Schoolyard Heat Islands: A Case Study in Waterloo, Ontario

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ABSTRACT

Schoolyards are hot places – they are urban heat islands, often covered by the three hottest materials found in the urban environment: asphalt pavement, steel or tar and chip roofs, and mowed turf. A study conducted at the University of Waterloo used satellite imagery to quantify the schoolyard heat island effect upon schoolyard users, building operation, neighbours, and the overall temperature of the city. The results provide justification for changes to the way schoolyards are designed. The need for policies to protect trees on schoolyards is discussed.

INTRODUCTION

Recognizing the problem

Schoolyards are hot places. Any teacher who has ever had yard duty knows just how hot schoolyards can be. As a parent, I first experienced this heat one beautiful day in May when I was out with my Grade One son for recess on his schoolyard. I had expected to see happy children playing Tag, Tick, Red Light Green Light, and other schoolyard games. Instead, I saw heat waves rising from the ground, dust devils spinning past, and children standing in a line with their backs pressed against the wall of the school building, trying to stay out of the sun by using the 45 cm strip of shade cast by the eaves of the building.

As an occupational therapist, I knew how important play is for the physical and intellectual growth and well being of children. I knew that something was wrong. I knew that something was missing because the children were definitely not playing that day. My first thought was: shade. There was no shade but perhaps some of the parents could work together, raise a bit of money, and plant a few trees – perhaps six.

The initial solution

Ten years later, the students, teachers, parents, and community volunteers of Mary Johnston Public School had planted more than 1500 trees and shrubs on the schoolyard. I had learned that money is available to create natural habitats on schoolyards and that people will come to help plant. I had seen, learned, and promoted the benefits of habitat creation on schoolyards. However, I had also learned that there were new problems to be dealt with if the newly created urban forest was to survive.

The long term threat

In the Waterloo Region District School Board, as in almost all school boards in Canada (Collyer, 2000), policies for schoolyard habitat creation are missing. There are no policies to include significant tree planting in the design of schoolyards. There are no policies to maintain and preserve trees once planted. While municipal trees are protected against removal, school board trees are not. As one teacher and long time tree planter said wearily at a Canadian Wildlife Federation workshop, "no matter what you do, in the end they always turn it back into grass" (Participants, 1998).

A long term solution

At about the same time that I became aware of this lack of school board schoolyard tree policy, I saw an opportunity to use my engineering background to quantify the need for and benefit of schoolyard trees.

The University of Waterloo and the Walter Bean Foundation were offering a course by a visiting scientist, Dr. J. Luvall of NASA. The mechanical engineering course would teach its students how to use satellite imagery to identify heat islands and how to mitigate heat island impacts. This paper describes the application of the techniques to schoolyards in Waterloo (Moogk-Soulis *et al.,* 2000).

HEAT ISLAND RESEARCH: A CASE STUDY

Background

Schoolyards are hot, very simply, because that is the way that they are commonly designed today. Schoolyards contain the three hottest materials found in the urban environment: asphalt, metal or tar and chip roofs, and mowed turf. When these materials are combined with the extreme temperatures and drought conditions experienced in Waterloo in the past several years, the result is burned turf, heat waves shimmering on surfaces, dust devils spinning across the schoolyard, and very little play by the children.

The case study was undertaken to determine three things: how hot schoolyards are; what impact that heat has upon the schoolyard users, building cooling costs, neighbouring properties, and the overall temperature of the city; and what mitigation strategies would be effective.

How hot are schoolyards

To answer this question, the temperature fabric of Waterloo was defined and selected schoolyards were examined.

A Landsat 7 satellite image (Lillesand and Keifer, 2000), acquired at approximately 10:20 am local time September 3, 1999 covering the City of Waterloo, Ontario, was used. This is the first Landsat satellite with reliable procedures for calibration of the thermal band, which made it possible to calculate the surface temperatures for the scene.

Fifteen schools in Waterloo were used in the study. They included junior, senior, composite, and high schools from both the public and Catholic school boards.

Using the satellite image, the temperature fabric of Waterloo was defined. The low-density urban land class that contained the sampled schools had an average temperature of about 47º C.

