Spring 2017

Concentration Levels of PM2.S and PM 10 Paper Dust in a Book Production Facility

Blake J. Cvengros
Western Kentucky University, cvengrosb@gmail.com

CONCENTRATION LEVELS OF $PM_{2.5}$ AND PM_{10} PAPER DUST PARTICLES IN A BOOK PRODUCTION FACILITY

A Thesis
Presented to
The Faculty of the Department of Architectural and Manufacturing Sciences
Western Kentucky University
Bowling Green, KY

In Partial Fulfillment
Of the Requirements for the Degree
Master of Science

By
Blake Cvengros

May 2017

CONCENTRATION LEVELS OF PM_{10} AND $PM_{2.5}$ PAPER DUST IN A BOOK PRODUCTION FACILITY

Date Recommended 4-17-17

Byan Reaka

Dr. Bryan Reaka

Shahnaz Aly

Dr. Mark Doggett

Dean, Graduate School 4/18/17

Date

I dedicate this thesis to my beautiful and loving wife, Emily, who was unbelievably supportive and patient throughout this process. I also dedicate this work to my parents and siblings, Marcia, Brad, Ashley and Banning, who have always trusted and supported all of my endeavors. Finally, I would like to dedicate this work to my thesis committee members, Dr. Bryan Reaka, Shahnaz Aly, Dr. Mark Doggett, and all of the faculty and staff in the AMS department of WKU. This group opened my eyes to a new way of thinking and they have been supportive, understanding and exceedingly obliging ever since, especially throughout the thesis process.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CONCENTRATION LEVELS OF $PM_{2.5}$ AND PM_{10} PAPER DUST PARTICLES IN A BOOK PRODUCTION FACILITY

Blake Cvengros May 2017 74 Pages

Directed by: Dr. Bryan Reaka, Shahnaz Aly, and Dr. Mark Doggett

Department of Architectural & Manufacturing Sciences Western Kentucky University

Concentration levels of $PM_{2.5}$ and PM_{10} paper dust were measured in a book production facility using a quantitative single subject study. Dust concentration data was collected in three processes of a book manufacturing facility; paper recycling, the digital pressroom and the digital bindery. Data was collected using the DustTrak DRX 8533 Aerosol Monitor, focusing on particulate sizes of $PM_{2.5}$ and PM_{10}. The data was used to determine if paper dust in the book production industry reached concentration levels that could have negative respiratory health effects on surrounding employees and to determine which process within the studied facility had the highest concentrations of paper dust. The study revealed that the paper recycling warehouse had the highest concentrations of paper dust. It was also determined that the paper recycling warehouse could cause negative respiratory health effects on surrounding employees. Further research is needed to determine the extent of those effects and potential remediation.

Introduction

Background

Dust particles are constantly released into the air in natural ways and as a result of human interaction with the world. Naturally occurring particulate release can result from volcanoes, forest fires, evaporation, pollination, hydrocarbon release from forests and many other ways (Sittig, 1977). Dust as a result of human activity has been most widespread since the Industrial Revolution, when manufacturing and manipulation of materials became more widespread. Processes within many industries cause a release of dust into the air. This release of dust can be the result of mechanical breakdown of material, such as grinding, drilling and cutting or the dispersion from transportation and handling of materials by way of impaction and friction (Bickis, 1998). In these instances, the dust created by the process has the same makeup as the original material that has been broken down.

Dust particles with diameters of less than 10 microns (µm) are of a more serious concern to respiratory health, primarily because of their ability to pass deeper into the respiratory tract (Buekens, 2009). Dust within this size range are considered inhalable and often identified as Particulate Matter, $PM_{2.5}$ and PM_{10}, with particle sizes of 2.5 µm and 10 µm, respectively. EPA (2016) provides an image to help better understand the size of a micron; Figure 1. These particles are of concern in certain concentrations, often measured by milligram per cubic meter (mg/m^3). A number of sources have documented varying ranges of respiratory complication severity related to different concentration levels, generally noting that higher concentrations of dust increase the likelihood of respirable health problems. Dahlqvist (1992) elaborated on lung function with employees in bookbinders, but gives limited information regarding the size of particles involved. While not as aggressive as many other industries, heavy exposure to paper dust is reported to cause deterioration of lung function and other symptoms. According to Holm, Dahlman-Hoglund, & Toren (2011) the exposure of employees to small concentrations of paper dust (1 mg/m^3) is associated with an increased prevalence of nasal crusting and nose bleeds, while Hoffman, Toren, Sallsten and Hennenberger (2001) elaborates on similar studies that show a larger (greater than 1mg/m^3) concentration of paper dust can cause chronic bronchitis.

The composition, size and safe concentration levels of dust particles in many industries is widely known, studied and regulated because of their more immediate and severe impacts on the health of surrounding individuals. Paper dust size distribution and

