A Research Study of the Feasibility of Implementing a Living Wall into the Environmental Studies 2 Building

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CONTEXT

Efforts done by staff, students and faculty have been undertaken to improve the University of Waterloos ecological profile mainly though a reduction of resource use and improve waste management. This has been done through courses the University offers and by volunteers. This undertaking is now an organization that calls itself WATgreen and has been around since 1990. A full time Waste Management Coordinator was hired not long after WATgreen was formulated to deal with all of the green ideas coming about. (Cook, 2004).

One second year course called ERS 250 'Greening the Campus', focuses on improving the many environmental aspects of the campus while working with WATgreen. Enthusiastic young students get to try their own hand at solving local problems. ERS 250 focuses on teaching the students how to look at their life on campus and its environmental implications. It allows them to identify different parts of campus life which may be improved through further research projects and study. The projects are made available to other students who are also interested in greening the campus for further study and reference. WATgreen has won awards throughout its history as well, such as the environmental achievement award for innovation in the KW area in 1992 and the General Ecology award in 1993 (Cook, 2004). The idea of implementing a living wall has already been a WATgreen project by a group of former ERS students but for that research assignment the idea was to put a living wall in the SLC while we are focusing on implementing a living wall in the old, south-facing architecture wing of ES2 building. This idea is not new but has never been implemented on campus. The University of Waterloo is also the only University in Canada with a Bachelor of Environmental Studies degree and is well know globally for environmental principles and therefore should be a leader in all environmental fields. Macleans Magazine has ranked UW number one in these four categories, Highest Quality, Most Innovative, Leaders of Tomorrow and Best Overall (Gillis, 2004). These rankings are taken very seriously and worked upon by school officials to be improved on each year to maintain and better UW's standings. The University has also had a very strong reputation in history, shown in its rankings from the past two decades (Redmond, 2004). The University of Waterloo does not have a green building on its campus while other Universities and companies in Canada do. This school needs to practice what it preaches and be a role model for other schools and organizations worldwide, so that the high rankings of the school can be substantiated without a doubt.

The term ‘Sick Building Syndrome’ is used to describe situations in which occupants in the building experience acute health and comfort effects that appear to be linked to time spent in a building. In 1984 the World Health Organization Committee report suggested that up to 30 percent of new and remodeled buildings worldwide may be the subject of excessive complaints related to indoor air quality (Vanee, 2004). This condition is frequently temporary, but some buildings have long-term problems. There are many causes of SBS such as poor ventilation, air conditioning and heating systems, materials used in the building such as paint, furniture and ink which can all emit VOC’s (Vanee, 2004). These health problems can be minor such as headaches to anemia then to the cumulative affects over time resulting in cancer. The health of the occupants of a building should be taken seriously since North American spend more than 85% of their time indoors and if VOC’s are being ingested, building owners should find ways to combat the source of the problem (Darlington, 240).

There are many educational opportunities that can arise from the implementation of a living wall. Faculty, professors, students and visitors alike can learn about different species of plants, their growing components, their maintenance, innovative ways to cleanse the air and help the environment etc. However, are problems that aspire when attempting to put a living wall into operation in the ES2 building. Besides the fact that the old architecture room that we are focusing on is not a picturesque setting there are technical problems that arise. Light, water, temperature and humidity are key factors in plant growing that must be assessed in the building. There is not a lot of natural light that enters this room due to the structure of the windows, the vines that cover the windows and the large pine trees just outside of the building. The temperature of the room is kept at an average of about 21ºC with small fluctuations. The humidity of the room is not very high, but would be raised by placing plants in the room which would benefit the respiratory health of the occupants (Dunnett, Kingsbury, 2004, 171). There are two sinks at the North side of the old architecture room and rain water is drained into three areas on the roof of the room so we would look to those supplies as a source of water for the wall. These factors can all be maximized by the proper placement of the living wall. We are focusing on house plants that can tolerate and flourish in the conditions set in the room.

Through the processes of air purification, plant life naturally cleanses the surrounding air. Placing vegetation in room can easily purify the area for all inhabitants. While cleaning the air in the ES2, the old architecture room would be made more esthetically pleasing for those working in or passing through the building which has the fine possibility of enhancing the productivity and attitudes of professors and students alike.

PURPOSE

The purpose of this study is to determine the feasibility of implementing a living wall in the abandoned, south-facing architecture studio, located in the ES2 building. The function of a living wall in the building would be to enhance the air quality, improve the working environment of the inhabitants, as well as to display the environmental practices of the University and be provided as an educational tool. This proposal would also be an inspiring step towards "the mission of the Greening of the Campus effort to transform the University of Waterloo into a showcase of environmental responsibility." (Cook 2004). This is especially important because the University is behind in "act[ing] as a model and a catalyst for other campuses and institutions" (Cook 2004), which is integral to the institution since it prides itself on its environmental programs.

KEY TERMS

Bio-filter - an engineered bed of filter medium above an air distribution system. Contaminant air is blown into the air distribution system and diffuses up through the media

CFC- chloro-fluoro carbons

EPA- Environmental Protection Agency

ERS- Environment and Resource Studies

ES2 – Environmental Studies 2 building

Foot Candles – designed as the amount of light received by one square foot of a surface that is one foot from a point source of light equivalent to one candle of a certain type.

Halogenated compounds – synthetic organic compounds containing hydrogen atoms

HVAC system - Heating ventilation and air conditioning system

KW- Kitchener & Waterloo area

LEED- Leadership in Environment and Energy Design

Living Wall- a vertical wall covered in vegetation used for filtering air and may include complex or simple watering systems. The illusion of a natural, wild surface is created. It may serve a number of aesthetic and environmental functions.

Off Gassing- the emission of volatile organic compounds from any materials present, such as adhesives, furniture, paint etc.

PSI – pounds per square inch

SBS - Sick Building Syndrome

UW- University of Waterloo

VOC (volatile organic compound) - any of various organic chemical compounds (such as formaldehyde or gasoline) that evaporate quickly especially from solvents, adhesives, fuels, or industrial wastes and that contribute to photochemical smog in the atmosphere

WATgreen – Campus-wide, program specializing in environmental endeavors to transform the University of Waterloo into a showcase of sustainability.

OBJECTIVES

When our group decided to undertake the task of improving the air quality of the ES2 building, we decided to look at three different factors. Between the group members, we had a limited amount of knowledge, but each of us had an idea of the structure and purpose of each of our research topics. The three components we decided to study were a living wall, the HVAC system and the use of non-toxic paints. The general objective for our study was to use these three systems in co-operation in an attempt to discover the best way to improve the air quality of the ES2 building through research and investigation. More specifically, we wanted to address the benefits of improving air quality and promote educational opportunities for students and the community through the implementation of a living wall. After having our first meeting, we decided that there were still many things we need to know about these three components.

We had very little knowledge of the structure of the living wall. We decided that we needed to research many different types of structures with the purpose of finding the structure that would be most feasible for our particular area in ES2. We knew very little about cost, maintenance, and plant species that were required to maintain a living wall.

As we began doing more research we came across many more things that we needed to decide on. We needed to decide what type of watering system we were going to implement and we also realized that we had to decide how to construct a living wall in an area which is not optimal for plant growth.

When discussing the HVAC system, we discovered that it was crucial to understand what kinds of systems are currently being used in the building, realizing that we needed floor plans and air duct drawings so that we could properly assess the improvements that could be made, if any were required. As with the living wall, we needed to research the cost, maintenance and adjustments, if any, or initial requirements that would be required to improve the system. Our study also needed to address the relationship that would occur between the HVAC system and the living wall. These two components are closely linked and we needed to research what systems would work best together and how they would interact. The building's HVAC system is important to understand because it allows us to be aware of what type of indoor air pollutants are emitted and therefore the plants in the living wall may need to be decided on based on their ability to absorb the specific emissions.

Finally, we discovered that the type of paint that is used in an indoor environment can have a negative impact on air quality. Therefore, we needed to know which types of paint were the safest and what the cost difference is between toxic and non-toxic paints. It was also apparent that we needed to address the concerns of faculty members that would be affected by paint colour. We needed to do some research on this as well as more specifics of the actual affects toxic paint can have on human health.

Overall, research needed to be completed to determine the feasibility of implementing these three components into the building as well as determining the relationships between them.

METHOD

We developed a conceptual framework, which included several methodologies that were used in acquiring the information necessary for this proposal. To begin with we looked at several case studies to obtain background information and the feasibility of living walls. These case studies included functioning living walls in Guelph and Niagara.

We also looked into a couple of expert companies that actually sell their individual models of living walls, such as Air Quality Solutions and BIOREM both in Guelph and The Verdir Company in British Columbia. These companies provided us with the most up to date information concerning all aspects of living walls. We also conducted several key informant interviews, one of which was with Alan Darlington who is the founder and CEO of Air Quality Solutions. We also interviewed Lynn Hoyles who is a member the Biology department at the University of Waterloo who specializes in greenhouse maintenance and plants biology; she was very helpful in providing us with information regarding plant species and irrigation systems. We also spoke with Liviu Cananau in the Plant Operations Department regarding the current HVAC system in the ES2 building. Before each interview we were certain to formulate a series of specific and relevant questions for the interviewee. From a context literature review we were provided with useful information regarding plant species and living wall structure; the recent book entitled “Planting Green Roofs and Living Walls” by Nigel Dunnett and Noel Kingsbury. This book also displayed and described many functioning living walls all over the world.

