A11 - Ethical and Environmental Analysis

Year: 2024 **Semester:** Spring **Team:** 1 **Project:** Dungeon Crawler Board
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Assignment Evaluation: See the Rubric in the Brightspace Assignment

1.0 Environmental Impact Analysis

Our project, the Dungeon Crawler Board, is built with electronic components including a PCB, LCD, and LEDs, and is mechanically constructed with polyethylene, wood, and 3D printed materials. Each of these components has environmental impacts throughout their creation and eventual disposal.

The largest manufacturing impacts involve the PCB and other electronic components in the project. When considering mass manufacturing, many people focus on the environmental impacts from carbon emissions produced by factories. While limiting emissions during production is important, PCBs are often manufactured overseas in China, and in 2018 alone Chinese flights made up 13% of global aviation emissions [1]. We could reduce our contribution to transportation emissions by sourcing PCBs locally. An example is OSH Park, a company that manufactures all its PCBs in the USA. The main tradeoff is a higher cost for these PCBs, but OSH Park has good quality reviews, so it may be worth the price. We can also follow these same principles with our other electronic components by buying locally rather than from overseas manufacturers.

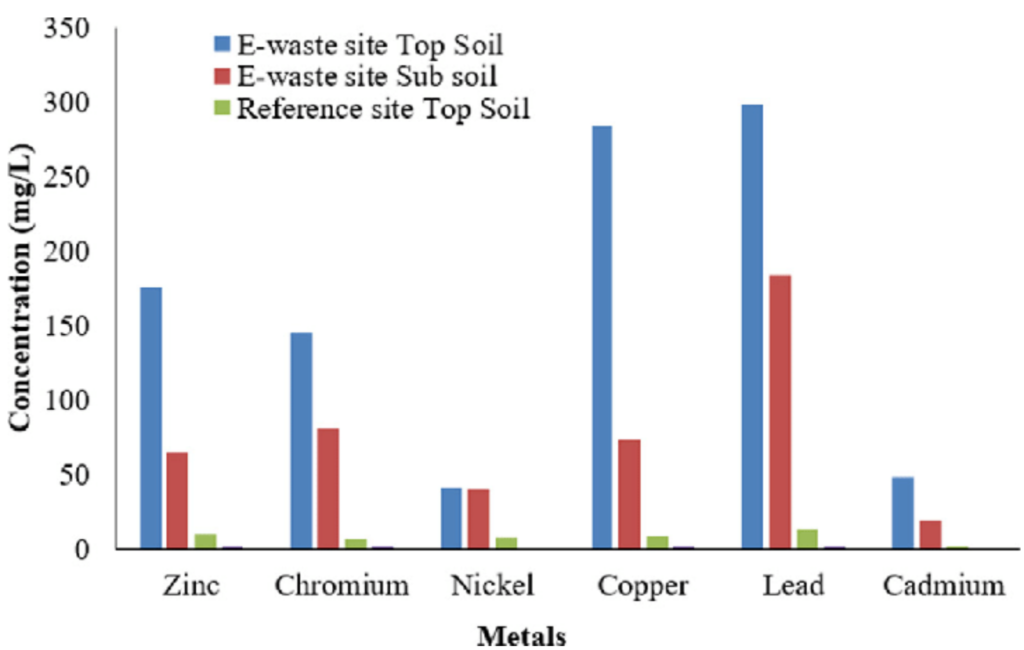
Another concern is the chemicals used to create electronic components and PCBs. Creating electrical pathways on a PCBs requires the board to be immersed in chemical baths and chelating agents that include chemicals such as formaldehyde. Most of the chemicals used are considered hazardous and are often not easily removed through wastewater treatment [2]. Over time, these pollutants can pose a serious threat to water quality in areas directly around manufacturing plants and for aquatic ecosystems downstream. Fortunately, a new process, called direct metallization, is slowly starting to replace this old chemical treatment process. Direct metallization eliminates the use of hazardous chemicals like formaldehyde and significantly decreases water consumption. Our team could research the methods that different manufacturers are using and prioritize manufacturers using direct metallization over other chemical-heavy methods.

For our mechanical design, the primary environmental concern is our 3D printed hex dividers. These dividers are all 3D printed, and it took 6 large prints to complete the full grid. While 3D printing has made a lot of advances since the 80s, 3D printers require a lot of energy per print. In an experiment comparing a 3D printed phone holder and a phone holder purchased from Amazon, it was found that 3D printers require nearly 10 times the energy per 1 kilogram of material compared to standard manufacturing processes [3]. Additionally, 3D printers release volatile organic compounds (VOCs), and the release rate can depend on the printer model, the temperature, and the printing material. Our team can reduce the emissions and the plastic waste of 3D printers by selecting material that is either made of recycled plastic or produces low levels of VOCs when melted. Alternatively, we could outsource to third party manufacturers to reduce the amount of energy needed for production.