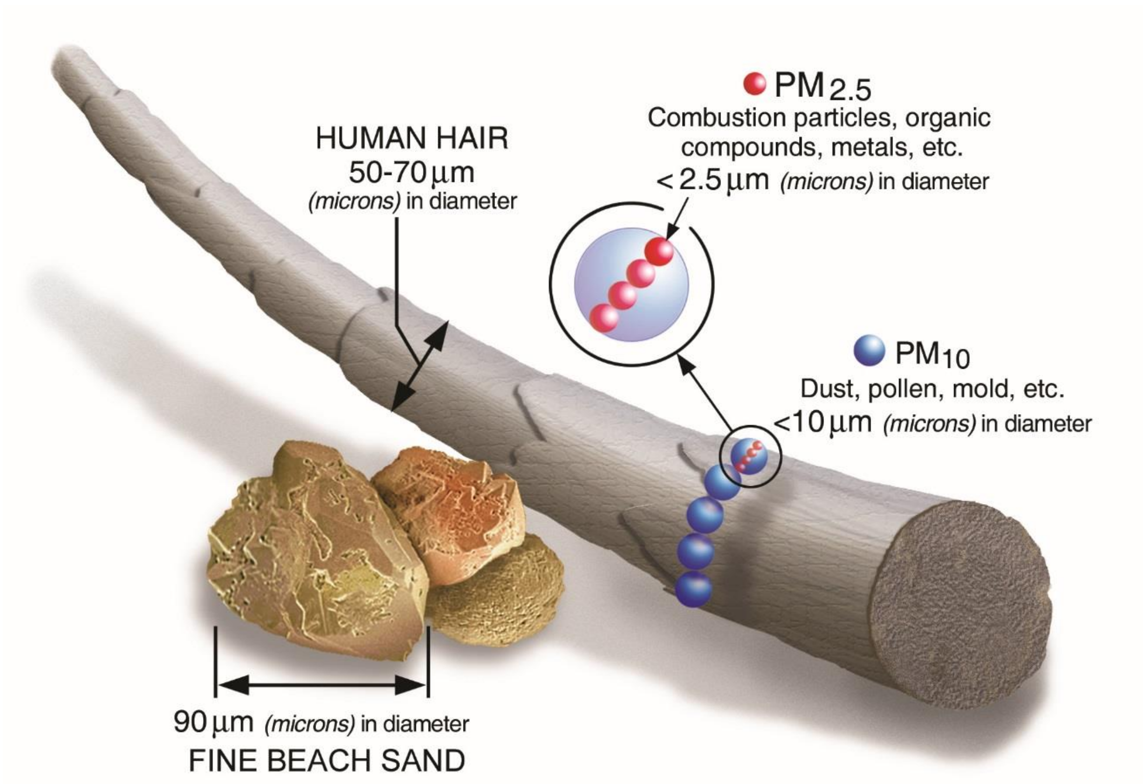

Figure 1. Size Comparisons of PM Particles (EPA, 2016).

concentration levels are not well documented for a book production facility. Recent technological advances have enabled digital print to gain ground as an economical choice for many printing needs (Cross, 2012). The book industry has adopted this method of digital printing that includes inkjet web printing equipment and quasi-traditional book binding equipment. This process enables the printer to offer a more flexible solution to what publishers are looking for. This solution includes on-demand printing with shorter production runs and improved manipulation of data. The printing of short run production in offset printing is inefficient and expensive because of the labor required to make equipment ready for each individual job. The offset production process requires digital imaging, but also requires production and installation of printing plates before the printing process can begin. Offset printing also requires a more cumbersome process to gather individual signatures (Bruno, 2000). Unlike digital print that creates complete book blocks at the end of the press, offset print provides stacks of like signatures that must be gathered in later processes. Additionally, waste of material before quality production is higher in offset printing. Digital inkjet printing allows printers to digitally prepare a job and print variable data without having to create mechanical impressions before each job change. This modern technology is relatively young and the understanding of how these new processes effect its employees is limited. Downstream equipment (book binders and recycling equipment) has not changed as much as the printers themselves, but still have undertaken major changes to process in order to react to shorter production runs.

Statement of Purpose

The purpose of this quantitative single subject research was to determine concentration levels of inhalable dust ($PM_{2.5}$ and PM_{10}) in suspected problematic areas of a book production facility (Creswell, 2009). This data was used to better understand the respiratory health implications of working in a book production facility. Additionally, the data collected provided the ability to see which of the studied processes has the greatest probability of high dust concentrations.

Significance of Research

While multiple texts discussed the health risks of dust in various industries (Sayer, 1922; Sittig, 1977; & Sakunkoo, Chaiear, Chaikittiporn, & Sadhra, 2011), few mention the book production industry as a source of these problems. Book production contains multiple processes that create dust, primarily bookbinding and paper recycling. Employees working around book production equipment in a print facility could be at risk of suffering adverse effects of high concentrations of inhalable paper dust, including $PM_{2.5}$ and PM_{10}. This research identified concentrations of inhalable sizes of paper dust in the facility and used this information to determine if further investigation is necessary to ensure the safety of employees in the book production industry.

Problem Statement

The book printing process contains equipment that slits, folds, grinds, trims, cuts, shreds, compacts and bales excess paper. Throughout this process paper dust is created. Respiratory health issues are known to be associated with high concentrations of dust found in other paper based industries (Holm et al., 2011 and Hoffman et al., 2001). New equipment and processes in the book production industry have not been the focus of paper dust studies. There is a need for a better understanding of the size distribution and concentration levels of inhalable paper dust surrounding book production equipment.

Research Questions

1. Does inhalable paper dust in a book production facility reach concentrations that could have negative respiratory health implications on surrounding employees?
2. Which of the studied processes is most susceptible to excessive paper dust; printing, binding or recycling.

Assumptions

1. Paper dust as it relates to respiratory health is important to employees and employers in the book production industry.
2. The facility has sufficient air quality controls (HVAC, dust collection, waste collection, etc.) that are comparable to other book production facilities.
3. The manufacturer of the equipment in the studied areas of the facility are comparable to different manufacturers of similar equipment.

Limitations

1. Only one facility located in United States was measured for data.
2. Only one manufacturer of each type of equipment was evaluated.

Delimitations

1. Temperature and humidity was not considered as part of this study.
2. Aerosol contaminants from inkjet operations besides paper dust was not considered as part of this study.
3. The chemical composition of the paper dust was not analyzed as part of this research.

Definition of Terms

1. Inhalable Dust – Dust containing particles with a size of 10 or less microns, including PM_{10} and $PM_{2.5}$ (Buekens, 2009)
2. Digital Printing – "Printing by plateless imaging systems that are imaged by digital data by prepress systems" (Bruno, 2000, p.211)
3. Signatures – "The name given to a printed sheet after it has been folded" (Bruno, 2000, p. 231)
4. Offset Printing – Printing process that transfers an inked image from a plate or blanket to a printing surface (Bruno, 2000).

Literature Review

Dust

Particulate matter is defined and quantified in many different ways and varies greatly in origin, size and concentration. According to Buekens (2009), some important characteristics of particulates include number and number size distribution, mass and mass size distribution, surface area and shape. Particle sizing is a primary factor in classifying particulate matter and dusts. Sizing determines where particles are deposited in the respiratory system and how they act after deposition (Sittig, 1977). Particle diameter is the determining factor for sizing particulate matter. For irregularly shaped particles, the equivalent particle diameter is used. Buekens (2009) defined equivalent particle diameter as "the diameter of a sphere having the same value of a physical property as the particle being measured" (p. 5). The diameter of these particles are measured in microns (µm).

Sittig (1977) is a technical resource of information pertaining to the removal of particulates and fine dust from industrial settings. The book's introduction defines particulates and describes the "deleterious aspects of particulate pollution" (Sittig, 1977, p. 3). The list of deleterious (causing harm or damage) aspects begins with health problems. Of which, the text breaks into three categories; respiratory, toxic reaction and eye or skin irritation. Sittig (1977) described the adverse effects of dust on human health as "related to injury to the surfaces of the respiratory system" (p. 4).