We conducted an ORE approved survey, which we administered to faculty members who are located in the ES2 building. We decided on a qualitative sample of our population partly because a campus-wide survey would be a great deal more difficult and also we felt it was most important to get the opinions of the people faculty would be directly effected by this implementation. We decided to send the questionnaire out by e-mail forgiving the likely low response rate because administering face-to-face would have been too difficult considering that all professors have different office hours. We designed the survey as mainly closed-ended questions so it would be easier to analyze the results (Palys 2003, 177) but we also included a couple open-ended questions because it is important to allow the respondents to have an opportunity to voice their opinions heard (Palys 2003, 176). The responses to these open-ended questions allowed us to have a greater depth of knowledge into their opinions (Palys 2003, 176), and so we were able to address them to the best of our ability. A lot of time was spent working on the questions to be sure they were properly worded and straightforward, as well as not to include bias or any other admonitions; also that each had a different idea that is important to the effects of the implementation of a living wall, and enough background information was included. (Palys, 2003, 185). In analyzing the results from the questionnaire we will compare the results from each question individually. We will display graphs for most of the closed-ended question sections, and will also include comparisons or notes of particular comments that were received.

Once we have compiled and analyzed all our data and research we will, as a group, look at all the different options of implementing the living wall and then decide on the best option of living wall, while also addressing any potential concerns of the model.

RESULTS

Survey Results

The purpose of the survey was to determine the feelings and ideas regarding current air quality and of improved biofiltration system of the faculty members that will be directly affected by the development. The method we used was an impersonal mail-out questionnaire. However understood that our response rate would be low due to the method chosen to survey the faculty, we were hoping to increase the response rate by sending it out through email because people would be more inclined to send it back through email than through the mail. The response rate for this type of questionnaire ranges from 10 to 40% (Palys, 2003, 151). The survey was sent out to 52 prospective participants who could potentially have offices in the ES2 building. We received 12 completed surveys. Our response rate was 23% which is usual for this type of survey.

The survey consisted of eight questions. Each one was designed to address a specific concern we had as researchers.

Question #1

Do you have any concerns about the current air quality of the building?

Yes/No

This question was included so that we could decide whether or not there is currently a problem with the air quality in the ES2 building. If individuals who work in the building feel that there are air quality problems, it cannot be kept in its current state since it leads to an unhealthy work environment. It is important that these questions be asked to faculty members because they spend a significant amount of time in the building. Sixty-seven percent of respondents had concerns about the current air quality of the building (see Chart 1). Some respondents felt that the building was stuffy, and that carbon dioxide levels were too high, however, this was not based on technical merit. Others felt that air quality was jeopardized when the door was left open and cigarette and exhaust fumes entered the building and lingered due to poor ventilation.

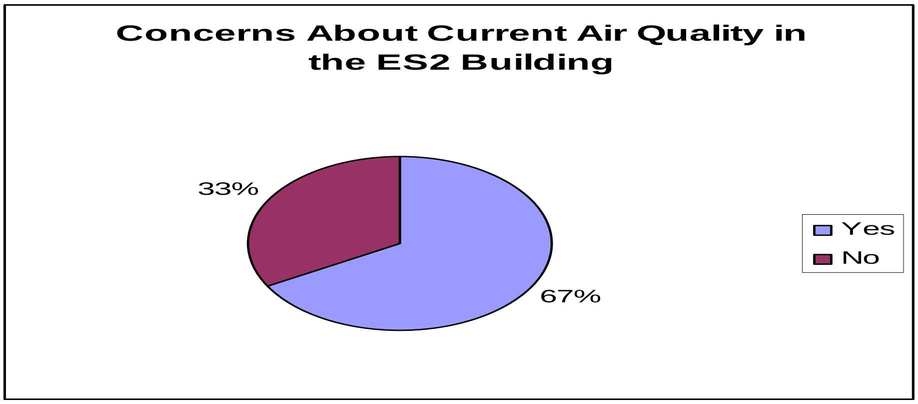


Chart 1 – This chart shows the results from Question #1 of the survey. Most respondents are concerned about the current air quality in the ES2 building

Question #2

Do you think the use of non-toxic paint is important to air quality in the building? Yes/No

This question was used to determine the feelings of faculty members on the importance of non-toxic paint. We wanted to decide if non-toxic or low VOC emitting paint is something that should be considered when addressing the air quality. We as researchers knew the effects that paint can have on building inhabitants such as Sick Building Syndrome. Not one person who responded stated that non-toxic paint is unimportant to air quality. Twenty-five percent of respondents said that they were unsure (see Chart 2). Some made comments stating that adequate ventilation is important to consider when addressing paint use.

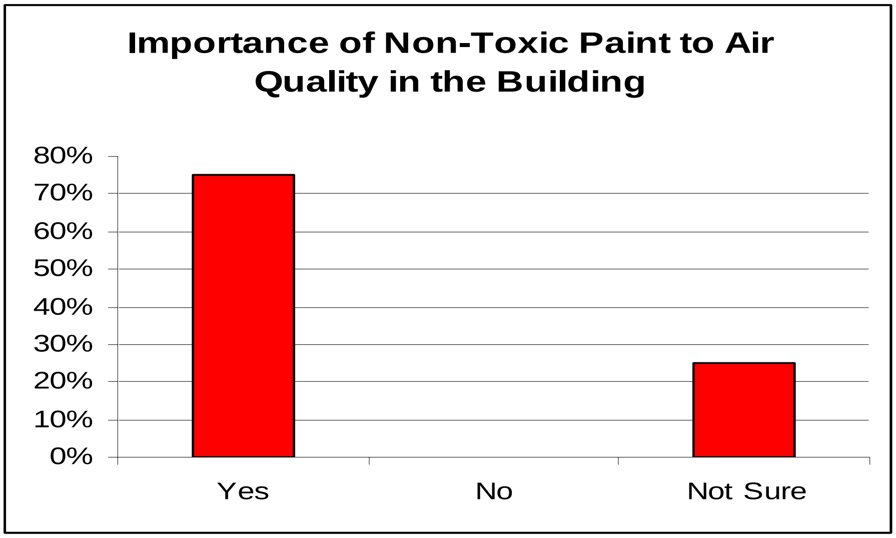


Chart 2 – This chart shows the results for Question #2. No one felt that non-toxic paint it unimportant to air quality.

Question #3

Would you feel the same way about your answer to the above question knowing that non-toxic paint is more expensive?

Yes/No

This question is directly related to Question #2 and it is designed to determine if expensive costs inhibit the benefits of air quality improvement. In other words, we wanted to find out if faculty members would change their feelings if they discovered that non-toxic paints are more expensive than regular paint. A majority of respondents answered that their feelings would be the same if non-toxic paint were more expensive. However, we must take into consideration the respondents who answered that they were unsure about non-toxic paint in Question #; these respondents stated that their answers would still be the same knowing that non-toxic paint is more expensive. Altogether, when looking at answers to Question #2 and #3, ninety-two percent of respondents stated that cost does not matter (see Chart 3). Most respondents made the comment that bad health has a higher long term cost than the extra money put into improving the paint quality.

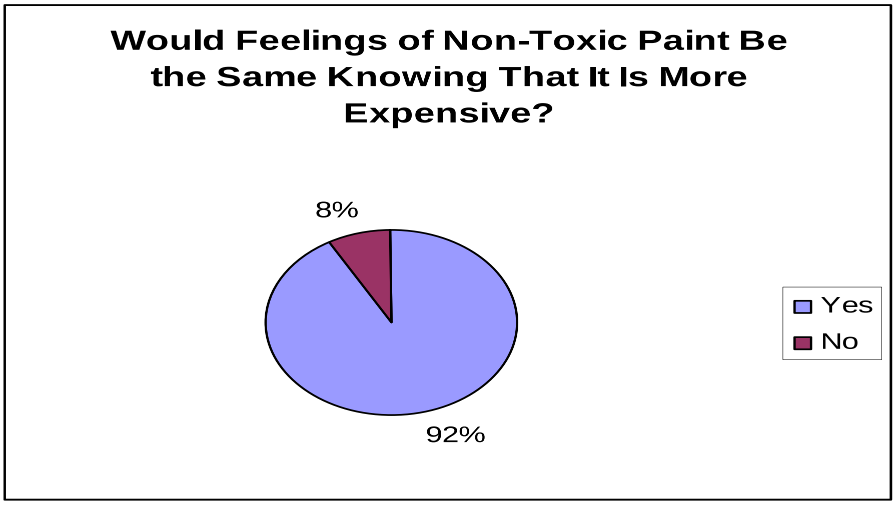


Chart 3 – This chart indicates that respondents feel that non-toxic paint use is important even if it means more money needs to be spent.

