Environment Monitoring Using Commercial Off-the-Shelf (COTS) Technologies

Vikas Nath, Artash Nath

Environment Monitoring using Commercial Off-the-Shelf (COTS) Technologies

A Case Study of the Odd-Even Rule for Pollution Control in Delhi

Vikas Nath and Artash Nath

HotPopRobot.com, Toronto, Canada
vikas.nath@gmail.com

Abstract. 195 countries gathered in Paris in 2015 to conclude the legally binding climate agreement to reduce their greenhouse gas emissions. Continuous environment monitoring is a prerequisite for designing policies which can reduce global climate emissions. Only a handful of countries have the capabilities to carry out advanced climate measurements. Commercial Off-the-Shelf (COTS) Technologies can lower the technological and financial barriers for developing countries to monitor climate emissions. The authors made use of environmental COTS technologies along with information and communication technologies (ICT) to assess the impact of pollution control initiatives rolled out by the Delhi government on experimental basis.

Keywords: Climate Change, Commercial Off-the-Shelf (COTS) Technologies, Delhi, Environmental Monitoring and Policies, Information and Communication technologies (ICT) Odd-Even Rule, Particulate Matter, Pollution, Sensors

1 Introduction

The historic climate agreement concluded in Paris in December 2015 commits all nations to reduce their greenhouse gas emissions. 195 countries adopted the legally binding global climate deal. Developed nations will provide US $100 billion financing every year from 2020 to fight climate change while all countries will be required to submit to external monitoring of their progress in reducing climate emissions [1]. The global "stocktaking" will happen every five years, starting in 2023, where countries will be assessed for their performance in cutting emissions compared to their national plans. Significantly, developed and developing countries will monitor, verify and report their greenhouse gas emissions using the same global system. A "Capacity-Building

Initiative for Transparency" has been set up to enable developing countries to meet the enhanced data and tracking progress requirements.

Continuous monitoring of emissions is the first step to meeting the goal of keeping increase in the global average temperature to well below 2°C above pre-industrial levels. It yields scientific data and evidence to assess the effectiveness of existing climate action plans and policies, and in designing newer ones. It compels countries to walk their talk on climate change; share their action plans on mitigating climate change, be transparent in their implementation mechanism, and compare outcomes and performances with other countries.

The climate deal opens up enormous opportunities to use Commercial Off-The-Shelf (COTS) products and technologies to set up robust mechanisms for monitoring greenhouse emissions and feed the results in policymaking process.

2 Commercial Off-the-Shelf (COTS) Technologies

Commercial off-the-shelf products and technologies are standard manufactured rather than custom-made. These are readily available, open to sale to the general public and are less expensive than their custom made counterparts. They have high levels of dependability as they have been tested on a large scale. Support, documentation and compatible technologies are readily available. COTS products and technologies cut down the costs and complexities of creating prototypes and bringing new products into the market. Semiconductor based electronics such as integrated chips and micro-controllers are examples of COTS products that can be purchased cheaply, and are able to withstand temperatures ranging from -40 centigrade to +85 centigrade allowing their operations in industrial environment.

With the growing use of COTS products, designers are engineering them to be more rugged and be able to operate in extreme environments. For instance, the National Aeronautics and Space Administration (NASA) backed PhoneSat project converted an Android phone into a small satellite for low-cost earth observation bringing down the total hardware cost to $3,500. It showcases how off-the-shelf; commercially available technology can be used for advanced applications.

3 Environmental COTS

Our planet is being continuously monitored for environmental changes. These include measuring rise in sea-levels, change in ocean temperature, shrinking of polar ice caps, concentration of greenhouse gases in the upper atmosphere, changes in ozone levels and increasing rates of deforestation. Such monitoring is expensive and require technological and financial capabilities which are beyond most countries.

Only a handful of countries have the capabilities to deploy weather and meteorological satellites to undertake remote sensing and climate monitoring. Even for gathering ground-based data, developing countries lack the know-how and financial resources to set up multiple environmental monitoring stations. For instance, Delhi - the populous and sprawling capital of India has only 10 stations to monitor pollution data which gives an incomplete picture of the air quality index. Outside Delhi, the data is even scarce.