Particle size. Particles with primary concern with respiratory health problems are those with a diameter of less than 10µm. Buekens (2009) defined these particles as $PM_{10.}$ These particles are considered coarse particles that are still inhalable. PM_{10} particles are generally deposited in the nose and upper parts of the respiratory tract. Buekens (2009) also pointed out that there is growing concern with particulates much smaller in diameter; $PM_{2.5}$ and below. These particles are defined as respirable and will travel deeper into the respiratory tract. Esworthy (2015) also suggested growing concern by elaborating on the Environmental Protection Agency's 1997 introduction of regulation on particulate matter measuring less than 2.5µm in diameter and their more recent 2013 stricter updates to regulations. Sittig (1977) stated that these fine particles are able to deposit deep into the respiratory tract principally because of their size and not because of their chemical makeup.

Lewis & Strebel (2016) also defined particles with a median diameter of around 10 microns as inhalable dusts. They classify these as particles that are typically trapped in the nose, throat or upper respiratory tract. Similar to Buekens (2009), Lewis and Strebel (2016) defined respirable dust as particles that are able to penetrate deep in to the lungs. In contrast, they consider particles with these qualities to be "smaller than 10µm in size" (p. 49). Esworthy (2015) used a similar definition for particulate sizing. According to Esworthy (2015), $PM_{2.5}$ is defined as fine particulate matter 2.5µm or less in diameter and "larger, but still inhalable, 'course' particles" (p. 1) are less than 10µm in diameter. Particles within 2.5µm to 10µm are considered thoracic coarse particles. These particles are inhalable and can penetrate deep into the lungs. Esworthy (2013) associated these dusts with roadways, construction, and industrial operations, among others.

Groves, Hahne, Levine, & Schork (1994) defined respirable dusts as particles capable of reaching the alveolar region of the lungs. The study attempted to evaluate differences in respirable dust sampling techniques and cites multiple different sizes used to define respirable dust between 2µm and 7µm. Some authors, Dahlqvist (1992), Kraus, Pfahlberg, Zobelein, Gefeller, & Raithel (2004), Pagliari & Maurer (2005), Sakunkoo et al. (2011) were less specific in their definition of inhalable and respirable particles. These authors described dust simply as respirable and focus on the exposure levels of such dusts to employees. These studies focus on paper dust, hygiene paper dust and sugar dusts, respectively.

Dust concentration. Dahlqvist (1992) tried to better understand the respiratory effects of low concentrations of respirable paper dust in a bookbindery. The study identified a total dust concentration of around 0.56 mg/m^3 and respirable dusts all below 0.2 mg/m^3. One third of the participants showed slight adverse effects to their eyes, nose and throat even at such a low exposure level. Sakunkoo et al. (2011) focused the study on respiratory and inhalable dusts in the sugar industry in Thailand. Using a variety of measurements, the study determined that workers within sugar plants are exposed to high concentrations of inhalable dusts. The majority of the particle sizes were in the range of 2.1 µm to 4.7 µm and the study elaborated on the ability of particles in this size range to penetrate deep into the respiratory tract. Average concentrations were measured at up to 9.29 milligrams per cubic meter (mg/m^3). The subjects in this study were considered to be "at risk of developing asthma and bronchitis" (p. 977).

Holm, et al. (2011) reported employees of a soft paper hygiene product manufacturer to have adverse health effects after being exposed to average concentrations as low as 1.64 mg/m^3 of inhalable dust. The employees in the study were manufacturing diapers. According to the study many subjects exposed specifically to paper dust experienced physician-diagnosed adult-onset asthma (8.3%), current asthma (11.9%), rhinitis (46.4%), nose blockage (30.4%), nasal crusts (40.5%), nose-bleeding (42.3%), conjunctivitis (22.6%), and hand eczema (13.7%). These numbers came from a study of 1043 workers in industry. The workers were divided into subgroups of exposure levels to super absorbent polymer (53 workers), paper dust (168 workers), both superabsorbent polymer and paper dust (636 workers), and no exposure to superabsorbent polymer or paper dust (186 workers). Table 1 shows basic results of the study. The study considers the most important finding to be the increase of the odds for nose-bleeding and nasal crusts with exposure to paper dust. The study considered its only weakness to be overlapping exposures to the workers. The large sample-size provided this study with strength and validity, showing that paper dust can have an effect on the respiratory health of exposed workers.

Table 1.

Paper dust and superabsorbent polymer study results

	No exposure to superabsorbent polymer or paper dust	Only exposed to superabsorbent polymer	Only exposed to paper dust	Exposed to both superabsorbent polymer and paper dust
All	186	53	168	636
Physician-diagnosed adult-onset asthma	17 (9.1%)	4 (7.6%)	14 (8.3%)	36 (5.7%)
Current asthma	20 (10.8%)	8 (15.1%)	20 (11.9%)	64 (10.1%)
Rhinitis	71 (38.2%)	22 (41.5%)	78 (46.4%)	300 (47.2%)
Nasal blockage	46 (24.7%)	20 (37.7%)	51 (30.4%)	232 (36.5%)
Nasal crusts	61 (32.8%)	19 (35.9%	68 (40.5%)	294 (46.2%)
Nose-bleeding	62 (33.3%)	16 (30.2%)	71 (42.3%)	316 (49.7%)
Conjunctivitis	35 (18.8%)	12 (22.6%)	38 (22.6%0	150 (23.6%)
Hand eczema	22 (11.8%)	8 (15.1%)	23 (13.7%)	81 (12.7%)

Note. Paper dust study in diaper production. Reprinted from "Respiratory health effects and exposure to superabsorbent polymer and paper dust – an epidemiological study" by M. Holm, et al., 2011, *BMC Public Health, volume 11:557*, p. 4. Copyright 2011 by BMC Public Health.

Exposure limits vary between different regulatory bodies (Groves et al., 1994) and are dependent on industry, location, indoor or outdoor applications and chemical makeup of particulates. Both indoor and outdoor air quality is a topic of regulatory compliance. Esworthy (2015) summarized an Environmental Protection Agency's (EPA) regulatory change introduced in 2013, changing exposure limits to $PM_{2.5}$. These exposure limits are for outdoor applications and cannot be considered for indoor air quality. The interpretation of the standard defines $PM_{2.5}$ as "fine" particulate matter. The paper described a change to the National Ambient Air Quality Standard, or NAAQS, in the EPA's 2013 review. This standard is only applicable to the outdoors. The regulation considers an annual and daily exposure limit for $PM_{2.5}$, but only a daily limit for PM_{10} particles. The EPA determined a daily limit of no more than one exceedance of 150 µmg/m^3 for PM_{10} and 35 µmg/m^3 for $PM_{2.5}$ per year on average over a three-year period (Esworthy, 2013). The annual standard is determined by a three-year average of PM concentration; this is regulated for $PM_{2.5}$, but there is no annual regulation for PM_{10}. Annual exposure limits for the $PM_{2.5}$ NAAQS were determined to be 15 µmg/m^3 in 2006, but updated in 2013 to a stricter 12 µmg/m^3. The PM_{10} standard relating to larger, inhalable course dust between the size of 2.5 µm and 10 µm was not changed from the 2006 standard. Esworthy (2013) explained that the EPA cited various scientific studies since the 2006 ruling as a reason for change:

> Based on its review of scientific studies available since the agency's previous review in 2006, EPA determined that evidence continued to show associations between particulates in ambient air and numerous significant health problems, including aggravated asthma, chronic bronchitis, non-fatal heart attacks, and premature death. (Esworthy, 2013, p. 1)

The EPAs outdoor average concentration standards are much lower than indoor concentrations regulated by groups like The Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH).

