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Review of stack emission and air dispersion modeling results during tire derived fuel use at the Lafarge, Brookfield Cement Plant, Nova Scotia, Canada

Report Submitted By
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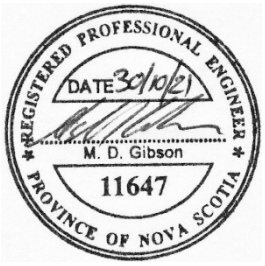

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Submitted To

Brookfield Community Liaison Committee

Brookfield Nova Scotia

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Introduction

This short report is a culmination of over fifteen years of research and consultation focusing on stack emissions while using tire derived fuel (TDF) as an alternative to fossil fuel at the Lafarge Brookfield cement plant. The previous work was conducted between 2006 to 2018 by my research group while I was an academic at Dalhousie University. The research included laboratory combustion emission experiments, theoretical modeling of emissions, visits to the cement plant, Provincial Government advisory group participation, community liaison committee participation, workshops, public open houses and presentations to the Municipality of Colchester and other stakeholders.

"The industry term for the use of scrap tires as a fuel source is "Tire Derived Fuel" or TDF and this description will be adopted in this report. TDF is an example of a class of lower carbon fuels that the cement industry is transitioning to as a result of the need to decarbonize."

This report will review the pilot project stack emissions and air dispersion modeling results during TDF use at the Lafarge, Brookfield Cement Plant, Nova Scotia, Canada.

In 2006 I joined Dalhousie University in Halifax, Nova Scotia as an academic, first as a research scientist, then in 2010 as an assistant professor of community health and epidemiology within the Faculty of Medicine, finally becoming an associate professor (full tenure) of environmental engineering within the Faculty of Engineering in 2016. During this time, I was awarded a Canadian Government NSERC Grant, and a few research grant and contributions from Lafarge, to conduct research into the use of TDF at the Brookfield cement plant. Part of the research included a comprehensive literature review of TDF use as an alternative fuel in cement kilns, including the health and environmental impacts of their emissions.[1]

From my groups theoretical predictions, we estimated a 71% reduction in fuel related sulphur dioxide (SO_2); 77% reduction in fuel derived oxides of nitrogen (NO_x) emissions; and a 3% reduction in carbon dioxide (CO_2) switching from 100% coal-coke to TDF.[1] Our predictions from 2015 showed no significant change in the total mass of gaseous products. Our second study theoretically calculated emission changes for a practical substitution rate of 30% TDF and 70% coal-coke. Fuel SO_2, CO_2, and fuel NO_x saw reductions of 21%, 1%, and 23% respectively.[1] We predicted that dioxin and furans formation was expected to be suppressed with the introduction of TDF, or at least remain the same as coal-coke.

[1] Gibson, Asamany, Wilson, Patrick, Pegg (2015) Use of scrap tires as an alternative fuel source at the Lafarge cement kiln, Brookfield, Nova Scotia, Canada. pp1-31. Final Report to Lafarge.

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Particulate matter emissions were expected to reduce with coal-coke being replaced by TDF. In blends of coal-coke with TDF, ignition performance is expected to improve compared to coal-coke only.[2]

Background to this Report

On October 10, 2018, Lafarge Canada Inc. were given an approval notice from the Government of Nova Scotia to conduct a pilot project to replace 20 tons/day, or 15% of the total daily fuel consumption, during the production of clinker at the Brookfield cement plant. The expiry date of the pilot project approval notice is January 10, 2022.

Conditions of the approval notice included the following:

1. The Approval Holder (Lafarge) shall ensure that emissions from the facility do not contribute to an exceedance of the maximum permissible ground level concentrations specified in Nova Scotia Environment's, Environment Act, Air Quality Regulations.

2. The Approval Holder must demonstrate compliance with air quality regulations through the development, implementation and maintenance of an air monitoring and reporting program. The air monitoring and reporting program may include, but is not limited to:
    - Ambient air monitoring.
    - Continuous Emissions monitoring.
    - Source testing; and
    - Dispersion modeling.

Once pilot project was approved, Lafarge constructed a state-of-the-art scrap tire kiln injection system. The injection system was completed and became fully operational in September 2019. I visited the plant in September 2019 to see the first trials prior to becoming fully operational, and to attend a public open house at the plant held on the same day. I was satisfied that the TDF injection system was fit for purpose and could inject the tires into the kiln in a safe and controlled manner.

[2]Gibson, Asamany, Wilson, Patrick, Pegg (2015) Use of scrap tires as an alternative fuel source at the Lafarge cement kiln, Brookfield, Nova Scotia, Canada. pp1-31. Final Report to Lafarge.

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The approval notice required Lafarge to meet stringent maximum stack emission limits for particulate matter (TSP, PM_{10} and $PM_{2.5}$), hydrogen chloride, Metals Class I, Metals Class II, Metals Class III, polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Other air contaminants were also sampled directly from the stack and included phosphorous, sulphur, polycyclic aromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), halogenated species and other metals and metalloids.

In addition, the approval notice required Lafarge to install continuous emission monitoring (CEMS) analyzers to continuously monitor oxides of nitrogen (NO_x), sulphur dioxide (SO_2), oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO) and total hydrocarbons within the stack. The CEMS were in addition to the existing opacity measurement, which is an indirect measurement of particulate matter and efficiency of the electrostatic precipitator.