Access to environmental COTS such as sensors for measuring concentrations of carbon dioxide, nitrogen dioxide, methane, ozone and particulate matters in the atmosphere will improve and democratize environmental data collection. Anyone can purchase a set of sensors, hook them to a microcontroller or even a mobile phone, and upload readily available program to start gathering local environmental data and share the date online. It will be possible to set up a mesh of sensors using COTS technologies such as WI-Fi, ZigBee, Bluetooth and Radio Frequency to aggregate and triangulate the data being gathered. Low cost of new COTS products such as drones and quad copters makes it possible to attach sensors on them and fly them over highways, coastal areas, lakes and forested areas to get detailed environmental data. Access to this 24/7 and on-demand data can trace the source and type of emissions, reduce their volume, check economic losses, and improve public health.

4 Pollution in Delhi

The world is rapidly urbanizing. More than half of the world's population currently lives in cities, and by 2050 over two-thirds will do so. While cities generate 80 percent of global GDP and are hive of employment, innovation, creativity, and commerce, they also emit almost 71–76 percent of energy related carbon dioxide emissions, and account for 37–49 percent of global greenhouse gas emissions [2].

Delhi is no different. With a population of over 20 million – the traffic volume is high, the traffic speed low and vehicles idle for a long time at traffic lights. Delhi air is heavily polluted from smoke, dust and exhaust of motor vehicles. As it is a landlocked city surrounded by industrial and agricultural zones, there is very little capacity in the atmosphere to clear itself of the pollutants. It is mainly dependent on rainfall to bring a sudden drop in particulate matter concentration.

Delhi pollution effects everyone – young and old, rich and poor, political class and common people. It is not uncommon for major newspapers and media channels to regularly carry briefings on pollution, the particulate matter count in the air, and its effect on the health of people. It does not help that India still follows Bharat Stage-III equivalent of Euro-III specifications which are 14 years behind the vehicular emission norms followed in Europe.

5 Odd-Even Experiment in Delhi: Using COTS for Measuring Pollution

On 1 January 2016, the Delhi Government embarked on a two-week Odd-Even experiment to bring down pollution levels. It meant that on "even numbered dates", cars with even numbered registration plates would run while on "odd numbered dates", cars with odd numbered registration plates would run. Similar experiments have been tried out in other cities in the world, including in Mexico, Paris and most noticeably in Beijing where the odd-even formula was imposed ahead of the 2008 Olympics with convincing results. In Delhi, there were several exemptions from the rule, namely two wheelers, public vehicles, cars powered by compressed natural gas (CNG), and cars driven by women could be on the roads at any time.

As we are "makers" and love building things, we planned an experiment while the Odd-Even rule was in effect in Delhi. The objective of our experiment was threefold. First, measure the decrease in pollution levels while Odd-Even rule was in effect. Second, determine how pollution levels vary at different times of the day. Third, come up with findings to reduce the effect of pollution on our health.

We built a "Pollution Sensor" using COTS, namely an Arduino - a low-cost, off-the shelf micro controller, and an Optical Dust Sensor (Shinyei PPD42NS) which is mass produced for measuring pollutants in the air. The Sensor uses infrared scattering to measure particulate matter concentration in the range of 2.5 microns - particles of this size have the greatest effect on human health. We wrote a program to get raw data from the sensor and convert it into particular matter readings (particles per 0.01 cubic feet). The program was uploaded to Arduino. The Arduino instructed the Optical Dust Sensor to take readings every 20 seconds and send it to our laptop. Later we added another low-cost COTS – a temperature and moisture sensor to our "Pollution Sensor" to take more detailed measurements. The data was imported into Excel to make graphs and draw conclusions.

