CHBE484

# Evaluation of two building air cleaning systems at UBC Life Science building based on environmental impact and cost analysis

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## 1.0 Introduction

It is an important process to fresh the air in Life Science Center in UBC, which requires quantities of energy and labor work. The air passes through the filters, getting purified to some degree. And then it will pass through the coil system to be heated or cooled. In the previous method, two kinds of filters were used. One is pre-filter, and the other one is box filter, which requires to be replaced every three months and every year correspondingly.

Now, the Nalco Company provides filter replacement to take the place of previous two filters and coil cleaning procedure as well. The new filters should be replaced every 2 years. Switching from previous filter system to new one reduces the costs, including the fan energy required to blow the air through the filters, waste disposal cost and the labor cost to replace the filters. The previous filter system contains four hundred pre-filters, 24x24x2 Red Excel filters, and 400 box filters, 24x24x12 MVP. In the new system, 400 24x24x2 3M filters are replaced.

From January 9$^{th}$ to 14$^{th}$ 2012, Nalco cleaned coils and changed the air filters on 11AHU's(2,3,5,6, 9,27,27A,28,28A,29,29A,34) at the Life Sciences Centre. Nalco also replaced the air filters on AHU #10 and the main plenum servicing all 34 AHU's.

Figure 1.Pre filter, Box filter, 3M filter

## 1.1 Goal and Scope

The purpose of this work is to compare the environmental impacts of previous filter system including pre-filter and Box filter with new filters (3M filters) in Life science building of the University of British Columbia. Furthermore, the cost analysis has been done to investigate whether it was economical to replace the previous filters system with new filters (3M).

For cost analysis, filter cost, energy cost, labor cost to change filters, and disposal cost have been considered. For the environmental Impact, The analysis will focus on the emissions resulting from filter raw material production, filter transportation from factory to UBC, and filter transportation from UBC to disposal field.

## 2.0 Cost analysis

### 2.1Method

Input data for this analysis was obtained in two stages: before January 10$^{th}$ and after January 15$^{th}$ The Fan power has been measured for 13 units including units – 2,3.5.6.9.10.27.27a,28,28a,29,29a,34 .Before January 10$^{th}$ the pre-filter and Box filter were used as the air filters in Life Science Center. The project was carried out during the week of January 10$^{th}$ – 15$^{th}$. This project included coil cleaning and filter changing. Pre filter and box filter were replaced with 3M filters.

For cost analysis, project cost includes coil cleaning, price of filters, and BC hydro incentive. In this study, fan energy consumption, filter cost, labor cost for replacement of filters, and disposal cost will be considered.

Table 2.1 summarizes the fan energy consumption for each unit before January 10$^{th}$ and after January 15$^{th}$.

Table 2.1 Fan energy consumption before Jan. 10th and after Jan 15th

| | Before Jan 10 | | After Jan 15 | |
|---|---|---|---|---|
| **Unit** | KWs(average value) | kwh/yr. | KWs(average value) | kwh/yr. |
| **2** | 62.557 | 547999.057 | 60.098 | 526462.247 |
| **5** | 7.138 | 62531.595 | 7.181 | 62902.144 |
| **6** | 7.138 | 62531.595 | 7.181 | 62902.144 |
| **9** | 14.827 | 129889.338 | 12.171 | 106615.945 |
| **10** | 15.213 | 133270.610 | 13.816 | 121027.634 |
| **27** | 24.122 | 211309.683 | 18.453 | 161650.47 |
| **27A** | 22.811 | 199832.419 | 17.923 | 157003.202 |
| **28** | 32.259 | 282591.117 | 27.843 | 243904.768 |
| **28A** | 29.062 | 254582.419 | 25.773 | 225768.326 |
| **29** | 37.290 | 326659.787 | 30.783 | 269663.109 |
| **29A** | 37.679 | 330066.463 | 31.465 | 275633.926 |
| **sum** | | 2541264.086 | | 2213533.915 |

Energy cost is estimated as 0.05 $/KWh. The difference between energy consumption before January 10th and after January 15th will result in Energy saving (Table 2.2).

