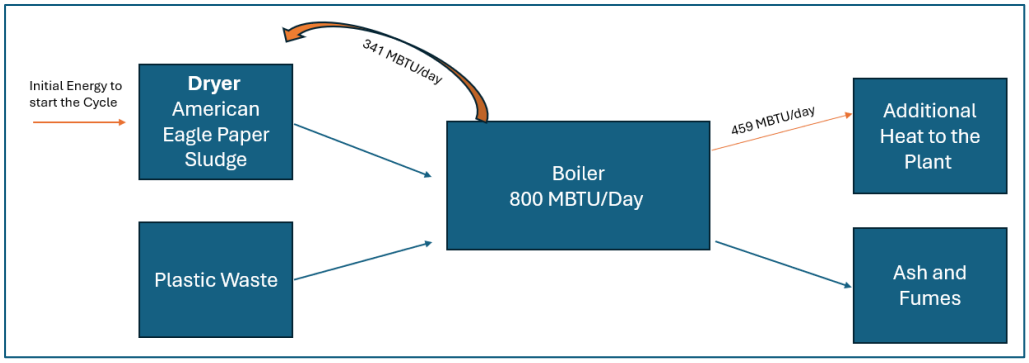

Figure 2. Combustion of paper sludge and LDPE waste produce enough energy to continue the drying process for the paper sludge and replace some of the natural gas used in the plant processes.

For the design, the excess energy produced and the energy required to dry incoming batches of sludge were calculated using established literature values along with results from combustion modeling. These calculations were used to evaluate system performance and ensure that the process met both energy balance and sustainability goals. The final proposal included specific dryer and boiler recommendations.

Students also included an EcoCost analysis – which quantified carbon dioxide release, harm to nature, depletion of natural resources, and harm to human health – of three different disposal methods which included the proposed combustion process, current land application process, and landfilling the waste materials. The EcoCost analysis showed that through creating an energy source from the co-firing of the sludge and LDPE and reduction of transportation, the proposed combustion process provided the least negative environmental impact. Carbon dioxide emissions were also approximated from the proposed combustion process and were found to be similar to those of natural gas.

Collaboration of Faculty, Students, and Licensed Professional Engineers

3 P.E.s, 1 Lab Technician, and 1 E.I.T were involved in the project.

- The primary advisor to the project was a professional engineer in environmental engineering. Primary advisor oversaw all design considerations and project development. Advisor also reviewed all drafts and presentations.
- Secondary advisor has a background in resource management and holds an M.B.A. They provided guidance and management for project development, planning, organization, and project advancement.
- Technical advisor, environmental and health safety manager with hazardous waste management background, provided guidance in preliminary design considerations and permitting decisions. Experience in environmental permitting.
- American Eagle Client is the Environmental and Sustainability Manager within the company – was the primary contact to the company during project. Is an E.I.T. in mechanical engineering.
- Additional PE guidance was provided on combustion methods and considerations.

Communication was maintained among all parties to support and advance the project. Design considerations were exchanged through every level, where ideas and suggestions were exchanged. This included instruction on the engineering design process and project management, technical feedback for reports, revisions for presentations, application of professional experience, and general support throughout the duration of the project. There was open communication and consistent exchange of ideas among all involved.

Protection of Health, Safety, and Welfare of the Public

The commitment of environmental engineers is to make the world a more efficient and sustainable place. Protecting public health and safety is at the core of every design decision. Any plan, drawing, or proposal should aim to improve the quality of life for others and should limit risk to the public. In addition, the conservation of natural resources and the integration of nature into engineering designs are crucial components of responsible environmental engineering.

The proposed designs focus on developing a sustainable solution while minimizing environmental, operational, and community risks. The objective of the project is to improve the management of paper sludge and avoid landfill disposal. The design proposed prioritizes employee safety, reduced transportation-related hazards, and the development of environmentally responsible practices that can benefit both the mill and the surrounding community.

Sustainability

American Paper Mill is the only fully recycled paper mill in the United States. Their emphasis on sustainability sets the standards and expectations for this project. Currently, the waste paper sludge generated in their process is disposed of in landfills or used in mine site soil applications.

The proposed combustion of these materials would eliminate the need for landfill disposal and ensure that waste streams are utilized more efficiently. By recovering the energy embedded in the material, the process can generate power to support the mill's operations. Additionally, the cost and energy requirements for transporting the materials would no longer be a concern for the mill.

The primary objective and criterion of this project was to ensure that the proposed solution addresses the waste management challenge without causing additional harm to the environment or society.