OSHA has specific definitions and regulations surrounding exposure limits for employees in certain fields of employment and focuses on indoor applications. OSHA Standard 1910.1000 defined exposure limits to specific air contaminants; referencing three separate tables of materials defining Personal Exposure Limits (PEL) (Occupational Safety and Health Administration [OSHA], 2017). OSHA PELs are determined using a time weighted average (TWA) over an 8 hour work period and uses gravimetric analysis as found in the NIOSH's 0500 and 0600 sampling methods (CDC, 2017). Paper dust found in book production previously fell into Table Z-3 as Inert or Nuisance Dust and had exposure limits defined as 5 mg/m^3 for respirable fraction and 15 mg/m^3 for total dust (OSHA, 1987). In a 1987 interpretation of Standard Number 1910.1000 TABLE Z-3, the director of the Office of Science and Technical Support with OSHA confirmed that there is currently no exposure limit for paper dust (OSHA, 1987). The Occupational Safety and Health Review Commission (OSHRC) determined that "the nuisance dust standard can no longer apply to organic dusts, such as paper dust" (OSHA, 1987, para. 1).

Printing

Printing is defined as a means of communicating graphically using images on a substrate, generally paper, that are able to be observed visually (Bruno, 2000). The earliest record of such a visual record dates back 30,000 years, found in the form of wall drawings. Since that time, the print industry has evolved into a primary form of communication and a profitable industry in the United States. According to Bruno (2000), the print and publishing industry in 2000 represented "about 3 percent of the gross domestic product" in the U.S. (p.8). At that time, the print industry was spread into many small shops and had the highest number of establishments at more than 60,000. Since then, the print industry has consolidated into fewer, larger companies, but is still an important producer in the U.S. This prevalence continues through advances in online reading applications (Bruno, 2000). According to Davis (2014), the print industry "produces approximately $156 billion in output annually" (p. 1) and the digital inkjet processes of production are growing, while the offset processes are declining. Davis (2014) provided an economic evaluation of the print industry. The paper discusses different trends within the print industry and reinforces the large footprint that print still has in the United States, with coverage in all 50 states and upwards of 47,000 facilities. About two thirds of these establishments are small, with fewer than 10 employees and another 14 percent have between 10 and 20 employees, although the larger facilities, while in the minority, have a larger share of the sales revenue in the industry.

Today, technology enhancements are enabling companies to deliver shorter run, on-demand book production using inkjet printers and short run, auto make-ready finishing equipment. Cross (2012) discussed the advantages of digital book production, citing the ability to run economical, on-demand, personalized, short run jobs to provide publishers with flexibility and the ability to discontinue costly storage of long run production books. The publication also references the growing ability of digital print equipment to run longer runs economically, making them a viable contender for a lot of work that has been previously printed using offset printing technology. Michelson (2015) echoed the advantages of digital print, in his elaboration of a discussion including a small group of book printers to discuss the new technology. The drastic reduction in the publisher's cost is due primarily to inventory reduction according to Michelson (2015). The article also noted the workflow changes that must take place for a printer to adapt to a faster, highly transactional process. These changes effect employees and equipment alike, with more job changes, more touches and more focus on small quantity product tracking throughout the process. While this new process boasts many advantages, many of the same obstacles in the printing, binding and waste collection processes remain the same. One of these obstacles is paper dust.

Sittig (1977) focused on dust control in various industries in great detail throughout the text, including the asphalt, cement, airline, electric utilities, food, fiberglass, metalworking, iron and steel, textile, forest products, and other industries. The information regarding the forest products industry focuses only on lumber, forestry, plywood and pulp. While these industries provided some similarity, none of them provide an identical particulate in an identical quantity as the print industry; having materials and techniques distinctly different from other forest product industries.

In the print industry, along with general material handling throughout the facility, there are many processes that involve manipulating paper to change the shape and size of the final product.   In the process of offset lithography, digital print, gravure printing and others, after passing through the units and receiving ink, rolls of paper are “slit” using cutting wheels on the press itself or on the folder (Bruno, 2000). Folding also occurs at this point in the process, where the slit sections of paper are stacked and folded into signatures. Signatures are “a printed sheet after it has been folded” (Bruno, 2000, p. 231). Signatures are combined together to form a book. There are many different methods of combining these signatures into one book, this process is generally referred to as binding. Binding is divided between saddle-stitching, perfect binding, mechanical binding and case binding (Lyman, 1993). Saddle stitching involves placing a staple through the center of the folded material. This type of binding is generally used for thin magazines and pamphlets. Perfect binding uses a liquid adhesive to combine the signatures and is the primary type of binding for books and magazines. Mechanical binding refers to several different methods used to hold signatures together using plastic or metal material punctured through the spine of loose leaf sheets. This type of binding is used in various applications to allow for the book to lay flat when open, but can be recognized as three ring binders and spiral-bound school notebooks. Lyman (1993) describes each different binding operation in detail. No matter the bind style used, there are several sources of dust within the process, due to cutting, drilling, punching, milling and grinding. Almost every process requires the paper to be cut, either using a three-knife trimmer or a guillotine type single side cutter. Perfect binding requires the most manipulation of material and has greatest potential to create dust.

Perfect binding involves the cutting and roughening of the backbone of the signatures for successful adhesion of glue to hold the signatures together, along with the outer cover (Lyman, 1993). While transported using clamps keeping the signatures together, the backbone fold of the signatures is milled away evenly using a saw or knife to expose each sheet. The signatures are then passed through a roughener; a device that grinds the newly cut edge of the signatures to improve adhesion. After adhesion, the newly bound book travels to a trimmer located at the end of the binding line. Lyman (1993) defined trimming as "the operation of cutting away the folded or ragged edges of a bound job to form smooth, even edges and permit all pages to open." (p. 62). Trimming occurs after the book binding process in perfect binding operations. Trimmers cut the bound book to size using steel or carbide knives slicing in a guillotine motion through the book. Lyman (1993) addressed dust in these applications as potential for causing quality concerns and adhesion issues and suggests central exhaust systems to assist in removing particles and dust from the process. These systems are strategically placed near the saws and rougheners to pull dust and particulates away from the signatures before glue is applied and at the knives of the trimmer to remove excess paper that is trimmed from the edges of the book.