Table2.2 Fan energy saving

| Fan Energy saving | |
|---|---|
| **Cost,$** | **Energy, kwh/yr.** |
| 16387 | 327730.171 |

Pre filter, Box filter, and 3M filter cost 6.75$/filter, 73.90$/filter, and 75.90$/filter respectively. Pre-filters, box filters, and new filters should be replaced every 3 months, every one year and every two years respectively.

Saving resulting from labor cost and disposal cost is due to different life time of filters. Also, it should be considered that 800 filters, 400 pre-filters and 400 box filter, were used in previous filter system and only 400 3M filters were installed. Furthermore, different filter cost and different life time of filters cause the saving in filter purchases after switching from previous filter system to new one.

It is obvious that labor cost is much more for previous filter system including pre-filters and box filters than new filters in that new filters have been replaced each two years. The cost analysis including filter cost, labor cost, and disposal cost are shown below in table 2.3.

Table2.3Energy saving (Filter cost, Labor cost, Disposal cost)

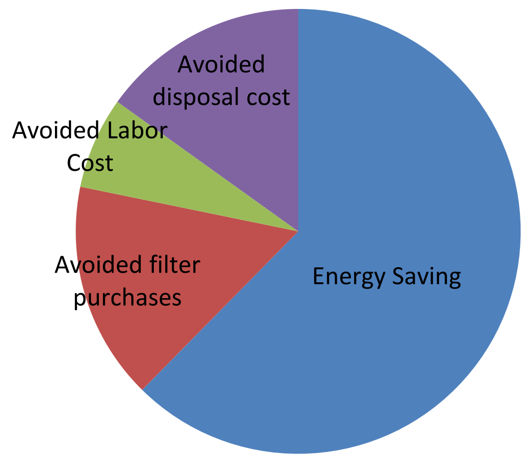
| Saving per year | saving($/yr.) |
|---|---|
| **energy saving** | 16387 |
| **Avoided filter purchases** | 4163 |
| **Avoided labor cost** | 1754 |
| **Avoided disposal cost** | 3968 |
| **Total saving/year** | 26272 |

The project cost includes coil cleaning labor cost, 3M filter cost. BC Hydro is also providing incentives based on energy payback from these programs which can help fund this work and provides for a very short payback period. Table 2.4 provides the project cost.

Table 2.4.Project cost

| Project Cost | Cost($) |
|---|---|
| **Coil cleaning** | 16500 |
| **3M filter** | 29519 |
| **Bc hydro incentive** | -12750 |
| **Total Costs** | 33269 |

Figure 2.1 Saving distribution




The reduction in fan energy consumption has the major impact on saving and the impact of disposal cost, labor cost, and filter purchases on saving is nearly the same. Based on the project cost and savings the payback period is nearly one year (Figure 2.1).

## 3.0 Environmental Impact assesement

There's no doubt that cost analysis will be a major concern when choosing the filters. However, as environmental issues have been more and more emphasized, the environmental impact assessment should also be carefully considered. Unlike other life cycle analyses which consist of numbers of factors, in our case, there are just three main parts that we take into consideration including emissions during filter production, emissions during transportation of filters from factory to UBC, and transportation of used filters from UBC to disposal field .

The three types of filters we study here are: pre-filter, box filter and new filter. Detailed information of these filters is listed below:

Table 3.1 Information of filters (American Air filters)

| Name | Type | Company |
|---|---|---|
| **Pre-filter** | Red Excel | Filter shop |
| **Box filter** | MVP | Freudenberg |
| **New filter** | 3M | American Air Filter |

## 3.1 Functional Unit

For the purpose of this study, a functional unit needed to be selected to provide equivalency amongst each system and enable comparison. For this analysis, the functional unit was set as per two years filter consumption for Life Science Center.

## 3.2 System Boundary

The boundary for Environmental impact assessment will be considered from material production to disposal of filters. The emission releasing from filter production is not included in this LCA because it is negligible in comparison with martial production.

## 3.3 Emission Inventory

### 3.3.1. Emissions during material manufacture

Emissions during the production may be divided into two parts, one is during the production of raw materials of filters, and the other one is during the manufacturing of filters. However, compared to the emissions from the production of raw materials, the later one seems negligible. As a result, only emissions during the production of raw materials are considered. Table 3.2 shows the components of each filter, and the composition of each component, as well.