Question #4

Do you have any colour preferences? Please specify.

This question was used to determine the colour preferences of the faculty members so that we can make recommendations about what colour of paint to use and more specifically, what brand to use; based on colour preference and cost. This was an open-ended research question. The majority of respondents stated that colours should be neutral or white. Some respondents stated that the "institutional" colours such as pale yellow and pale green are not appreciated. Other respondents suggested white because it reflects the sunlight and makes the room brighter. White would also be beneficial to a living wall because plants would have more light. One of the surveys mentioned that the paint colours chosen can actually benefit the productivity of the workers in the building.

Question #5

If we were to suggest implementation of a living wall, where do you think it would be most beneficial?

a) **front foyer/entrance (facing Ring Road)**
b) **former architecture studio in the form of a common room**
c) **other (please specify)**

This is the first question in the survey that directly addresses a living wall. We put this question in to get a better understanding of the best location for such a wall. As researchers, we understand that there are other factors that affect the location of the living wall but it is important to consider the opinions of faculty members who may come into contact with the living wall every day. The majority of respondents were split between a common room in the architecture studio and other suggestions. Each had a response rate of forty-two percent (see Chart 4). The respondents who chose ‘option C’ made some suggestions. Some felt they needed more information about the size of the wall to make an informed decision. This is a valid statement and must be taken into consideration by the researchers; perhaps we should have included an approximate size in our survey. One respondent suggested placing the wall in a linear fashion against the windows in the studio. While this would be ideal because it would allow for the plants to have access to more sunlight, the windows in the studio are quite small and there are pine trees planted outside which block most of the light. It would also mean that people inside the building would not have access to the windows. Overall, most respondents felt that there needed to be some sort of balance between visibility for educational purposes and for effectiveness so that air quality will still be enhanced.

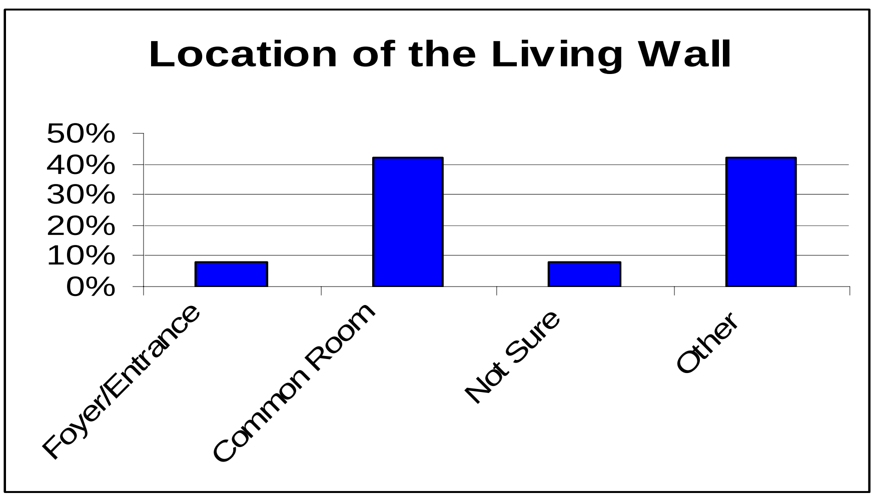


Chart 4 – The chart shows the location the respondents felt would be best for the living wall. Most felt that a common room would be best, while others offered different suggestions which may or may not be feasible.

Question #6

Do you have any concerns regarding the implementation of a living wall? Please address all that apply.

- **a) bugs**
- **b) smells**
- **c) maintenance**
- **d) allergies**
- **e) other (please specify)**

This question was included so that we could address the concerns that faculty members have about the implementation of a living wall. Only twenty-five percent of the respondents stated that they did not have any concerns regarding the living wall. All other respondents stated that each of the mentioned possible problems are a concern. Specific comments were made with regards to maintenance. One respondent felt that money should be set aside for maintenance costs and special consideration should be given to the maintenance required because a project that is not well-maintained is not worth building. There also seemed to be some concerns about the earthy smell that a living wall may cause. These comments have been taken into consideration throughout the research and we hope to offer solutions to the problems or more education since it is possible that the respondents have very limited knowledge about the benefits of a living wall.

Question #7

If a living wall were to require simple maintenance (such as watering) would you be willing to contribute a small amount of your time (15 minutes or less per week)? Yes/No

This question was designed to determine if people working inside the ES2 building would be willing to contribute their time to do some simple maintenance. People who contribute may demonstrate a greater enthusiasm for the wall and may also help to reduce costs because someone would not have to be hired to maintain the wall. We looked at various requirements that the wall may need, but hope to propose a system where watering and fertilizing can be automated. Although these procedures would likely be automated, it would be helpful to have someone check the system to ensure that there are no blockages in the watering pipes or ensure that the plants are healthy. Sixty-seven percent of respondents stated that they would be willing to contribute a small amount of time towards maintenance (see Chart 5).

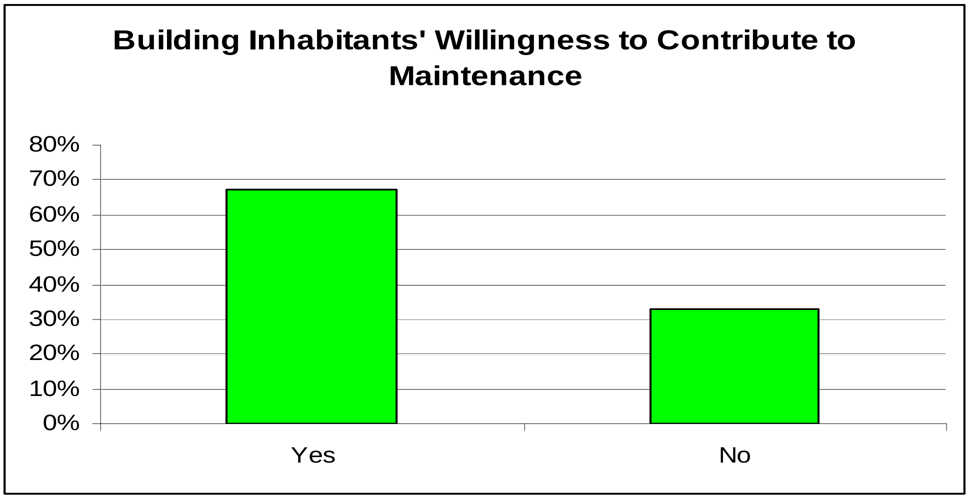


Chart 5 – This chart shows that a majority of the respondents are willing to contribute to maintenance of the living wall.

Question #8

Do you think a living wall would be a positive or negative development to the old architecture wing in ES2? Why or why not?

This is perhaps the most important question that was asked in our survey. By asking this question we are hoping to get an understanding of the enthusiasm that ES2 building inhabitants have toward implementing a wall. If the building inhabitants express interest, than hopefully there would be a push to get the wall implemented. Ninety-two percent of the respondents stated that they felt a living wall would be a positive development (see Chart 6). Some made comments about the aesthetic improvement. Many stated that the building is very dreary and a living wall would be a great improvement. Others felt that it would be an excellent educational experience if it worked properly and most felt that the air quality would be improved as long as it was properly maintained.

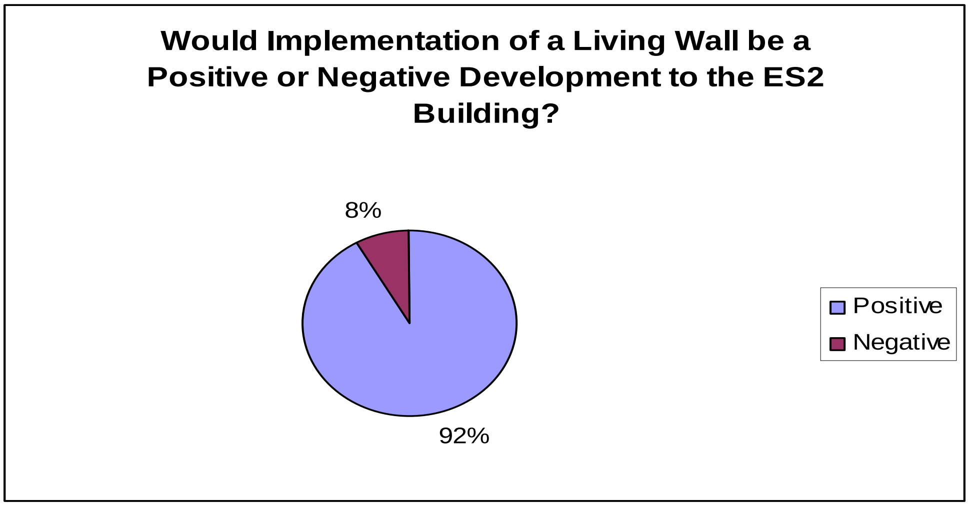


Chart 6 – This chart shows that a large number of respondents felt that a living wall would be a positive improvement to the ES2 building.