Our experiment ran from 29 December 2015 to 7 January 2016. We took our pollution sensor to different places in Delhi including Paschim Vihar, Punjabi Bagh, Janakpuri, Red Fort, Raj Ghat, Kasmeri Gate, Delhi Domestic Airport, Dhaula Kuan, Safdarjung Enclave and Narela. These venues were in West, East, North, Sound and Central parts of Delhi to get fair representation of pollution levels in the city. The sensor was also taken outside of Delhi to Panipat (Haryana state) and Mumbai (Maharashtra state) to get comparative data for analysis. We even took the sensor high up in the air (in Spice Jet and Indigo airlines) to get cleaner air data for calibration. Observations taken ranged from 30 minutes to 30 hours continuously.

6 Observations from our Experiment

The particulate matter concentration in Delhi ranged from a thousand particles per 0.01 cubic feet in quiet residential areas to 40,000 particles per 0.01 cubic feet in busy intersections (near Punjabi Bagh and Dhaula Kuan). Fig. 1 shows the average count to be 25,000 particles per 0.01 cubic feet in the busy Chandni Chowk area and never went below the 10,000 mark. In comparison, Fig. 2 shows that the concentration was less than 1000 particles per 0.01 cubic feet in the airline cabin of Spice Jet airlines from Delhi to Mumbai at the cruising height.

Fig. 3 shows that particulate matter count was lowest during late morning and afternoon and climbed up rapidly in the evening. Particulate matter concentration was higher at the intersections and where traffic movement was slow. Even though Mumbai has lesser number of vehicles compared to Delhi, the pollution levels were higher (up to

45,000 particles per 0.01 cubic feet) at some of the intersections (on the way from Chakala to the domestic airport) because of slower moving traffic and greater number of diesel vehicles.

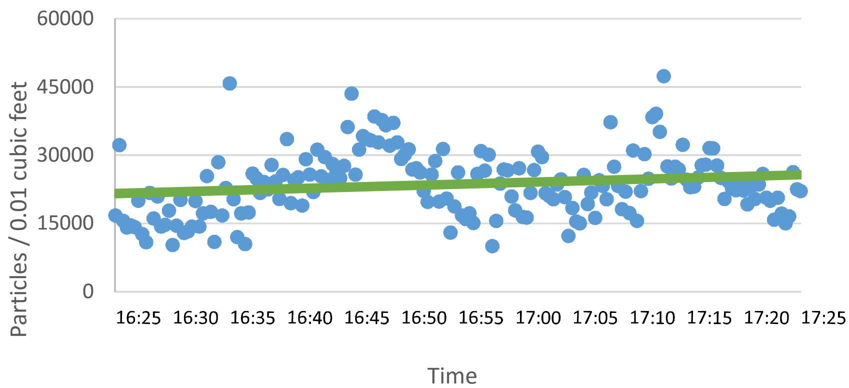

Fig. 1. One-hour Pollution Level Count at Chandni Chowk. Delhi. India (5 January 2016)

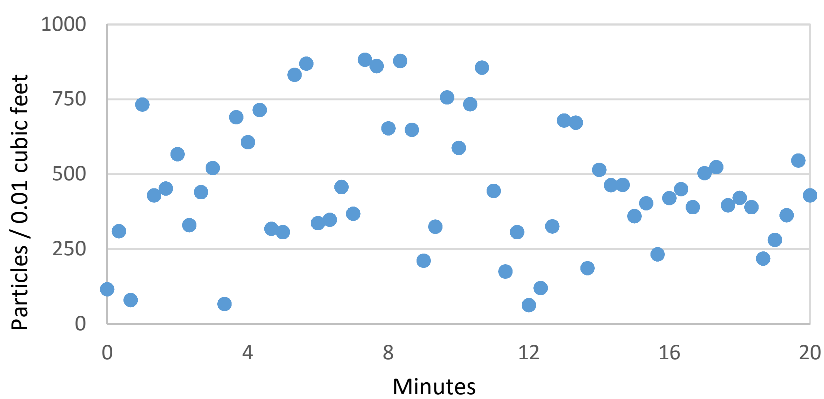

Fig. 2. Pollution Count in Spice Jet Airlines from Delhi to Mumbai, India (9 January 2016)