During normal use, our game board will have very little environmental impact. The board plugs into a wall outlet, so we don’t have to worry about battery usage and consumption. The next concerning step of the product lifecycle is the disposal and recycling of our product’s components. We’ll focus on the recycling of the PCB and other electronic components, the polyethylene surface, and the 3D printed plastic.

When PCBs and electronics are not recycled properly, the materials used inside can contaminate landfills and possibly harm production workers. These materials include lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ether [4]. Fortunately, nowadays there are processes for properly recycling electronics. The industry recycles using methods such as recovering tin from tin or lead solder doss and extracting copper oxide from wastewater used during production. Additionally, scientists have found ways to use the nonmetallic parts of electronic components. For instance, nonmetallic PCB parts can be used to absorb heavy metals in water. We can contribute to this recycling process by asking users to either instructing users how to dispose of the electronic components when the product reaches the end of its life, or have defective products sent back to us so we can correctly dispose the electronics ourselves.

Presence of Heavy Metals in E-Waste Contaminated Sites



On top of the hex dividers sits a sheet of polyethylene, a plastic made from petroleum and frequently used in products such as milk jugs and auto parts. Typically, when polyethylene is sent for disposal, it is incinerated. While incineration reduces the amount of physical waste in the environment, it also releases toxins and microplastics into the air, threatening the environment and public health. Alternatively, recycling old polyethylene products expends about half as much energy as incineration disposal, and it's cheaper to produce new products from recycled products [5]. Like the electronic components, we could encourage our users to take the polyethylene top to a recycling compound or have them return a defective product back to us so we can follow the correct recycling procedures.

Third, we need to consider the process for disposing of the 3D printed plastic hex dividers. Currently, we are using PLA, or polylactic acid, as the filament material for creating the hex dividers. PLA is a bioplastic made from renewable biodegradable resources. While this is good for reducing the use of man-made plastics, proper recycling processes are needed to reap the benefits of this biodegradable material. Even though it's biodegradable, it can still take hundreds of years to decompose if not disposed of correctly. PLA recycling requires special composting conditions and microorganisms to accelerate the decomposition process [6]. Due to this, finding PLA recycling centers can be difficult and potentially inaccessible for many users. Rather than instructing our users to recycle the hex dividers, this is a case where it may be better to have them send the product back so we can handle the recycling efficiently.

2.0 Ethical Challenges

Since our product is designed to be stationary throughout use, there aren't many ethical concerns for our product. The main concerns lie in possible misuse of the game board and its components.

The first concern is regarding the wall-connected power supply. We are using a 5V DC power supply converter to connect our board to a wall outlet. While the power supply converter should have protection, it is possible that a power surge could damage electrical components and potentially hurt users as they use the board. In the future, we could include a fuse or a fail-safe in the firmware that will automatically shut off the board if an unusually high amount of power or current flows through the board. Furthermore, if the connection between the power supply and the board is exposed for any reason, the user could be at risk of being shocked. While a 5V voltage won't significantly harm the user, limiting any possibility of harm occurring is important. In our current design, the board should not be exposed, but we could include more reinforcement around that area in future designs to prevent any possible accidents.

The next concern is the character tokens that come with the board. These tokens will have magnets glued to the bottom of them and will be used to move players around the board. These tokens are relatively small, and could present a choking hazard, especially to young kids. Since our product is a game board, it should be expected that some of our audience could be younger. We can include warnings on our product packaging and in the user manual to warn kids and adults about the potential choking hazard. We could also add a minimum age to the product, especially since a power supply needs to be handled to use the board.

Another concern is the size and handling of the product. The game board will be about 1.5 feet for its length and width, and the box will be made of wood. The wood material could cause the product to be a bit heavy and cumbersome to transport around. This could cause a problem for users if they wish to move the game board between locations. While adults could handle this, younger kids would probably struggle with the weight and could potentially injure themselves. One solution to his could be to redesign our board in the future to condense it to be about the size of a chess board. This would significantly reduce the weight and size of the board, making it easier to carry. Alternatively, we could add warnings in the user manual and add a minimum age for handling the game board to prevent young users from hurting themselves.

The final concern involves the misuse of our product. If a user tries to disassemble our game board, they could potentially cause a short or damage the PCBs in other ways that could result in the boards overheating or shocking the user. Additionally, since our boards are inside a wooden box, electrical issues could lead to the box catching on fire. While this chance is slim, we want to prevent the user from being injured in any way possible. We could add a warning in the user manual to not disassemble the board or misuse it outside of its designated instructions. We could also redesign our board in the future to have a thin metal or plastic casing underneath the wood to limit the chances of the box catching on fire.

3.0 Sources Cited

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