Overall, this survey was extremely useful when we were looking at components of a new biofiltration system. The comments helped us to look at different possibilities for the system and allowed us to research information pertaining to the concerns of the faculty members so that we can hopefully, reduce those concerns and offer information that would further enhance the positive aspects of the wall and air quality system.

RESEARCH RESULTS

Through research methods mentioned earlier in this paper, we have examined the three components of a living wall, paint use, and HVAC systems in an attempt to look at the different options available and we determine the best option for the architecture studio in the ES2 building. We have researched various problems that may be associated with each component and offered solutions or at the very least, the component that we feel would cause the smallest amount of problem.

Structure and Design of the Living Wall

Our interview with Lynn Hoyles provided us with a lot of important information. To start off we had to deal with the issue of very low light in the studio. She first recommended that all the ivy outside the south-facing windows be removed to allow more sunlight to come through. She also mentioned that the ivy is bad for the bricks and eats away at the surface. It was suggested that perhaps we should consider placing the living wall in the foyer because there would be a lot more light, but we decided to keep our options open, so she gave us several recommendations for the low-light studio. Supplemental lighting wouldn't be very successful because it is difficult to light a whole wall; therefore there are many low-light plants that we could use. She suggested a few plant options such as ferns, which work very well cause they renew themselves through offspring, also bromeliads such as moss which has a long life, basically any understory plant. She also suggested using vines as a backdrop on the wall. Care must be taken in the distribution of these plants; they must be spaced properly so each individual plant receives the needed airflow and nutrients, this will also decrease the chances of competition between the plants allowing them to put more energy into taking VOC's out of the air and prevent rotting or fungal growth which was a major concern of the ES2 residents. Humidity will also be substantially increased by the natural process of plants and there were some concerns of this shown in our survey results, which could be an issue, but due to the current dryness of the building, expressed by respondents in the surveys, we feel this would be an added benefit. Irrigation would also contribute to humidity increase especially if we implemented a mist irrigation system. Although a mist system could be potentially dangerous because the mist be will likely to go more than only where is needed, this could create slippery zones all around the living wall. It would be possible for us to apply a mist system if we were sure to have a border around the wall enclosing the wet floor. In the greenhouse at UW they use Arizona mist pumps and a mist master and they have no problems with slippery floors but there also is not nearly as much traffic in the greenhouses and having to border off the living wall would be a deterrent from the educational function of it. Therefore a drip or trickle irrigation system would be beneficial. Hoyles recommended installing perforated or junctions of 3/8 inch tubing behind the wall, which would provide adequate irrigation, and no water would be lost on the surrounding floor. The perforated tubing is cheaper according to Hoyles, or we could also put in drip irrigation nozzles on the tubing running behind the plants on the wall. Another issue with the irrigation is the fact that the city water that is used in ES2 has a pH of around 8 and high calcium content. This will cause a problem for our substrate, peat moss, which would require a pH of 4.5-5.5 while nutrients in the soil necessary for healthy plants require a pH of about 6-7. Therefore to counteract the pH of the city water we could add phosphoric fertilizer or high acid fertilizer, Hoyles recommended 'Plant Product 21-7-7' – high acid NPK fertilizer. In our irrigation some sort of pressure system will also be needed to ensure the living wall is irrigated proportionately, it is possible to use the pressure of gravity, which would have few PSI but tap water has a pressure of about 60 PSI and all that is required for drip irrigation is approximately 25 PSI therefore the current system is satisfactory.

Another concern we brought up was the issue of bugs on the living wall. She advised we stay away from any flowering plants that require insects to be pollinated, though it is possible that the wall will attract bugs so if there is a problem we can contact Natural Insect Control in Stevensville Ontario. They have many environmentally friendly supplies such as pesticides and traps to combat any insect problem; and their goal is to "change to a poison-free thinking and make a future possible." (NIC®, 2004).

For the structure of the wall she suggested that we include a heavy liner of 45 mil against the back wall so the wall doesn't rot and so the plants can't penetrate it. As a medium for the plants she recommended we use a long milled sphagnum peat moss, although this wouldn't provide a lot of nutrients to the plants. Therefore this must be regulated carefully and the person who is in charge of the wall must have a lot of knowledge regarding plant biology. Hoyle's information helped us to determine our options for a living wall in ES2.

We were also in touch with Alan Darlington, who is a plant agriculture professor at the University of Guelph and a recognized expert in the area of indoor biofilters. From his expertise he formed a company called, Air Quality Solution's, in 2001 that brought the technology of biofiltration to the market place, also known as Naturaire® Systems. After providing him with some brief information on what our tentative plans, were he was able to offer some advice. He told us to be careful when using low-light plants because what may seem low light to us could actually be quite bright to these plants and gave us a link of very useful information regarding the lighting requirements of plants (Trinklein 2003). He mentioned that the sphagnum moss we were planning on using would degrade within 6 months to a year. Also the mesh we planned to use for the plants to grow up creates an issue of flammability indoor, even the flow of water through it does not ensure that it is not flammable. They use a synthetic weave material which is resin treated in their Natuaire® systems and is not flammable. As for maintenance of the wall, it is possible for one person to maintain up to $10m^2$ of biowall per hour. This maintenance is required every 2-4 weeks after the system has been established; initially there is more maintenance required. The approximate cost of implementing a living wall is $1,000 to $2,000 per m^2 of biowall; and $1m^2$ biowall of treats $100m^2$ of floor according to Natuaire®. Therefore since the architecture studio is $535m^2$ we would need approximately $6m^2$ to treat all of the air in this room. The cost of this system would be roughly $9000 including; plants, growth medium, support structure and plumbing. Other possible costs include; maintenance, drainage, insect control and fertilizer.

He also provided us with a document outlining all the initial requirements for the implementation of a living wall, please note these requirements are specifically for Alan Darlington's Naturaire® Systems, although they can be applied to most indoor living walls.

Water Requirements:

Water sources

- The system can tolerate a range of potable water quality. However, the lower the salt content of the water (the hardness) the better. The use of softened water is not recommended and can damage the plants.
- Directly connecting the system to the water source will greatly reduce the required maintenance

Waterloo has hard water and the potential locations of the living wall took water sources into account.

Drain requirements

- The system needs to have a certain amount of water sent to the drain at regular intervals to control the build of salts that are left when the input water evaporates. This is most effectively done by a direct connection to the building's drain system.
- Failure to drain an adequate amount of water from the system can result in damage to the biowall.

Lighting Requirements:

- The better the light environment, the better for the biowall
- However, the biowall will do well in as little as 75 foot candles of light.
- This can be provided by good exposure to a south facing window or the use of sky lights.

The windows in ES2 architecture studio, although small, are south facing.

Air Handling:

- To function properly an adequate flow of air must be drawn through the biowall and returned to the occupied space
- To be most effective the biofiltered air should be distributed by the building's air handling system.

The HVAC systems has recently been upgraded in the architecture studio which would adequately circulate the air.

These two key informant interviews were very helpful in providing us with specific information and options that are crucial to the implementing the most effective system.

The vegetation that is put onto the living structure is the most important aspect of the living wall. These plants will have to flourish in conditions that are not suitable for all plant life. Of the two areas we are focusing on; the old architecture room and the front foyer of ES2, there will be low to medium light and low temperatures which are not an optimal environment for the flora. The temperature needed by the suggested plants is between 19-24ºC which is what you would find in the ES2 building. For these reasons house plants will be our focus during the implementation. The watering system chosen will affect the plants for reasons of erosion, the need for a moist or dry soil continuously, and safety reasons. The drip system was chosen after considering these factors. The pH and nutrient level of the soil is a big consideration also. A phosphoric or high acid content fertilizer should be used to deal with the high calcium of the city water (Hoyles, 2004). Since house plants are the only plants we will be using there is relatively low maintenance for these plants and their conditions do not need to be monitored very closely. This is vital since we want the living wall to be beneficial and not a hardship bestowed upon the staff and students. There are some concerns that come along with the plant speciation of the living wall such as, pests, pollen production (allergies), moisture and bacteria. To counteract these concerns plants can be put in that are non-flowering, moisture levels can be kept down by the HVAC system circulating the air and the idea that bacteria is produced is a misconception and pests can be controlled through the usage of mild soaps or through contacting the Natural Insect Control (NIR®, 2004). Long milled sphagnum peat moss is to be used as the growing medium on the wall. Although Darlington mentioned that the peat moss would degrade but it is the best option since it works with available growing conditions, compliments the mesh structure and it easy to replace and maintain. It also has a high nutrient content as well as a fiber content greater than 66%, which makes it the most important type of peat for horticultural use (Reeve, 2002).

Many issues arise when the nation spends such a great amount of time indoors. SBS and the increased release of VOC’s are main concerns because of that fact. The three main pollutants found in buildings that were focused on are Benzene, Formaldehyde and Trichloroethylene.