Dust Control

The central exhaust system that pulls excess dust and paper waste away from the process is referred to as a trim waste system. The principles behind this form of waste consolidation can be found in the book written by the American Conference of Governmental Industrial Hygienists [ACGIH] (2004). This handbook provides all necessary information to design, maintain, and control industrial ventilation systems, including multiple-hood exhaust systems similar to those used in the print industry. These systems are designed to collect and consolidate particulates and waste into a central location using a hood at the point of use, ductwork to transport the material, a fan to create flow for the material to travel and a central collection location. In the print industry, that central location of collection uses a cyclone to collect all materials into a shredder to break down material before dropping into a baler or a briquetter to consolidate the dust and paper waste into a compacted solid for disposal. The cyclone collects trim and dust from each of the machines using blowers and fans to transport the trim filled air from the machine. The cyclone circulates air down a cone-shaped vessel. As the air reaches the lower portion of the cone, the speed is reduced to drop the heavier paper waste from the contaminated air. The remaining paperless air is pulled back up through the center of the cyclone using a return fan (GF Puhl, 2017). The paper trim that is dropped from the cyclone is compacted in a baler below. The dust laden air is transported to the briquetter for compaction and removal. Metal wire is used to contain the compacted paper trim for shipping to landfills. This is a form of balefilling. Balefilling is a process that greatly reduces the impact of solid waste on landfills. Today's landfill space shortage requires every space saving possibility to be considered when disposing of solid waste. The processes of shredding and baling solid waste are two ways to improve the waste removal process altogether. The shredding process began in France in the early 1950's and quickly became a very popular form of waste consolidation (Robinson, 1986). Shredding waste allows for greater and faster compaction of material and reduced fire hazard. Robinson (1986) also noted that shredded waste produces organics at a higher rate than non-shredded waste. Along with shredding, there are numerous advantages to balefilling including extended landfill useful life and improving cost effectiveness by reducing space and time needed for transport.

Review of Literature Summary

Dust as it effects respiratory health has been studied and characterized within multiple industries. Dust sizes of 10 µm and below are considered inhalable, while finer particles (around 2.5 µm) are considered respirable. Both of these size ranges are considered cause for concern with regard to respirable health in large concentrations. Dust concentrations are measured as milligrams per cubic meter (mg/m^3). Different organizations and studies have noted different concentrations as causing deleterious respiratory effects. The book production industry contains processes that create paper dust, but there have been few studies dedicated to discovering concentration levels of respirable and inhalable dust in the book production industry. Until 1987, paper dust was regulated by OSHA with limits of 5 mg/m^3 for respirable dust and 15 mg/m^3 for inhalable dust (OSHA, 1987). There have been more extensive studies within other industries working with paper products. Studies focused in the paper industry, Holm et al. (2011), Dahlqvist (1992) and Hoffman et al. (2001), showed relatively similar concentrations of paper dust having varying effects on surrounding employees. Holm et al. (2011) associates an average concentration of around 1.5 mg/m^3 of soft paper dust in the diaper production industry with potential nasal crusting and nose bleeding of long time employees. Dahlqvist (1992) associated long term exposure to inhalable concentrations of paper dust in a book bindery of 0.56 mg/m^3 with the possibility of "slight lung function deterioration without clinical relevance" (p. 49). Respirable concentrations were all under 0.2 mg/m^3 in this study. Hoffman et al. (2001) considered an elevated risk of bronchitis to be found with employees exposed to average concentrations over 1 mg/m^3 in the paper production industry. While Dahlqvist (1992) reported slight lung deterioration due to long term exposure, because it was determined as clinically irrelevant, the concentration level of 0.56 mg/m^3 was considered to be safe. There was no research found that classified concentrations under 1 mg/m^3 as unsafe with clinical relevance. In summation, average inhalable paper dust concentrations under 1 mg/m^3 can reasonably be considered to be safe for surrounding employees. With less research pertaining specifically to respirable sizes of paper dust, the concentration defined by Dahlqvist (1992), 0.2 mg/m^3, was considered a safe operating limit for the purposes of this study.

Methodology

Introduction

The purpose of this quantitative single subject research was to determine the average concentration levels of inhalable dust (PM_{10} and $PM_{2.5}$) in suspected problematic areas of a book production facility. The study focused on PM_{10} and $PM_{2.5}$ as particulate matter that could cause concern for employees' respiratory health. The study was designed to gather data that will be useful in determining if the facility needs improved dust control or employee protection. The research will also provide guidance for other book production facilities in search of information on paper dust causing respiratory health concerns in their facilities. There were no known formal complaints of dust issues in the facility prior to testing, but with limited research available regarding concentrations of paper dust in similar applications, the researcher found it important to better understand the dust concentrations in the facility.

Procedure

In order to determine the average concentration levels of inhalable dust (PM_{10} and $PM_{2.5}$) in suspected problematic areas of a book production facility, the DustTrak DRX 8533 (DRX) desktop aerosol monitor (TSI Inc., Shoreview, MN) was used to collect samples of air at three different locations in the book production facility; one in the digital pressroom, one in the digital bindery and one in the paper recycling warehouse. These sample locations were chosen because processes in these locations cause the greatest manipulation of paper, producing a possibility of high concentrations of paper dust in the air. The instrument was placed at a location within three meters of the primary dust creating components in each process at a height of one to two meters off the ground to capture data in the area an employee spends most of their time throughout a shift. The height was selected to capture data in the employee's breathing zone. These locations provided the most accurate exposure concentrations for the employees working nearest to the operation. The DRX was placed on a flat surface, similar to the orientation seen in Figure 2. The samples were collected every minute in 12-hour intervals. The 12-hour interval started at 07:00 EST and ended at 19:00 EST, running simultaneously with the operators' shift schedule. This provided a total of 720 samples at each location; one sample x 60 minutes x 12 hours. The DRX was setup to measure concentrations of both PM_{10} and $PM_{2.5}$ at the same time, therefore the equipment monitored PM_{10} and $PM_{2.5}$ for one full shift at each location. Only day shifts were measured as this is when the majority of product passes through the processes and provides the highest concentrations of dust throughout a 24 hour period. The total duration of data collection was three days, allowing one day of sampling at each location. The DRX maintained a flow of 3 L/min. This instrument and similar photometers and optical particle counters were developed to provide real-time readings of mass concentrations. These instruments provide a convenient alternative to the gravimetric sampling process, as found in NIOSH 0500 and 0600 sampling method for personal exposure limits for particulates not otherwise regulated (CDC, 2017).