Local Risk Mitigation and Community Development

The mitigation of on-site and local risks was a fundamental component of the project design. Current site operations involve significant transportation of waste materials, increasing risks to both drivers and surrounding communities. The development of an on-site process, such as combustion, for the sludge substantially reduces these transportation-related risks.

All personnel involved in the proposed system would receive thorough training on the risks associated with the newly implemented drying and combustion processes. This training is critical to ensuring the safety of employees who are exposed to the system daily.

The use of an alternative fuel source for combustion limits environmental damage to both local communities. Additionally, the composting process serves as a potential method through which the local farming community could obtain a viable fertilizer, if there were a nitrogen source that could be locally and simply sourced. Although this process was not the primary proposal of the project, the research conducted could allow the mill to use paper sludge as a composting source in the future.

Multidisciplinary Collaboration

For this project, the primary group consisted of two environmental engineering students. Throughout the course of the project, they were assisted by 3 professional engineers, 1 E.I.T, and 1 lab technician with ranging backgrounds and expertise. The multi-nature aspect of the project made it essential for communication with a range of engineers, E.I.T, and an environmental specialist. The team of two students gained experience in environmental, industrial/processing, and chemical engineering.

Environmental and Chemical Engineering

The group's primary focus was on environmental sustainability and compliance with state and federal regulations. With the advice and support of a P.E. with experience in environmental permitting, several sludge disposal methods were proposed, all of which were evaluated based on regulatory standards. The options included combustion, composting, and daily landfill cover, each with specific requirements that determined their feasibility as design alternatives. As a result, chemical analyses were conducted to determine the composition and properties of the paper sludge and low-density polyethylene (LDPE). The testing results were analyzed, evaluated, and compared to regulatory limits. Both sets of permit requirements were met based on the chemical and physical characterization of the sludge. Along with chemical analysis, pilot-scale composting experiments were also conducted.

Chemical quantification—through both proximate and ultimate analyses of the waste materials—provided a detailed understanding of their composition. For the composting experiments, this understanding allowed for evaluation of the maturity of the paper sludge compost across a range of mixing ratios with nitrogen-rich feedstocks. This information was used to optimize conditions for effective decomposition and stabilization of the material and served as the basis for the final design selection. Following the selection of the combustion process, emissions from the alternative fuel source were modeled to evaluate environmental performance. This model was based on chemical mass balances.

Process and Industrial Engineering

Following the choice of combustion as the primary process, understanding of industrial and process engineering was useful in designing a functioning system. Contact with the E.I.T., who has experience in this field, supported the students' understanding of the industrial design process. An efficient design was developed, transforming the paper sludge from a waste product into a usable form of energy, while also allowing the incorporation of another waste material (LDPE) into the process, an additional benefit. Final dryer and boiler considerations involved substantial research into state-of-the-art industrial equipment.

Professional Knowledge and Skills Gained

Both students who worked on the American Eagle Paper Mill project developed the following skills:

Project Management and Communication Skills

- Effective communication with team members, faculty, advisors, clients, and other stakeholders involved in the project – understanding consultant and client relationships
- Conducting research related to the project and applying findings to develop solutions
- Adapting to different engineering practices and integrating multiple engineering disciplines
- Planning, coordinating, and executing work to meet instructor and client deadlines
- Scheduling and participating in meetings with professional engineers and project advisors
- Receiving and applying feedback from professionals to improve project outcomes
- Participating in weekly meetings to discuss progress, delegate tasks, and develop solutions
- Delivering both technical and non-technical presentations to clients, advisors, and peers

Technical Skills

- Conducting research and literature reviews on the environmental impacts and decomposition of paper sludge and low-density polyethylene (LDPE)
- Developing data analysis plans for each proposed disposal alternative
- Designing and conducting composting experiments
- Understanding environmental permitting processes
- Analyzing combustion laboratory results
- Developing selection criteria and decision matrices
- Performing combustion calculations
- Conducting environmental life cycle analysis
- Performing chemical analysis of sludge before and after composting experiments
- Analyzing proximate and ultimate test results of fuel sources
- Applying chemical principles to understand composting processes and reaction mechanisms
- Collecting and analyzing data on the plant's current processes and waste streams
- Evaluating and presenting different dryer and boiler options
- Performing dewatering calculations
- Modeling optimal ratios for alternative fuel sources
- Designing a full-scale combustion system integrated into plant operations
- Performing energy calculations and comparing system performance
- Modeling the overall system