- Benzene: is a skin and eye irritant, low level exposure causes headaches, appetite loss, drowsiness, nausea, nervousness, anemia, psychological disturbance, bone marrow disease, carcinogenicity. It comes from inks, dyes, synthetic fibers, tobacco smoke, paints, plastics, rubbers.

- Formaldehyde : irritates mucous membranes, of eyes, nose throat, can cause contact dermatitis, can cause asthma and rare throat cancer, irritation of upper respiratory tract and eyes and headaches. It comes from foam insulation, plywood particle board, pressed wood products, waxed paper, grocery bags, paper towels, adhesive binders in floor coverings carpet backings, natural gas, permanent press clothing
- Trichloroethylene: is a potent liver carcinogen. It comes from metal degreasing and dry-cleaning industries, printing inks, paints lacquers, varnishes, and adhesives. (Prescod, 1990)

These pollutants are very harmful and need to be taken out of the air that building occupants breathe in. We have put together a list of plants that are proven to remove these harmful pollutants. The chart provides information on common plants that can be bought at most nurseries for a reasonable price (see Appendix 1).

We found several optional structures for our living wall; these include a couple models from the Verdir Company in BC (Verdir, 2004), and a structure found in a case study of a living wall implemented at The Northern Center for Advanced Technology (NORCAT) in Sudbury (WATgreen, 2004). One of the models from the Verdir Company is actually a living screen (see Appendix 2) and only includes a structure for vines to grow up the wall, as opposed to an actual living wall that includes a growing medium on the wall for plants to mature in (see Appendix 3). Therefore the latter model provides for increased plant mass, which would increase the air filtration, although it would be more expensive. These models could potentially be located on either the wall in the foyer of ES2 facing ES1, or on the back wall facing south in the studio (see Appendix 4). The structure implemented at NORCAT is a circular structure that would be optimally located in the center of the architecture studio (see Appendix 5) This structure would allow for a greater diversity of plants because the circular nature causes different amounts of sunlight to fall on different areas of the wall; therefore this differentiated sunlight would result in a greater species diversity. This would further increase amount of VOC's absorbed by the plants.

Paint Research

There are many benefits to using non-toxic paints in an indoor environment. The most obvious is related to human health. Indoor air is three times more polluted than outdoor air (Eartheasy, 2004). Paint can emit low levels of toxins even for years after it has been applied (Eartheasy, 2004). The ES2 architecture studio will need to be painted because currently the paint is chipping and there is writing all over the walls.

Today, there is a variety of products available that have low-VOC and zero-VOC emissions. These paints are slightly more expensive than their high-VOC emitting counterparts but the long term benefits outweigh the greater health and environmental costs. Low-VOC or zero-VOC paints reduce toxins that may causes allergies or respiratory problems, including Sick Building Syndrome. The use of these paints benefits the environment because it reduces ozone depletion as well as groundwater and landfill contamination that otherwise may be emitted due to construction or destruction of buildings (Eartheasy, 2004). These paints are also water-based which means they are easy to clean up. They have very little or no hazardous fumes and there is no off-gassing. They perform in the same way as the other paint and the painted areas can be occupied faster since there is no odor (Eartheasy, 2004).

Latex paint is the best option for non-toxic paint. It has almost as many colours as acrylic and in some cases it can even be cheaper (GreenSeal, 1998). Some of the paints that were researched included low-VOC paints such as Benjamin Moore Pristine EcoSpec, AFM Safecoat, Cloverdale EcoLogic and zero-VOC paints such as Alistagen CALIWEL (antimicrobial), and Sherwin Williams Harmony line.

We decided that zero-VOC paints would be more beneficial and cost-effective because they would not contribute to air pollution and the price is not much different from that of low-VOC paints. We decided that the two best options for paint use in the ES2 building is either Sherwin Williams Harmony Interior Latex Egg Shell or Alistagen CALIWEL Antimicrobial Coating which is available in ten colours. From the survey, it was made clear that inhabitants of the ES2 building would prefer light, neutral colours. The paint by Sherwin Williams is available in white and is less expensive than the CALIWEL paint. However, much preparation needs to be done when applying Sherwin Williams paint to prevent mildew and chipping (Sherwin Williams, 2004). There is also no guarantee that small amounts of VOC’s will not be emitted.

The CALIWEL paint is a revolutionary new development. It uses a Bi-Neutralizing Agent (BNA) which inhibits the growth of harmful organisms on the paint surface and eliminates toxins (Alistagen, 2004). It does however come with a cost. CALIWEL BNA Antimicrobial paint is approximately $500 for 5 gallons which is about one hundred dollars more than the paint made by Sherwin Williams (Alistagen, 2004).

However, the health and environmental benefits would be very high, so it is a matter of determining how much money UW is willing to put forth.

HVAC System

A HVAC system is very important because its function is to provide proper airflow, heating, and cooling to each room (California Energy Commission, 2004). The airflow is particularly important in assisting the living wall to reach its maximum efficiency by continually providing the wall with old air to cleanse and by distributing the purified air throughout the building. Though we must keep in mind that generally every $1m^2$ of living wall treats $100m^2$ of floor. (Darlington, 2004). Therefore since the area of the architecture studio is approximately $535m^2$ we would need just over $5m^2$ of living wall to purify the air in the architecture studio. Therefore the function of the living wall would be primarily for the architecture studio and not the entire building. Though the building will still benefit because the air wouldn't be contained in the one room; therefore the purified air would be distributed throughout the building increasing all air quality. The current HVAC system in the ES2 building harbors a filter for only dust and large particulate, therefore the presence of a living wall would be much more beneficial because VOC's can also be present, especially after new construction since there will be off-gassing from new materials, construction adhesives, paint and so on.

Several concerns were expressed in the survey, some of which were: adequate ventilation, stuffiness and dryness. The new additions to the HVAC system in 1999 addressed many of these problems; the new additions also increased the air changes per an hour (see Appendix 6). In the old architecture studio the air is now changed 6.5 room air changes in an hour. An important role of the plants on the living wall is increasing the humidity levels to the 45-65% that is necessary for a comfortable working environment (Dunnett, Kingsbury, 2004). This will deal with the issue of dryness in the building.

There were also some concerns about smoke from the smokers coming inside, this can be solved but a regulation that requires smokers to be in a certain area away from the door as well as the intake pipe for the building. Another worry was regarding the carbon dioxide quantity in the building, there are monitors installed but they never went off, the carbon dioxide can increase substantially in an occupied room; this could be solved by a ventilator that helps maximize efficiency in delivering required ventilation. A specific model that addresses this has a fully integrated carbon dioxide sensor, for example the AAP® Herman Nelson® Unit Ventilator by McQuay International (McQuay International, 2004). Also the Designflow™ Outdoor Airflow Measurement System by McQuay Applied Rooftop Systems and Air Handlers; this accurately measures outdoor air intake to within 2.5% of required levels to help maintain required ventilation amounts (McQuay International, 2004); although both these options would require the complete overhaul of the current system which would greatly increase costs, therefore as a group we decided that the current system is in fact adequate for the needs of the living wall, especially with the new additions that focused on enhancing the ventilation in the studio. A living wall can also help to reduce maintenance of an HVAC system by extending the filter life and reducing the cleaning requirements (MacQuay, International 2003).

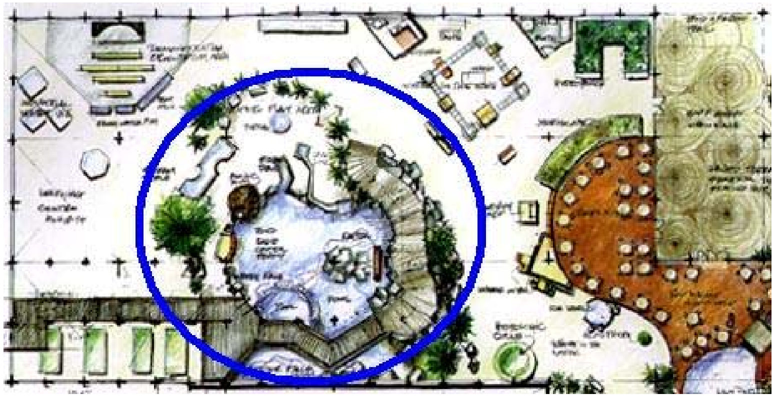
CASE STUDIES

At the University of Guelph they proudly display a new and innovative way to filter indoor air. A research group at the University, Wolfgang Amelung from Genetron systems, engineering consultants and personnel from Canada Life Assurance teamed up to create this new system. This case study is important since it the first time a vegetated air purifying system has been done on a scale that can be used for commercial or home use. This air filtration system is an entire room called the 'Canada Life Environmental Room' and is composed of three main sections. The first section houses green household plants, the second section is an aquatic system with plants and the third section is the scrubber which is composed of fibreglass panels with external faces of porous lava rock that is covered with moss. The air is drawn through these sections and then into the ventilation system. We are using many similar techniques to purify the ES2 buildings air but we will not be incorporating an aquatic system or using up an entire room (Persaud, 1991).