The schoolyards were identified using a map to find major landmarks such as major roads, parks, and water features. At first, there was some concern that it would be impossible to locate the small schoolyards from a height of 705 kilometres. However, there was no difficulty because, due to their heat, the schoolyards stood out like beacons from the surrounding areas.

Polygons were created for each school enclosing the building, the parking area, and the schoolyard. The average surface temperature was calculated for each of the polygons (Table 1). The schoolyards ranged in temperature from 48.4º C to 55º C. The average surface temperature was 52º C. This was 5º C hotter than the average of the surrounding land class.

Table 1. Average temperatures of the 15 schoolyards examined in this study.

Reference	School name	Average temperature ºC
1	Mary Johnston	52.8
2	Centennial	48.4
3	Keatsway	51.2
4	Holy Rosary	55.0
5	Westvale	50.5
6	Laurelwood	52.1
7	Northlake Woods	53.1
8	WCI	53.4
9	Northdale	53.0
10	McGregor	50.3
11	Brighton	51.5
12	Bluevale	52.0
13	Harold Wagner	52.3
14	Sandowne	52.8
15	Cedarbrae	51.0

What are the consequences of the schoolyard heat?

The consequences of the heat were considered for schoolyard users, building cooling costs, neighbouring properties, and the city as a whole. Mary Johnston Public School, the site of the habitat creation project, was used for ground truthing, specific examples of heat island problems, and testing of mitigation strategies.

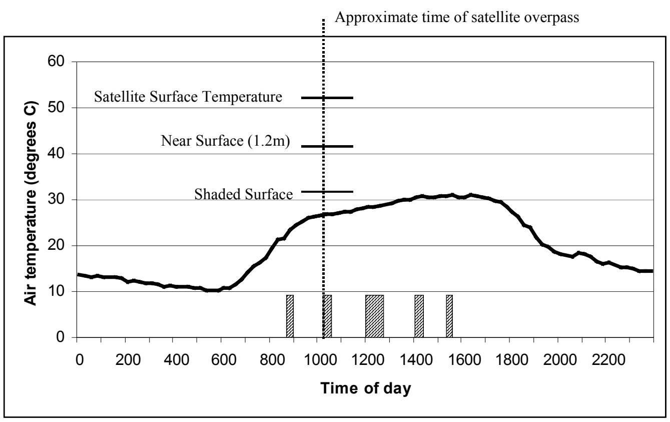

Figure 1. Air and surface temperatures at Mary Johnston Public School during the satellite overpass.

The consequences of the heat for the schoolyard users are shown in Figure 1. When air temperature was just under 27º C, the unshaded surface temperature was 52.8º C and 20º C hotter than that of the shaded surface. These temperature differences are consistent with those found in other studies (Oke, 1987;

Akbari, 1993). At these temperatures it was no wonder that the children did not feel like running around to play.

Furthermore, temperature declines as one moves upwards from the surface (Oke,1987). This means that the shortest people have that part of their bodies most vulnerable to adverse consequences from excess heat, the brain, closest to the highest temperatures. This finding explained for me why children at an outdoor summer event on a hot day often preferred to be in an adult's arms rather than in a stroller or standing on the ground. It is 10º C to 15º C cooler at the level of the adult head than at the head level of a preschooler.

Overheated schoolyards increase the cost of cooling the buildings on the schoolyards. Heat is conducted through roofs and walls, and hot air infiltrates through cracks. In addition, 40% of the cost of cooling a building is due to the cost of cooling air that is brought into the building for ventilation.

Figure 2. Temperature profile with Mary Johnston Public School at centre

The consequences of schoolyard heat upon neighbouring properties are shown in Figure 2 and Figure 3. Heat, like noise, does not respect property boundaries. The hot schoolyard exports heat pollution to its neighbours. The greatest effect is in the first 80 metres but the effect is still evident in Figure 3 at 150 metres.

These neighbouring properties would be more uncomfortable for their users. One school neighbour had been unable to sit out in her backyard on a hot sunny day when the schoolyard was completely unshaded. The cost of cooling neighbouring buildings would be elevated as well.