Instrumentation

The DustTrak Aerosol Monitor was validated as an acceptable particle monitor by Wallace et al. (2011) and used in several studies (TSI, 2016) to better understand concentrations of particulate matter in various industries and practices. This equipment was selected because of its reputation as a reliable replacement to traditional filter-based gravimetric methods (Wallace et al., 2011) and availability to rent at a reasonable price. The minimal intrusiveness of the equipment to the process and its operators as compared to personal sampling equipment was also a consideration.

Figure 2. DustTrak DRX Aerosol Monitor Model 8533 (TSI, Inc, 2017).

Data analysis was performed using Minitab, version 17. Minitab was created in 1972 by professors at Penn State. The software is on its 17th version and is known for its widespread use in companies and universities throughout the country. The software is a leader in the industry of statistical analysis, education and quality improvement (Minitab, 2017). Minitab was selected because the researcher has full access to the program at no cost.

Location

The book production facility used for the study was selected based on accessibility and researcher's knowledge of the facilities' processes. This facility contains digital equipment required to produce various types of books, including hardcover, softcover, saddle stitched and mechanically bound books and is representative of a typical large book production facility in the United States. The facility is in production every day for 24 hours with few exceptions. It is important to note that this is a large facility compared to the smaller establishments defined in Davis (2012) and Bruno (2000). This facility employs more than 500 employees. For purposes of this study, the focus was kept to the perfect bound paperback book making process; the most common type of book produced in the facility. The locations selected in the facility touch each process in perfect bound paperback book production workflow.

The first sampling location was in the paper recycling warehouse. This is the location in the facility that takes all trim waste from the different processes in the facility and collects, compacts and bales the materials into a transportable size and shape. The equipment was set on top of a flat protruding portion of the bailing equipment about three meters from the outfeed of the bailer where product is picked up by employees. The height of the equipment was about 1.25 meters off the ground. It is important to note that this area is generally less occupied by employees, with only occasional entrance on fork trucks to pick up the compacted bales for transportation. Daily cleaning and infrequent maintenance procedures on the equipment would be the exception and could require employees in the area for longer periods of time. Daily cleaning consists of about one hour of dust sweeping and blowing down each day. This area provides the greatest manipulation of material in the facility.

The second sampling location was in the digital bindery. This is the location where perfect binding occurs. The equipment was set flat on top of a small table about one meter off the ground at a location between the trimmer and saw and roughener. The equipment was placed about three meters from each of the dust producing sections of the machine. There is a large amount of paper manipulation in this area, where books are sawed, roughened and trimmed.

The third sampling location was in the digital pressroom. This is the location where the inkjet print process takes place. The equipment was set flat on top of a small table about 1 meter off the ground near the folding and slitting section toward the output of the press at the operator's desk. The manipulation of paper in this area is minimal and includes slitting, folding and stacking.

Threats to Validity

The collection process took two extra days due to machine failure at the beginning of collection on day two in the bindery. A new DRX had to be delivered and the original had to be returned to the rental facility for cleaning and maintenance. The new DRX was the exact same model as the original and no differences in data are expected between the two. While the equipment functioned properly throughout the collection process on day one, there is still a potential of the data being convoluted due to using two separate pieces of equipment to measure the different areas. There is also a threat to the validity of the data collected on day one. The equipment showed no signs of error during that day, but it was the last day of full functionality so the concern is notable.

The potential of employee tampering or intentionally skewing the results of the research is also a threat to the validity of the data collected. None of this behavior was witnessed or suspected, but the researcher was unable to attend the equipment during the entire procedure so employee disturbance was possible.

Data Analysis

Data

Paper recycling warehouse. Data was collected in the paper recycling warehouse on Thursday March 9, 2017. No significant breakdowns or irregular operating conditions existed on the day of collection, representing a standard day of operation. Samples were collected every minute between 07:00 and 19:00. The average concentration of respirable paper dust ($PM_{2.5}$) in the paper recycling warehouse was 0.3873 mg/m^3. The average concentration of inhalable paper dust (PM_{10}) in the paper recycling warehouse was 0.5066 mg/m^3. Both size ranges represent a normal distribution of data as represented in Figures 3 and 4. Basic statistics of data collected in the paper recycling warehouse can be found in Table 2.

Table 2.

Basic statistical data of $PM_{2.5}$ and PM_{10} in the paper recycling warehouse

Particle Size	N	Mean	Standard Deviation	Minimum	Median	Maximum
PM2.5 mg/m3	720	0.3873	0.03493	0.063	0.321	3.84
PM10 mg/m3	720	0.5066	0.4817	0.072	0.3825	6.03

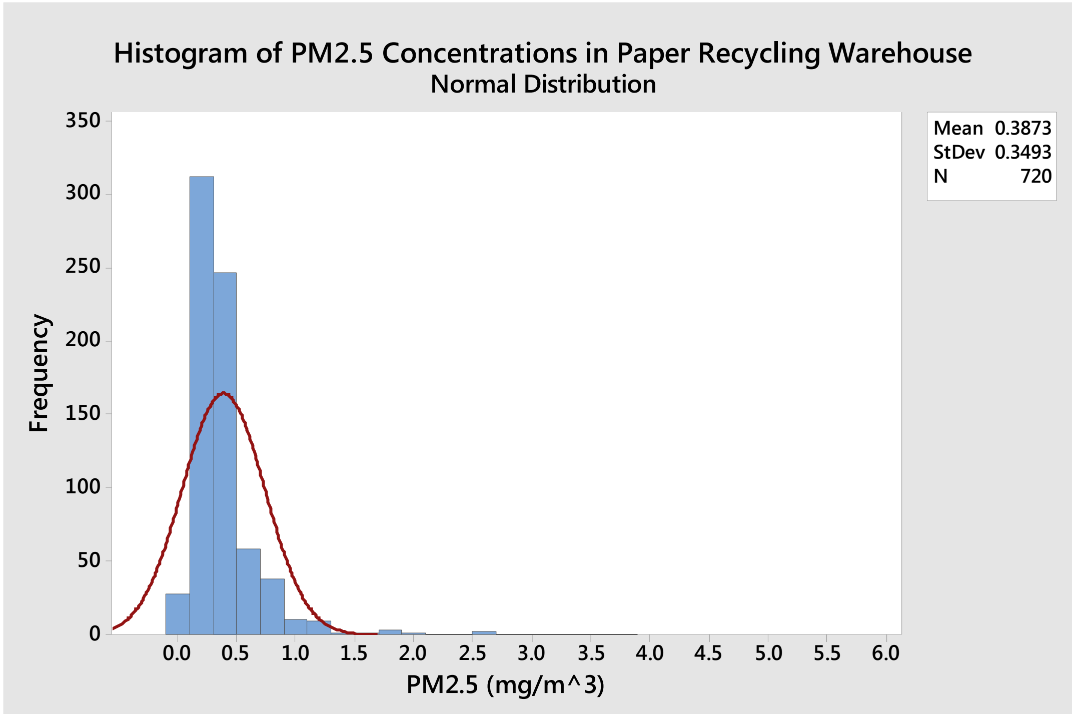

Figure 3. Histogram of $PM_{2.5}$ data collected in the paper recycling warehouse