'Niagara Under Glass' is located in Vineland, Ontario. It has two different types of systems: a biofilter and a living wall without a biofilter which functions to eliminate humidity in the building (WATgreen, 2004). The biofilter was constructed by a company called Clean Air Solutions. The 'Niagara Under Glass' building serves mostly as an educational unit for tourists and students. However, we felt it important to our study because of its structure. Even though the biofilter system is not as effective at cleaning the air as a living wall, it is certainly an improvement and would not take up as much space. It could be centralized in a room and become more of a focal point (see Picture 1 below).

Picture 1 – This is a picture of the biofilter in Niagara Under the Glass, although it may not be as effective as a living wall, it is certainly a step in the right direction.

Niagara Under the Glass, which is not an option for ES2, also has a living wall, but it is quite large and uses a significant amount of water, however, the picture below (see Picture 2) demonstrates that it would be possible to construct a living wall and use the surrounding room as a lecture studio or classroom.



Picture 2 (Ontario Science Centre, 1997) – The area in the blue circle is the living wall system that is implemented in the Niagara Under Glass project. It is significantly larger than what we propose for the ES2 building but demonstrates that possibility of using the room as a classroom.

LIMITATIONS

A major restriction to this project was time and resources. Due to time restraints, the sampling population of our survey consisted of professors in the environmental studies program that made our survey biased. We did not have enough time to get a broad sample of the University population that consists of professors from all faculties, students, and alumni. There were few resources when it came to the actual realization of the project. Also we have a lack of knowledge when it comes to the proposed layout of the room in ES2 where we hope to implement the living wall. One large limitation of this project proposal is that we are trying to retrofit an existing building with modern technology and not working from the ground up. Since our boundary is just the one room in the ES2 building, there might not be enough space or proper requirements in the room to design a living wall that will be able to filter all of the stale and contaminated air properly. A specific problem we found in the ES2 building in general was the low lighting. To conserve energy the building uses fluorescent lights. This is problematic because there may not be enough light is produced in the room to sustain the plant life on the living wall.

The quality of the components we chose for the living wall was limited to the finances available since we did not have an accurate figure of how much money was available. We assumed limited funds were available and picked the most cost effective plants, paints and HVAC system modifications. While looking at case studies we found a few limitations or setbacks to the living wall. Though there are certain conditions that the wall requires to be fully efficient. Low temperatures may slow or stop the removal of pollutants, unless the bio filter is climate controlled. The efficiency of the microbial flora that filters pollutants can be compromised if the concentration of halogenated compounds is too high (Dessau-Soprin, 2002).

With most of the case studies analyzed, the reoccurring problem was the breaking down of contaminants in the buildings. With biodegradation, some contaminants are hard to break down due to their mixture of chlorinated and non-chlorinated VOC's. Due to this, the byproducts and effluent stream must be monitored consistently for excess bacteria clogging the filter and the release of fugitive fungi (TechTree, 2002).

ANALYSIS

After we completed research on our three main focuses of the biofiltration system, we were able to analyze the variety of options we discovered and related them to the specific characteristics of the ES2 building. This was done in an attempt to determine the most feasible and effective option.

A living wall constructed in the ES2 building would enhance the university's reputation by becoming a role model in environmental innovation. The HVAC system and paint options had to be researched to ensure that we are recommending the best living wall system for its desired purpose. Our results mentioned above depict the goals of WATgreen and the ERS 250 Greening the Campus and Community course by keeping in context with the social, economic and ecological boundaries. The above results assume we have a certain amount of funding and with our limited knowledge of this funding may not be fully optimized. However, it is important to understand what creating a green campus could mean for UW and its community. A benefit to our three main focus approach is the fact that if the funding is not available now it is possible to slowly implement the different necessary factors in a step-by-step approach so in the near future a fully functional living wall can be implemented on the UW campus.

CONCLUSION

With research, we determined that the best type of paint for use, contained zero VOC. Although more expensive than the generically used paint, this low VOC paint had a better long-term health and environmental impact in contrast to only looking at the short-term cost. We specifically looked at two brands of paint; Alistagen CALIWEL and Sherwin Williams Harmony line. They both had advantages and disadvantages but in the end, we decided on the Sherwin Harmony line because it was substantially cheaper yet still effective. In the living wall process, HVAC systems are important because they circulate stale air towards the living wall and distribute cleansed air throughout the building. The ES2 building already has an adequate system that changes the air in rooms 6.5 times per hour. We felt this was sufficient for the air exchange of our living wall so we recommend maintaining the HVAC system which is already in use.

The backbone of a living wall is the plants. The functionality of the wall depends on the plants used and how they respond to the climatic environment of the room. The conditions found in the ES2 building are a room temperature of approximately 21˚C and low lighting. For maximum efficiency, we decided that houseplants would be the best choice. Long milled sphagnum peat moss was the ideal medium for plant growth because of its high fiber content and long strands to prevent fallout from the vertical structure.

By combining our research findings and looking at the floor plan of the ES2 building, we have come up with three options for the location and structure of the living wall. These options are all feasible but have advantages and disadvantages when compared to each other. We feel that the best option is a centrally located living wall similar to the one located in the Northern Centre for Advanced Technology in Sudbury. Constructing the living wall in this fashion allows for plants to have access to more sunlight throughout the day and the wall would be more of a focal point for the room. It would also benefit a greater number of building inhabitants. A central location would also mean that the wall would have access to a rain water system already present in the ES2 building.

Since the approximate cost would be $9000, it is evident that UW will need to contact outside sources for funding. Looking into donations from local and commercial suppliers could be an option. Fundraising events on campus could also be productive in gaining support. We may also be able to reduce maintenance costs by recruiting various environmental groups and courses which could give students the chance to learn about green buildings through a hands-on approach. However, we may have to hire an expert biologist or horticulturalist who would study the wall approximately once a month to ensure the living wall is productive for example making certain the plants are flourishing and that there is no bacterial growth. It may be possible to recruit Lynn Hoyles to participate in this maintenance. Faculty members, as demonstrated in our survey, have also expressed a willingness to contribute time for maintenance activities which may include ensuring plants are still living, checking pipes to make sure they are not blocked, or viewing substrate to make certain that it is still plentiful.

In conclusion, we feel that a living wall is a desirable, feasible, and acceptable development to the ES2 building because after all, we should practice what we preach!

Appendix 1

A Chart Depicting the Plant Species Available for Use in the Living Wall

(Prescod 1985, 1990, 1992)

Plant	**Light Requirements**	**Water Requirements**	**Additional Features**	**Placement Ideas**
Chinese evergreen	Low	Dry out in-between	Warmer water	Bottom of wall
Bamboo palm	Low	Dry out in-between	High humidity liked	Near circulatory system
Spider plant	Medium to Low	Keep moist	Temperature of 5ºC tolerated	Near watering system
Pot mum	Medium to Low	Keep moist	Toleration of low temperatures	Near watering system
Janet Craig	Low	Keep moist		Near watering system
Striped corn plant	Low	Dry out in-between	Warm environment liked	Bottom of wall
Madagascar dragon tree	Medium to Low	Dry out in-between	Warm environment liked	Bottom of wall
Weeping fig	Medium to High	Keep Moist	No temperature change	Near watering system
African daisy	Medium to High	Keep Moist	Toleration of low temperatures	Near watering system, side
English ivy	Low	Keep Moist	Toleration of very low temperatures, high humidity	Bottom of wall
Variegated snake plant	Low	Dry out in-between	Warm environment liked	Bottom of wall
Peace lily	Low	Keep Moist	Flowers	Near watering system
Spotted dumbcane	Medium to High	Keep Moist	Cold sensitive	Centre

Golden pothos	Low	Dry out in-between	Temperature of 10ºC tolerated	Edge
Variegated liriope	Medium to High	Keep moist	Temperature of 10ºC tolerated	Near watering system
Heart-leaf philodendron	Low	Keep Moist	Warm environment liked	Near watering system
Lacy-tree philodendron	Medium	Keep Moist	Warm environment liked	Near watering system
Miniature umbrella plant	Medium to High	Keep moist	Warm environment liked	Near watering system
Bromeliads	Medium to High	Dry out in-between	Flowers only in high light	Bottom of wall
Orchids	Medium to High	Keep Moist	Flowers, high humidity	Near watering system
Holly fern	Low	Keep Moist	Many types of ferns can be used	Near watering system
Grape Ivy	Low	Dry out in-between	Toleration of low temperatures	Bottom of wall
Fern moss	Low, partial sunlight only	Keep moist	Good pollution indicator	All over or in back

(Prescod 1985, 1990, 1992)