A 3rd party company (Air Testing Services Inc.) were retained by Lafarge to conduct the stack emissions sampling and conduct independent continuous emission monitoring for NO_x, SO_2, O_2, CO_2, CO, and total hydrocarbons (THC). John Chandler, of Environmental Management Consultants, was then retained by Lafarge to conduct statistical analysis of the stack emissions results. I then reviewed the results contained within John Chandler's report 'A comparison of emissions from the Lafarge Brookfield facility in Nova Scotia'. The results contained in John Chandler's report showed that the replacement of 15% coal-pet coke, either did not statistically significantly (95% confidence interval, α 0.05) increase emissions of the various air contaminant's, except for the 2020 naphthalene result[3]. However, even the naphthalene result was less than 1% of the emission limit. It was found that the SO_2 concentration during TDF usage was significantly lower when compared to both the 2017 and 2019 baseline fuel usage. The reduction in the SO_2 being due to there being less sulphur found within a scrap tire than coal and pet-coke. This was a result that was predicted by my research group while I was at Dalhousie University.

Interestingly, the NO_x measurements conducted by Air Testing Services Inc. during the 2019 TDF sampling showed no statistically significant difference to the 2017 and 2019 baseline sampling, this was surprising as my research group had predicted a reduction in NO_x after TDF usage.[4]

[3] Observed to be approximately three times the observed concentration seen during the 2017 and 2019 baseline sampling tests.

[4] Gibson, Asamany, Wilson, Patrick, Pegg (2015) Use of scrap tires as an alternative fuel source at the Lafarge cement kiln, Brookfield, Nova Scotia, Canada. pp1-31. Final Report to Lafarge.

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However, when scrutinizing the facilities new CEMS continuous monitoring results from before TDF usage (July 2018 – August 2019) and after (September 2019 – July 2021), a clear decline can be seen in NO_x which validates my former research groups prediction that NO_x would decline after TDF usage.

Both SO_2 and NO_x are important criteria air pollutants and seeing a significant reduction in their emissions is beneficial for the environment and public health. Other important emissions seen both during the 2019 and 2020 TDF tests were for dioxin and furans, not only seen to be lower than baseline, but approximately eight times lower than the NSE stack emission limit of 80 pg I-TEQ/Rm^3, and even found to be below the Environment and Climate Change Canada limit of quantification of 32 pg I-TEQ/Rm^3.[5,6] While the variability of the PCB results suggests that there might be limitations in the data, the lower 2020 TDF results compared to the 2019 baseline and the 2017 baseline suggest that for the 2020 series the use of TDF may have led to reduced emissions of all but the octa, nona and deca-PCBs. The 2020 TDF runs were seen to be lower for both benzo(a)pyrene (the most carcinogenic of the PAHs) and Indeno (1,2,3-cd)p, but there is a large statistical variability within the three measurements made for each so this conclusion is speculative. Apart from naphthalene, there does not appear to be a consistent trend in high/low concentrations of any of the PAHs. In addition, it was observed that the benzene, toluene, ethylbenzene and toluene concentrations decreased (but not statistically significantly) during the 2019 TDF sampling test.

Air Dispersion Modeling Results

Lafarge retained the services of a 3rd party company (GHD) to conduct air dispersion modeling. GHD used AERMOD[7] to conduct the air dispersion of contaminants from the Brookfield facility. The model used emission values obtained from the stack and estimates from 24 other emissions sources within the facility fence line, including fugitive dust from the parking lot and haulage roads. The conclusion from GHD's report reads "The dispersion modelling assessment of Lafarge Brookfield, based on the information provided in Air Testing Service's source test report and predicted AERMOD air concentrations, indicates that the Brookfield Cement Plant

[5] I-TEQ – International Toxic Equivalents to 2,3,7,8 tetrachlorodibenzodioxin (TCDD)
[6] Reference cubic meter (i.e. the volume of dry gas at 25 degrees celsius (°C) and 101.3 kilopascals (kpa) corrected to 11% oxygen).
[7] Mark D. Gibson, Soumita Kundu, Mysore Satish (2013) Dispersion model evaluation of $PM_{2.5}$, NO_x and SO_2 from point and major line sources in Nova Scotia, Canada using AERMOD Gaussian plume air dispersion model. Atmospheric Pollution Research, 4,2, pp157-167.

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is in compliance with published NSE and Ontario Ministry of Environment Conservation and Parks (OMECP) air standards and guideline values". Indeed, most of the air contaminants were found to be <2% of both the NSE point of impingement limit (POI) and the OMECP limits, with only fine particulate matter ($PM_{2.5}$) rising to approximately 44% of the NSE POI limit.

Conclusion

After reviewing the stack testing emissions results and air dispersion modeling results, replacing 15% of the coal and pet-coke fuel with TDF fuel shows that either the emissions have:

- no statistical difference on contaminant emissions, apart from naphthalene, which is a suspected anomaly.
- the emissions remain approximately the same, or
- the emissions are significantly lower, especially for NO_x, SO_2, dioxins and furans, Metals Class I, Class II and Class III.

Based on these results, I can recommend that the Lafarge, Brookfield, cement plant be permitted to continue using TDF to displace 30% fossil fuel.

Recommendations

The naphthalene result is suspected as being an anomaly, and I recommend that a further sample of this metric is conducted to make sure this was indeed an erroneous result.

Disclosure

The research funds from Lafarge while at Dalhousie University were used to hire staff, pay for student stipends, and cover the cost of laboratory equipment and consumable costs. I did not benefit financially from the research funding from Lafarge during this time. In 2019 I left Dalhousie University to become a consultant with AirPhoton in Baltimore, Maryland, USA. Because of my long history of conducting research at the Brookfield plant, I was awarded a consultancy contract to continue my role as an independent expert to review the emission and air dispersion model results from the pilot TDF project.

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