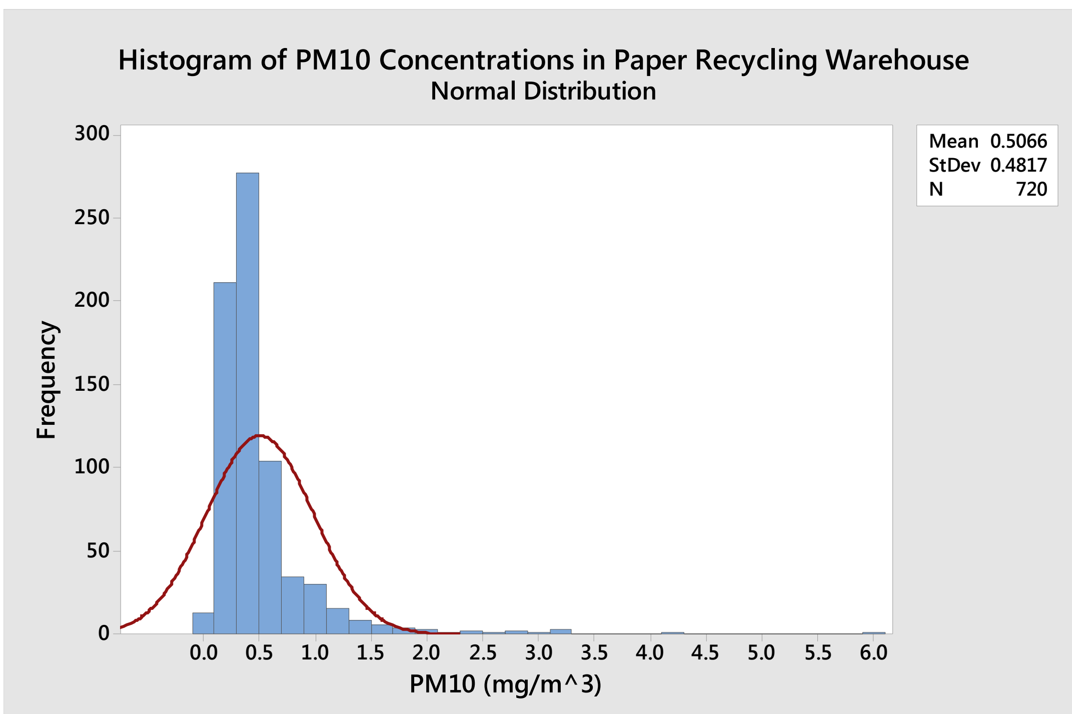

Figure 4. Histogram of PM_{10} data collected in the paper recycling warehouse

The concentration levels of both $PM_{2.5}$ and PM_{10} followed similar patterns throughout the day. This data indicated frequent minor spikes and infrequent significant spikes throughout the day of both particle size groups. Figures 5 and 6 show the time series data of $PM_{2.5}$ and PM_{10} in the paper recycling warehouse throughout the day. The highest concentrations of both sizes are found at around 17:30. This is the time the employees go through daily cleaning activities; including blowing down equipment with compressed air and sweeping the surrounding floors. This disturbance releases dust into the air and accounts for the highest dust concentrations of the shift for both $PM_{2.5}$ and PM_{10} in the paper recycling warehouse. Other smaller spikes in concentration in both size ranges can be attributed to equipment cycles, as this machine operation is triggered by sensors detecting levels of paper accumulation.