We did not observe any significant difference in pollution levels when the Odd-Even rule was in effect. In part because variables such as temperature, moisture, sunlight and wind speed change rapidly and measuring their collective impact on pollution level was beyond the scope of the experiment. We found that the particulate matter concentration

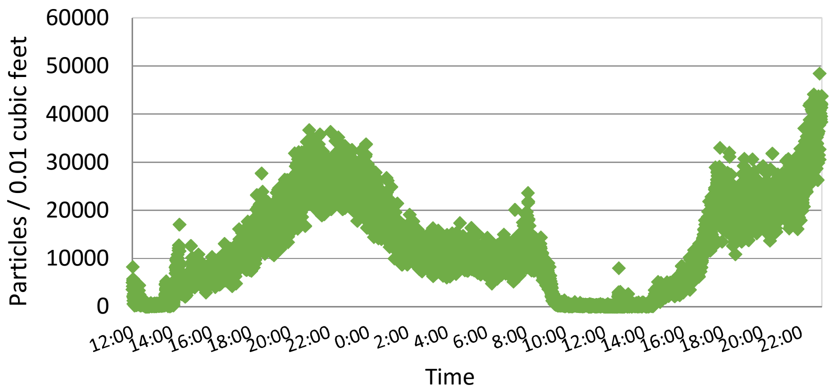

Fig. 3. Pollution Levels Peak during Evenings and Drop in the Afternoon (36-hour observation from 31 December 2015 - 1 January 2016)

decreases when temperature increases and increases when the moisture level in the air rises as shown in Fig. 4 and Fig. 5 respectively. This explains why pollution count is low in late mornings when the sun is out and the moisture levels are lower.

Interestingly while our Sensor measured data in particles per 0.01 cubic feet the data collected by the Government through the System of Air Quality and Weather Forecasting and Research stations (SAFAR) collected data was in micrograms per cubic meter. Nevertheless, the trend in pollution levels (of 2.5 micron particles) aligned with each other in most instances.

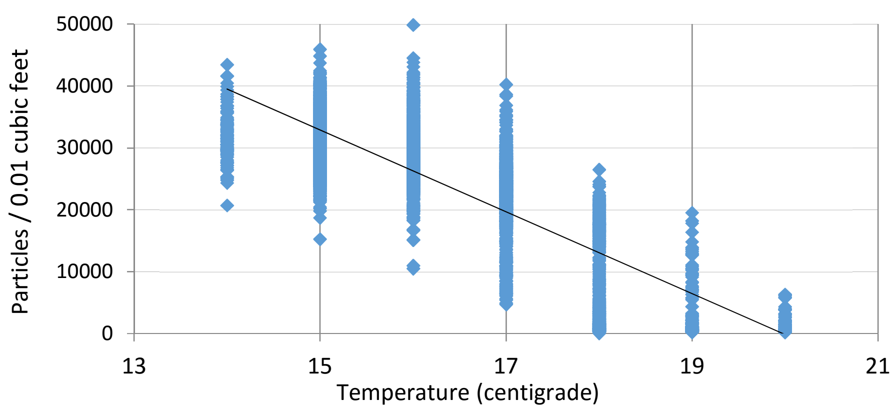

Fig. 4. Pollution Levels Decrease with Temperature (26-hour observation from 11 am, 6 Jan to 1 pm, 7 Jan 2016)