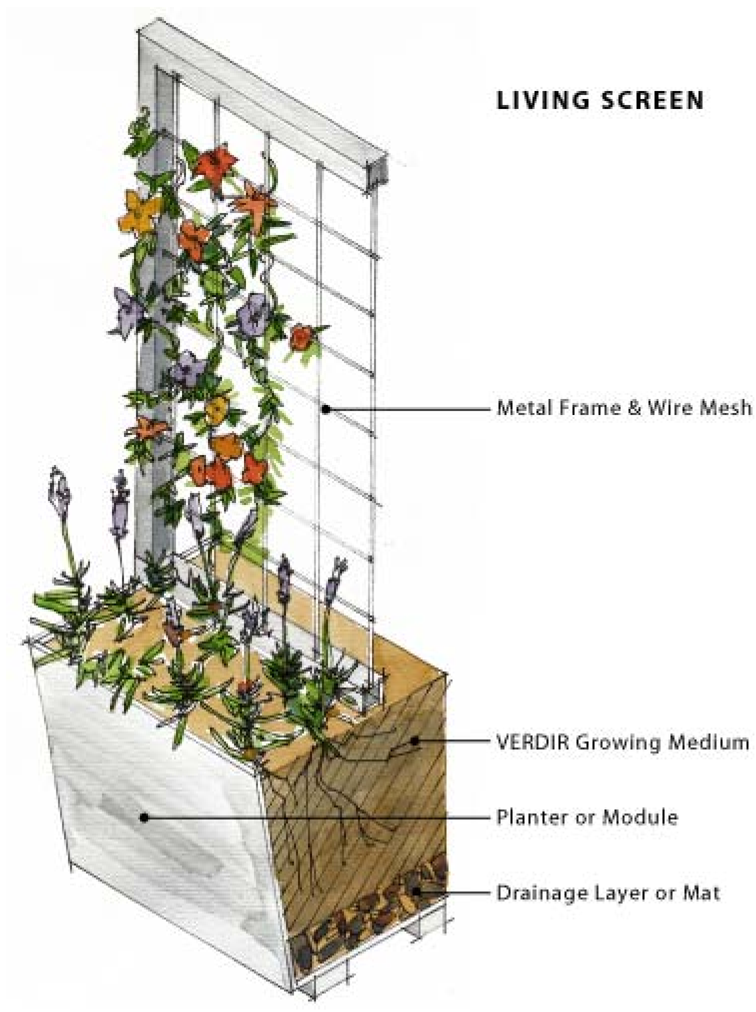
Chart Description

The rationale behind the suggested placement of the plants is to maximize their growing requirements and to use each plant advantageously. The plants that grow best while the soil is kept continuously moist should be placed at the top of the wall, closest to the watering system and vice-versa for the plants that prefer dry soil. The plants that can handle the colder temperatures should be put on the edges of the wall and closest to the duct system because of the outside air that may be coming in and affecting the plant life.

Appendix 2

Verdir Living Screen

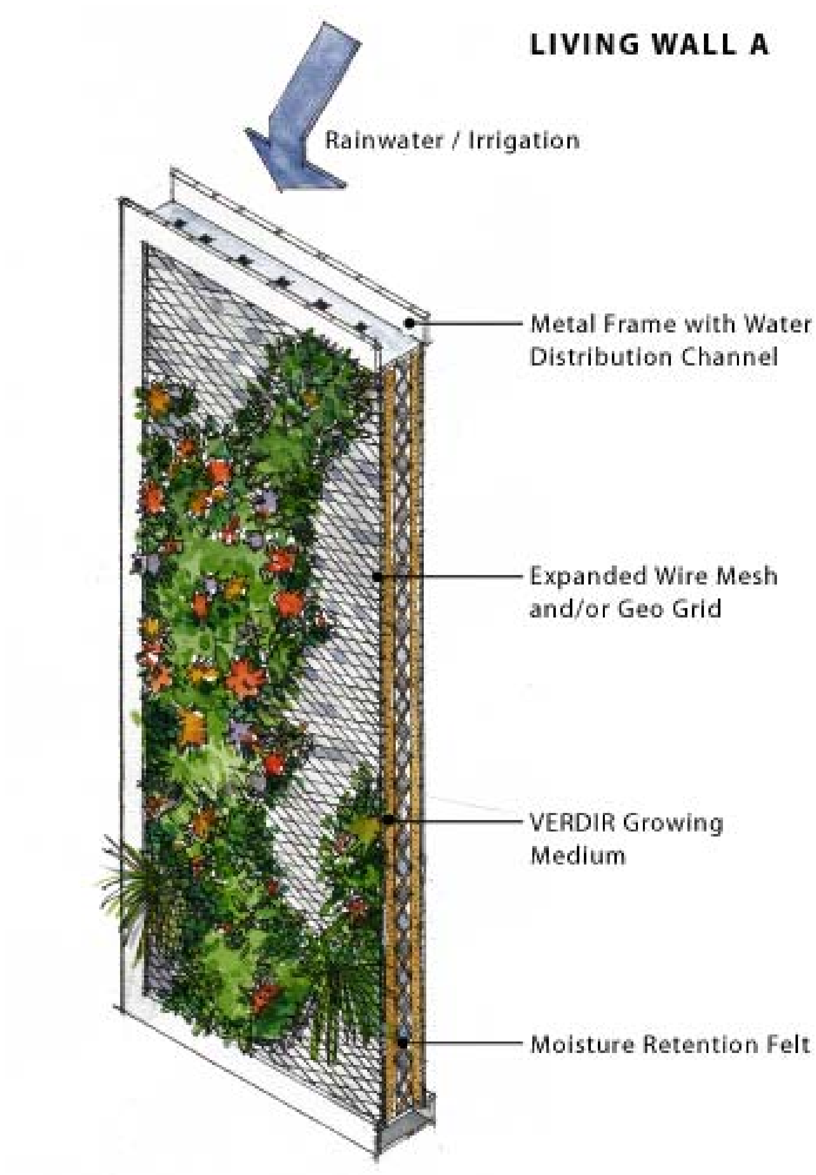
http://www.verdirsystems.com/html/living-walls.html



Appendix 3

Verdir Living Wall

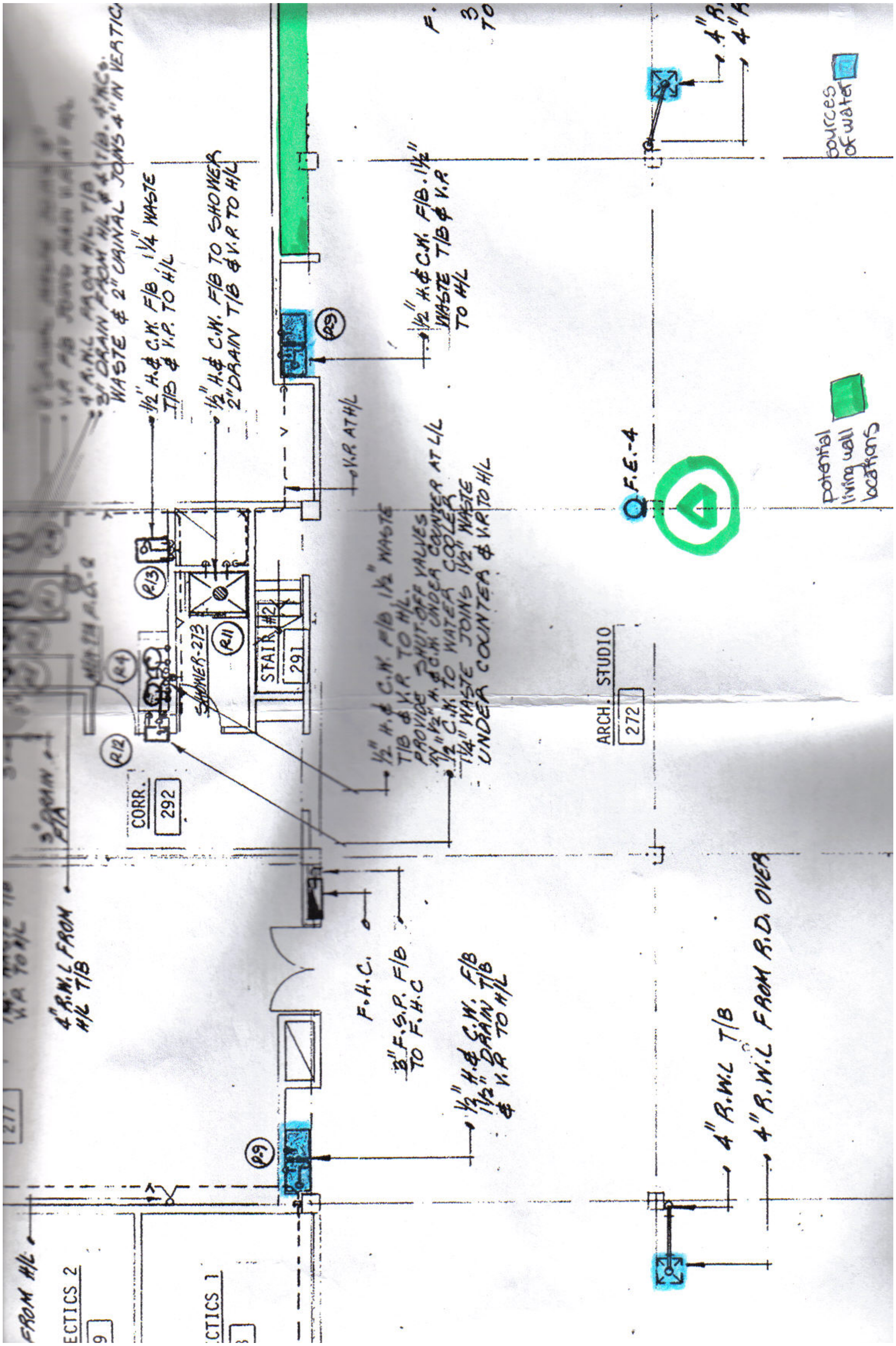
http://www.verdirsystems.com/html/living-walls.html



Appendix 4

Floor Plan of ES2

Water Systems and Recommended Living Wall Location



The blue areas depict water sources that would be available for use by the living wall. The green lines represent a linear living wall structure while the circle represents the living wall system that is circular and could be centrally located in the room.