Table 3.2 Components and compositions of filters

| Pre-filter | | |
|---|---|---|
| **Component** | Weight fraction, % | Weight, kg |
| **Synthetic fibers** | 100% | 0.56 |
| **Box filter** | | |
| **Component** | Weight fraction, % | Weight, kg |
| **Micro-glass fiber** | 30.87 | 0.92 |
| **Halogen-free plastic** | 69.13 | 2.06 |
| **New filter** | | |
| **Component** | Weight fraction, % | Weight, kg |
| **Ultra-fine glass fiber media** | 51.03 | 0.74 |
| **2" plastic** | 48.97 | 0.71 |

Table 3.3 shows the emission factors of each component.

Table 3.3 Emission factors of each component, g/kg-component (U.S. Life Cycle Inventory Database, K.G. Harding et al., 2007, Jyri Seppala et al., 2002. S.V. Joshi, 2004)

| | **Pre filter** | **Box filter** | | **New filter** | |
|---|---|---|---|---|---|
| | Synthetic fiber | Glass fiber | Halogen-free plastic | Ultra-fine glass fiber media | Plastic |
| **$CO_2$** | 2.04 | 2.04 | 19.30 | 2.04 | 19.3 |
| **CO** | 0.80 | 0.80 | 0.12 | 0.80 | 0.12 |
| **$NO_x$** | 2.93 | 2.93 | 0.014 | 2.93 | 0.014 |
| **$SO_x$** | 8.80 | 8.80 | 0.023 | 8.80 | 0.023 |
| **PM** | 1.04 | 1.04 | 0.0001 | 1.04 | 0.0001 |

Then we can get the emissions of these three filters during the production.

Table 3.4 Emissions from material production, g/filter

| | Pre filter | Box filter | | New filter | |
|---|---|---|---|---|---|
| | Synthetic fiber | Glass fiber | Halogen-free plastic | Ultra-fine glass fiber media | Plastic |
| **$CO_2$** | 1.14 | 1.88 | 39.76 | 1.51 | 13.70 |
| **CO** | 0.45 | 0.73 | 0.25 | 0.59 | 0.085 |
| **$NO_x$** | 1.64 | 2.70 | 0.03 | 2.17 | 0.0099 |
| **$SO_x$** | 4.92 | 8.10 | 0.05 | 6.51 | 0.016 |
| **PM** | 0.58 | 0.96 | 0.0002 | 0.77 | 0.000071 |

Table 3.5 Emissions from two systems for two years, g/2 years

| | Old system | New system |
|---|---|---|
| **$CO_2$** | 36963.52 | 6085.04 |
| **CO** | 2220.16 | 270.88 |
| **$NO_x$** | 7430.11 | 871.26 |
| **$SO_x$** | 22284.30 | 2611.33 |
| **PM** | 2629.28 | 307.87 |

### 3.3.2 Emissions during transportation from manufactures to UBC

While filters are transported, the vehicles may give rise to serious emissions, like greenhouse gases, $NO_x$, $SO_2$, etc. Based on the emission factors we get from the internet, the emissions of these pollutants will be calculated hereby: emissions=emission factors ×distance. Also, we assume that the vehicles are all large diesel trucks, with a full load of 20 tones.

For Life Science Center, there are 400 filters working inside the building. Each pre-filter can last for three months, box filter for one year, while new filter can be used for two years. We consider the emissions based on two years' usage. Therefore, 3200 pre-filters, 800 box filters and 400 new filters are considered. Table 3.6 shows the location of factories and the distance from factories to UBC.