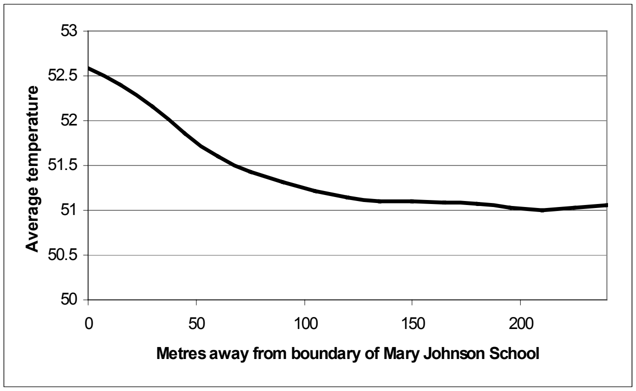

Figure 3. Average temperature of consecutively larger polygons surrounding Mary Johnston Pubic School

The impact of hot schoolyards on the City as a whole is to raise the average temperature of the City.

What can be done about schoolyard heat

The two most effective mitigation strategies are one, to replace low albedo surfaces or two, to use trees to shade surfaces, cool the air through evapotranspiration, or act as windbreaks to decrease the infiltration of hot air into buildings. The feasibility of each was examined.

Mary Johnston Public School has a number of low albedo surfaces. These are: metal roofing, asphalt parking lot and playing areas adjacent to or abutting the building, and mown playing fields. The roof is considered to have several decades of utility remaining before replacement would be considered. Concrete costs five times the cost of asphalt and it is not considered to stand up well to the local weather conditions. The playing fields are a necessary part of the school, neighbourhood, and city recreational resources. Therefore, it is not likely that these surfaces would be replaced, and surface albedo altering was discarded as a feasible mitigation strategy for this site.

Trees have three primary cooling mechanisms. Trees cool the air around them through evapotranspiration and by absorbing heat into their leaf mass. They act as a windbreak to decrease the rate of infiltration of hot air into buildings. They shade surfaces and cut the clear sky radiation by up to one half, decreasing surface temperature by as much as 25º C (Akbari, 1993). Trees were the mitigation strategy chosen for the Mary Johnston Public School site. The results are shown in Table 2.

Table 2. Benefits of trees on schoolyards in Waterloo

Area	Benefits
Schoolyard	· Decrease shaded surface temperature ~ up to 25º C · Decrease shaded air temperature ~ 10º C
Plant Operation	· Decrease cooling costs by 25% for that proportion of the building surface shaded by trees · Decrease cooling costs due to cooling of intake air (typically 40% of cost) by as much as 10ºC
Neighbourhood	· Decrease radiant and convective heat gains to properties within ~ 80 m
City	· Contribute to overall City cooling (0.15º C)

CONCLUSION

Schoolyards are hot. Often they are too hot for children to play on them. Trees or money to purchase trees are available from private and public sources such as foundations and ministries. People will help to plant trees on schoolyards, but policies must be put in place to protect these schoolyard trees.

Trees have measurable benefits. Trees will transform a hostile schoolyard environment into a pleasant one where children can play. Trees shade walls and roofs to decrease building operating costs. If we cool hot schoolyards we will make neighbouring properties cooler and cool the surrounding city. Schoolyard design criteria should include the use of trees to shade play surfaces and the building. Finally, if we can develop policies so that all urban forests, including those on schoolyards, are protected we will have benefits and a legacy for generations to come.

REFERENCES

1. Akbari, H., Kurn, D.M., Taha, H., Bretz, S.E. Bretz, Hanford, J.W. 1993. Peak Power and Cooling Energy Savings of Shade Trees. *ME772 Course Notes.* University of Waterloo, 2000.
2. Collyer, C. 2000. Personal communication, Executive Director, The Evergreen Foundation, Toronto.
3. Lillesand, T.M. & Kiefer, R.W. 2000. *Remote Sensing and Image Interpretation, 4th Edition*. New York: John Wiley & Sons, Inc.
4. Moogk-Soulis, C., Seglenieks, F., Lessard, J., Divinyi, S. 2000. *Analysing and Mitigating Schoolyard Heat Islands in the City of Waterloo*, Department of Mechanical Engineering, University of Waterloo.
5. Oke, T.R. 1987. *Boundary Layer Climates*. Cambridge: University Press.
6. Participants, 1998. Personal communication at the Canadian Wildlife Federation Schoolyard and Community Habitat Workshop, Leslie Frost Centre.