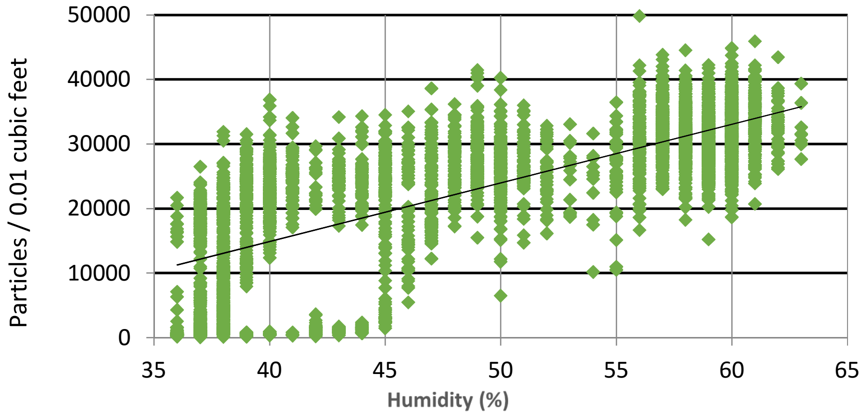

Fig. 5. Pollution Levels Increase with Humidity (26-hour observation from 11 am, 6 Jan to 1 pm, 7 Jan 2016)

7 Findings from our Experiment

First, face masks are effective. Wear your face mask when the pollution count is likely to be high. Even the cheapest face mask in the Delhi costing Rs. 10 (USD 0.15) cuts down particulate matter concentration by more than half as shown in Fig. 6.

Second, the best time to step outside the home is in late morning when the sun is out and temperature is higher and humidity is low. It is advisable to come back by evening. The worst time to go out is late in the evening when pollution levels starts to rise due to lower temperature and higher humidity.

Third, pollution count changes with local factors. The bursting of fire crackers at the midnight of 31 December 2015 to celebrate the New Year increased the pollution count significantly. The pollution count was found to be lower in areas where trees and bushes are planted. Local actions to curb pollution matters and everyone should do their part.

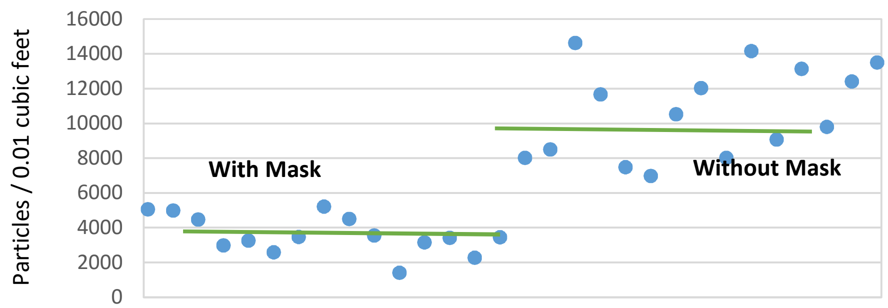

Fig. 6. The Mask Effect: Face mask cuts pollution intake by half

8 Suggestions

Odd-Even rule in Delhi brought awareness on the need to act to curb pollution. Health and lives of people are at stake. There should be follow-ups and piloting of other projects and strategies to make Delhi air cleaner.

Based on our experiment, we have three suggestions to bring down pollution levels in Delhi and elsewhere. First, there should be more COTS based pollution sensors fielded by NGOs and citizen scientists to gather detailed local data on emissions. This will allow us to identify the major sources of pollution and validate air quality data provided by the government. Second, growing hardy shrubs and bushes on road dividers and trees on the road sides can cut down exposure to particulate matters. Third, free the pavements from commercial encroachments and create cycling paths to promote walking and cycling as an emissions free mode of transport.

9 COTS and Environmental Sector Start-ups

As climate change affects everyone, it opens up huge markets for products, technologies and services which can reduce the impact of climate change and allow people to lead better quality of lives.

From farming to clean water, and from food supply chains to energy access, the start-up sector is growing - boosted by the interest and financing from angel investors and venture capitalists. Disposable pollution masks vending machines, wearables that repel pollutants, collar sensors that warn people when entering high pollution zones, and mobile air purifiers are COTS based products that are already in the market. Innovative products and services are also being developed through hackathons, in incubation zones, maker spaces, and in garages and basements of young entrepreneurs. The spread of environment maker fairs and the rise of sharing economies can only catalyze the adoption and scaling up of COTS for addressing climate change.

References:

1. United Nations (UN), Framework Convention on Climate Change, Conference of the Parties, Twenty-first session, Adoption of the Paris Agreement (2015)
2. Intergovernmental Panel on Climate Change (IPCC), Climate Change 2014: Synthesis Report, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014)