Table 3.6 Distances from factory to UBC

| Filter | Address | distance ,km |
|---|---|---|
| **Pre-filter** | 5711-103A Street, Edmonton, Alberta, Canada | 1179 |
| **Box filter** | 2975 Pembroke Road, Hopkinsville, KY, USA | 4073 |
| **New filter** | 10300 Ormsby Park Place Suite 600 Louisville, Kentucky, USA | 3223 |

Table 3.7 Emissions of three filters during transportation from factory to UBC

| | Emission factors g/km | Emission, g | | |
|---|---|---|---|---|
| | | Pre-filter | Box filter | New filter |
| **$CO_2$** | 1419 | 1673001 | 5779587 | 4573437 |
| **CO** | 0.9 | 1061.1 | 3665.7 | 2900.7 |
| **$NO_x$** | 7.74 | 9129.88 | 31540.29 | 24958.11 |
| **$SO_x$** | 1.12 | 1320.48 | 4561.76 | 3609.76 |
| **PM** | 0.11 | 125.27 | 432.76 | 342.44 |
| **VOC** | 0.17 | 198.96 | 687.32 | 543.88 |

Table 3.8 Emissions Inventory during Transportation from Factories to UBC, g/2 years

| | Old system | New system |
|---|---|---|
| **$CO_2$** | 7452588 | 4573437 |
| **CO** | 4726.8 | 2900.7 |
| **$NO_x$** | 40670.18 | 24958.11 |
| **$SO_x$** | 5882.24 | 3609.76 |
| **PM** | 558.03 | 342.44 |
| **VOC** | 886.28 | 543.88 |

### 3.3.3 Emission during filter usage

### 3.3.4 Emissions during disposal process

As for the usage period of filters, the pre-filter should be changed every three months, box filter can last one year, and the new filter is supposed to be useful for two years. All of them are not recyclable, therefore while disposing the used filters, emissions do exist.

In Vancouver, the Cache Greek landfill is located North Shore Transfer Station- 30 Riverside Drive, North Vancouver BC, 23.4 km away from UBC. Again, it is assumed that large diesel trucks are used as vehicles. The emissions are as follows:

Table 3.9 Emissions of three filters during disposal process, g/2 years

| | emission factors, g/km | emission, g | | |
|---|---|---|---|---|
| | | Pre-filter | box filter | new filter |
| **$CO_2$** | 1419 | 33204.6 | 33204.6 | 33204.6 |
| **CO** | 0.9 | 21.06 | 21.06 | 21.06 |
| **$NO_x$** | 7.74 | 181.20 | 181.20 | 181.20 |
| **$SO_x$** | 1.12 | 26.21 | 26.21 | 26.21 |
| **PM** | 0.11 | 2.49 | 2.49 | 2.49 |
| **VOC** | 0.17 | 3.95 | 3.95 | 3.95 |

Table 3.10 Emissions Inventory of Transportation during disposal process, g/2 years

| | old system | new system |
|---|---|---|
| **$CO_2$** | 66409.2 | 33204.6 |
| **CO** | 42.12 | 21.06 |
| **$NO_x$** | 362.41 | 181.20 |
| **$SO_x$** | 52.42 | 26.21 |
| **PM** | 4.97 | 2.49 |
| **VOC** | 7.90 | 3.95 |

## 3.4 Comparison of the old filters and the new one

Based on the previous emissions we get, now we'll make a summation of the emissions from production and transportation for the old and new filter systems, respectively. The results are as follows:

Table 3.11 Summary of emissions of two systems

| | **emissions during production, g** | | **emissions during transportation, g** | | **total emissions, g** | |
|---|---|---|---|---|---|---|
| | old system | new system | old system | new system | old system | new system |
| **$CO_2$** | 36963.52 | 6085.04 | 7518997.2 | 4606641.6 | 7555960.7 | 8070398.4 |
| **CO** | 2220.16 | 270.88 | 4768.92 | 2921.76 | 6989.08 | 4109.36 |
| **$NO_x$** | 7430.11 | 871.26 | 41032.58 | 25139.31 | 48462.70 | 29947.89 |
| **$SO_x$** | 22284.30 | 2611.33 | 5934.66 | 3635.97 | 28218.96 | 13668.8 |
| **PM** | 2629.28 | 307.87 | 563.00 | 344.93 | 3192.28 | 1010.57 |
| **VOC** | 0 | 0 | 894.17 | 547.83 | 894.17 | 547.83 |