Appendix 5

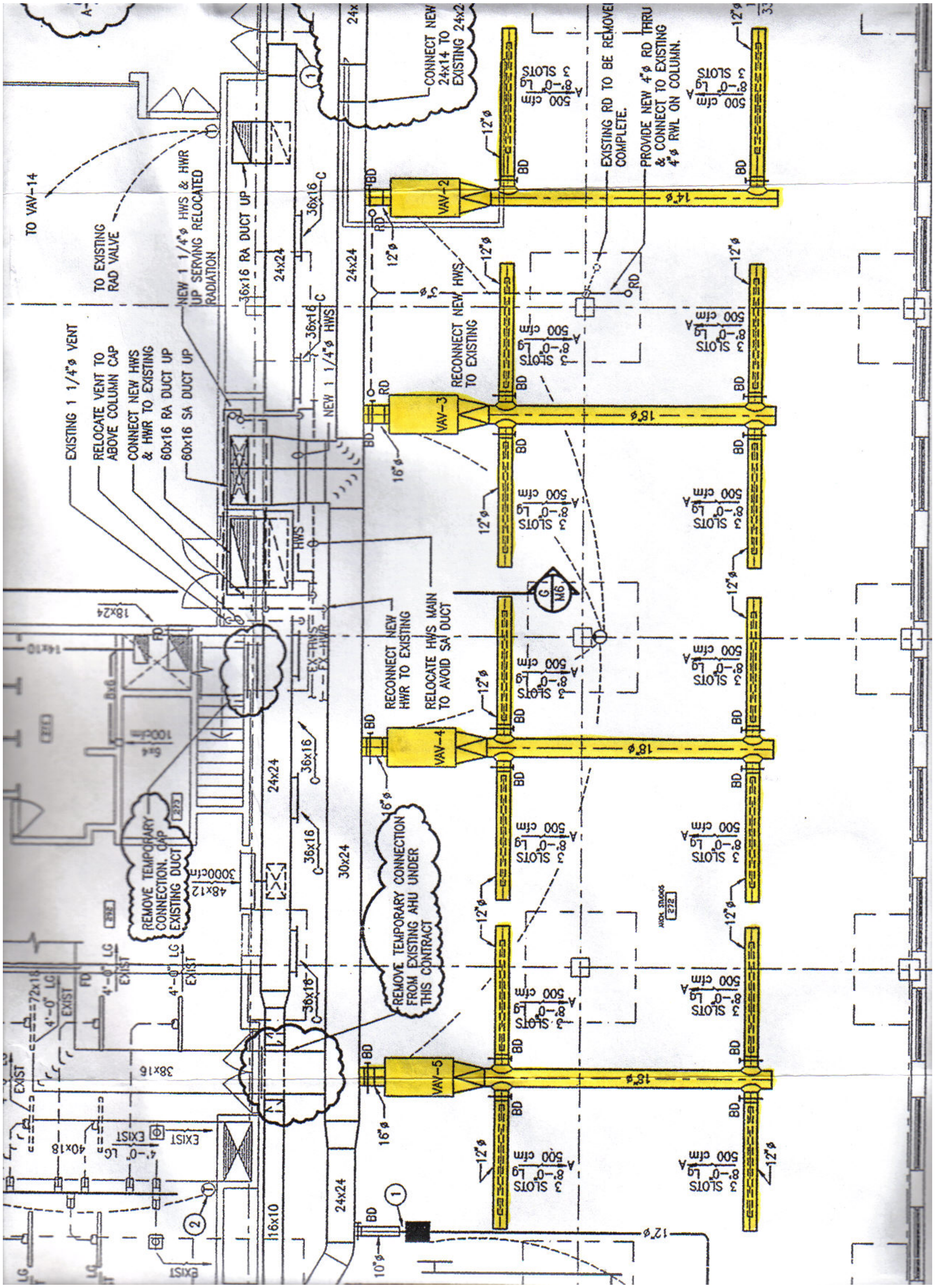
Living Wall structure located at the Northern Centre for Advanced Technology in Sudbury

(WATgreen, 2004) – This is an example of a circular structure that we feel would be best suited for implementation in ES2.

Appendix 6

Floor Plan of ES2

HVAC System in the Architecture Studio



The yellow area depicts the recent upgrades to the HVAC system in the architecture studio.

REFERENCES

Alistagen Corporation: CALIWELL Paint "Caliwel BNA Microbial" November, 2004. http://www.caliwel.com/purchase_caliwel.htm

Alistagen Corporation: CALIWEL Paint "Description of Product" November, 2004. http://www.caliwel.com/products.htm

California Energy Commission. 2004. Quality Homes. http://www.energy.ca.gov/efficiency/qualityhomes/procedures.html

Cook, P. 2004. WATgreen. http://www.adm.uwaterloo.ca/infowast/watgreen/

Darlington, A, Dat J, Dixon, M. 2001. The Biofiltration of Indoor Air: Air Flux and Temperature Influnces the Removal of Toluene, Ethylbenzene, Xylene. Environmental Science and Technology 35:240-246.

Dessau-Soprin.: Biofiltration of gaseous effluent "Air and gas treatment" January 2000. http://www.enviroaccess.ca/fiches_2/F2-04-96-aa.html

Dunnett, N.D., N.K. Kingsbury. 2004. Planting Green Roofs and Living Walls. Timber Press, Inc. Portland, Oregon.

Eartheasy "Non-Toxic Paints" November, 2004. http://www.eartheasy.com/live_nontoxic_paints.htm

Gillis, C. 2004. Comprehesive Winner, University of Waterloo. http://www.macleans.ca/universities/article.jsp?content=20041104_160541_5484.

GreenSeal "Green Report: Architectural Paints" September, 1998. http://www.doi.gov/oepc/reports/cgr_paints.pdf

McQuay International. 2003. Engineering System Solutions – Building Sustainability and HVAC Systems. http://www.mcquay.com/eprise/main/mcquaybiz/Lit_Systems/EngNews/0403Final.pdf

McQuay International. 2004. McQuay Products Catalogue 2004. http://www.mcquay.com/mcquaybiz/literature/lit_corporate/Brochures/McQuay_Products_Catalog.pdf

NIC® 2004. Natural Insect Control. http://www.natural-insect-control.com/

Palys, T.P. 2003. Research Decisions: Quantitative and Qualitative Perspectives, Third Edition. Nelson, a division of Thomson Canada Limited Canada. Scarborough Ontario.

Persaud, A. 1991. The Canadian Life Environmental Room.
http://www.ces.uoguelph.ca/research/envweb/content.htm.

Prescod, W. 1985. Selecting Healthy Indoor Foliage Plants. Pappus Volume 5 Number 2.

Prescod, W. 1990. Growing Indoor Plants as Air Purifiers. Pappus Volume 9 Number 4.

Prescod, W. 1992. More Indoor Plants as Air Purifiers. Pappus Volume 11 Number 4.

Redmond, C. 2004. UW's historical rankings in Macleans magazine.
http://communications.uwaterloo.ca/macleans.html

Reeve, M. 2002. Horticultural Teaching Plan. http://www.peatmoss.com/hortprog1.html.

Sherwin Williams "HARMONY: Interior Latex Eg-Shel B9 Series" November, 2004.
http://www.sherlink.com/sher-link/ImgServ?id=datapages/harmony_int_latex_egshel_101-23.pdf

Tech Tree: "Biofiltration" July 2002. http://www.cpeo.org/techtree/ttdescript/biofil.htm

Trinklein, D.T. 2003. Lighting Indoor Plants. Department of Horticulture, University of Missouri Extension.
http://muextension.missouri.edu/explore/agguides/hort/g06515.htm#much

Vanee. 2004. Sick Building Syndrome.
http://www.vanee.ca/iaq/sick_building_syndrome.htm.

Verdir.2004. "Green Roof Products & Living Wall Systems"
http://www.verdirsystems.com/html/living-walls.html

WATgreen "Living Wall: A Feasibility Study for the SLC" 2004.
http://www.adm.uwaterloo.ca/infowast/watgreen/projects/library/f02livingwall.pdf