Figure 3.1 Emission comparison

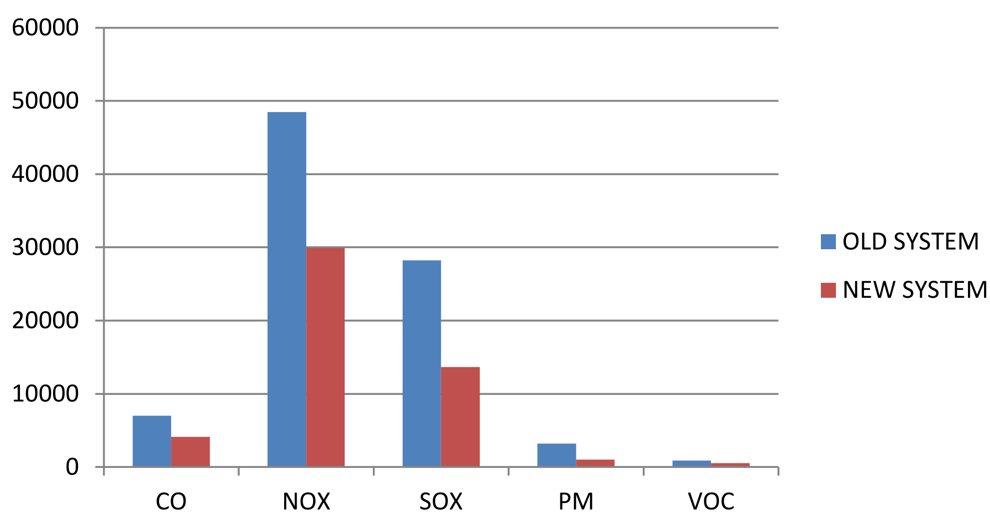


Table 3.12 Comparison of two systems in emissions

| Emission | Percentage of reduction, % |
|---|---|
| $CO_2$ | 38.95 |
| CO | 54.32 |
| $NO_x$ | 46.33 |
| $SO_x$ | 77.86 |
| PM | 79.55 |
| VOC | 38.73 |

## 3.5 Impact assessment

Once the emissions have been aggregated for the life cycle of filters, the environmental impacts can be determined. Table 3.13 contains the impact indexes used to evaluate the environmental and health impacts associated with whole life cycle of filters. Impact indexes were taken from IPCC 4th assessment report, 2007. GWP(Global Warming Potential), SFP(Smog Formation Potential), and ARP( Acid Rain Potential) are all measures of environmental impacts.

Table 3.13 Environmental Impact indexes

| Environmental Impact Index | | | |
|---|---|---|---|
| **emission** | GWP | ARP | SFP |
| **CO2** | 1 | 0 | 0 |
| **CO2** | 1.9 | 0 | 0 |
| **NOX** | 27 | 0.7 | 0 |
| **SOX** | 0 | 1 | 0 |
| **PM** | 0 | 0 | 0 |
| **VOC** | 0 | 0 | 1 |

Table 3.14 Environmental Impacts

| | Old system | New system | Reduction, % |
|---|---|---|---|
| **GWP, g CO2-eq** | 8877733 | 5321078 | 40.06 |
| **ARP, g SO2-eq** | 62142.85 | 24454.7 | 60.65 |
| **SFP, g ORG-eq** | 894.17 | 547.83 | 38.73 |

Based on the GWP, SFP, ARP, we can know that the new system will help greatly in the reduction of SFP and ARP, and the GWP remains almost the same (Table 3.14).

## 4.0 Conclusion

Switching from pre-filters to the new filter system reduce labor cost, waste disposal cost, and filter cost. The payback period is nearly one year so based on cost analysis; it seems that it is reasonable to change the old system to new one.

Moreover, according to the total emissions, compared to the old system in which pre-filter and box filter are used together, the new system(3M filter) only consisting of 3M filter can reduce the emissions of CO, $NO_x$, $SO_x$, PM and VOC significantly. The new system also reduces CO2 emission by 38.95%. The exchange of pre-filter and box filter with new filter will help to reduce the emissions to the ambient environment

Besides Cost analysis and Environmental Impact, there are other factors which should be investigated before filter selection. For instance, another major problem of previous filter system was that they occupy a huge storage place before transportation from UBC to disposal place. The old filters occupy 6 times of the storage space that 3M filters occupy. The filter performance is another factor which should be evaluated. Evaluation of 3M filter performance needs much more time.

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