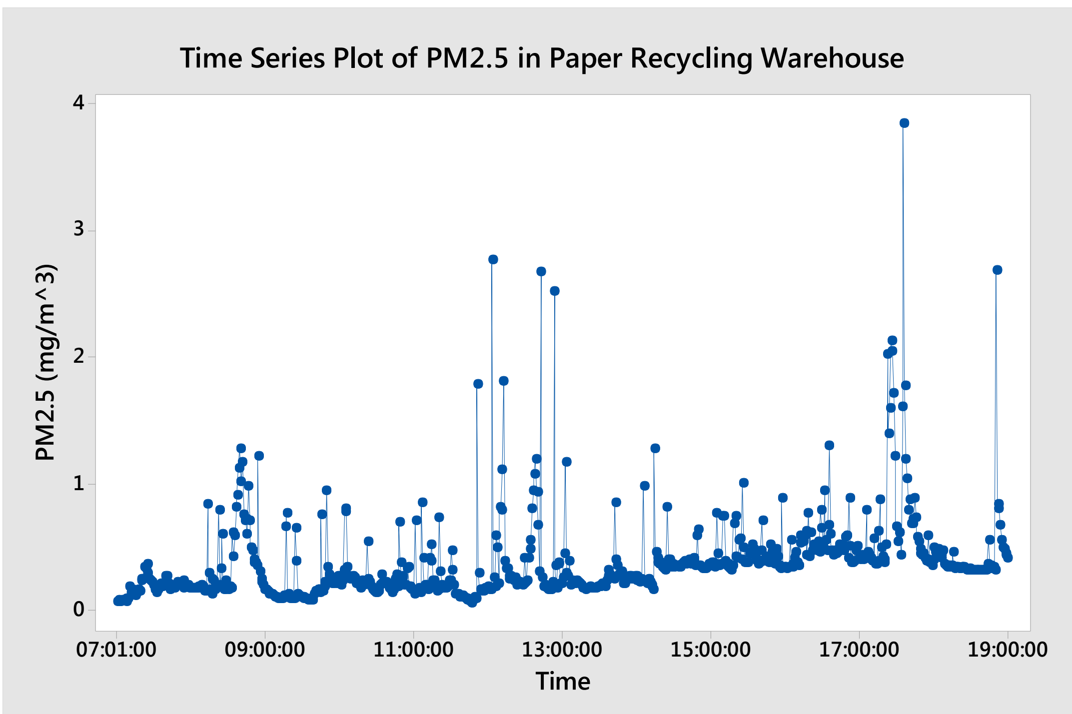

Figure 5. Time series data of $PM_{2.5}$ in the paper recycling warehouse

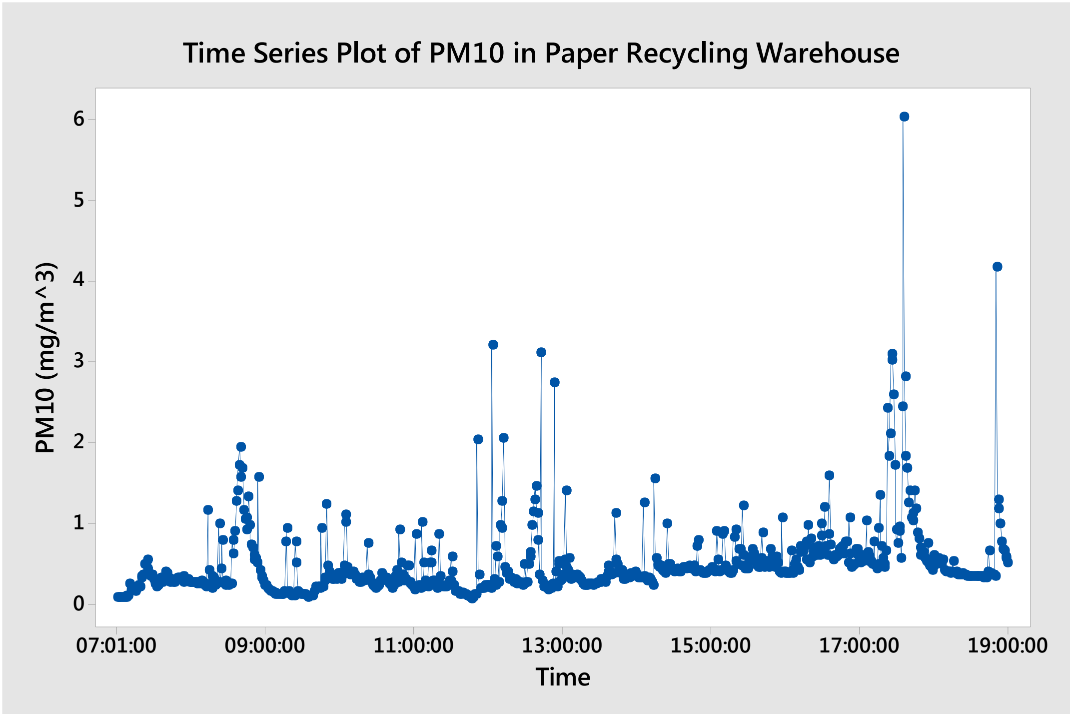

Figure 6. Time series data of PM_{10} in the paper recycling warehouse.

Pressroom. Data was collected in the pressroom on Monday March 13, 2017. 720 samples were collected representing one sample every minute from 07:00 to 19:00. No significant breakdowns or irregular operating conditions existed on the day of collection, representing a standard day of operation. The average concentration of respirable paper dust ($PM_{2.5}$) in the pressroom was 0.020889 mg/m^3. The average concentration of inhalable paper dust (PM_{10}) in the pressroom was 0.028415 mg/m^3. Both size ranges represent a normal distribution of data as represented in Figures 7 and 8. Basic statistics of data collected in the pressroom can be found in Table 3.

Table 3.

Basic statistical data of $PM_{2.5}$ and PM_{10} in the pressroom

Particle Size	N	Mean	Standard Deviation	Minimum	Median	Maximum
$PM_{2.5}$ mg/m^3	720	0.02089	0.014013	0.006	0.019	0.171
PM_{10} mg/m^3	720	0.02842	0.021768	0.006	0.025	0.261

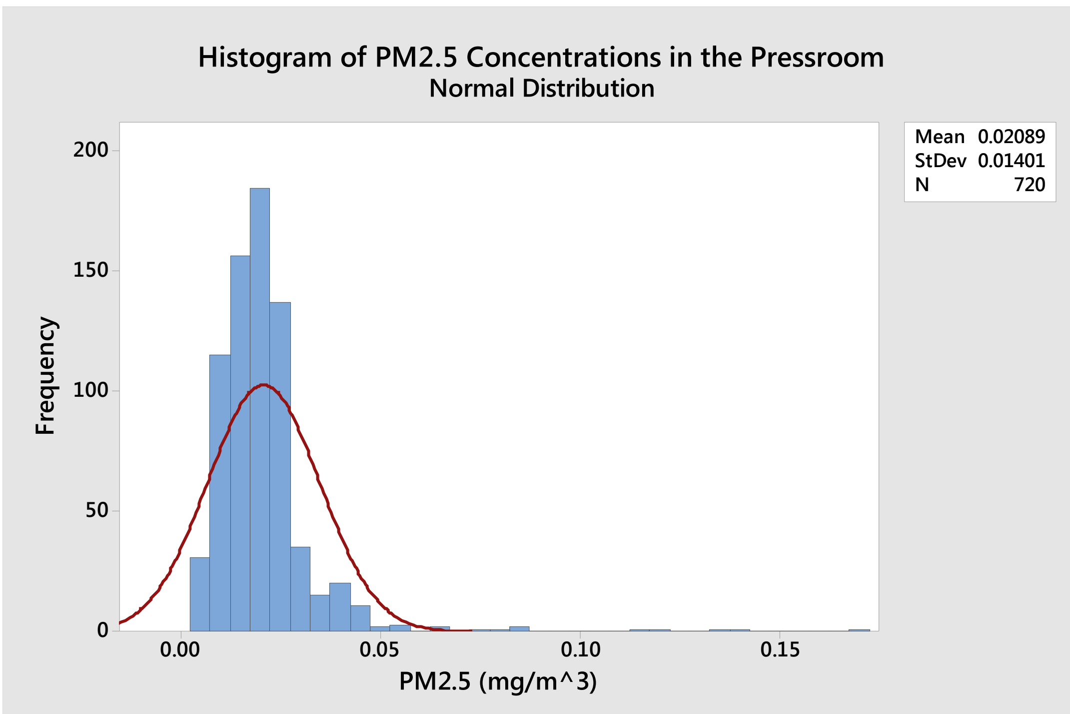

Figure 7. Histogram of $PM_{2.5}$ data collected in the pressroom

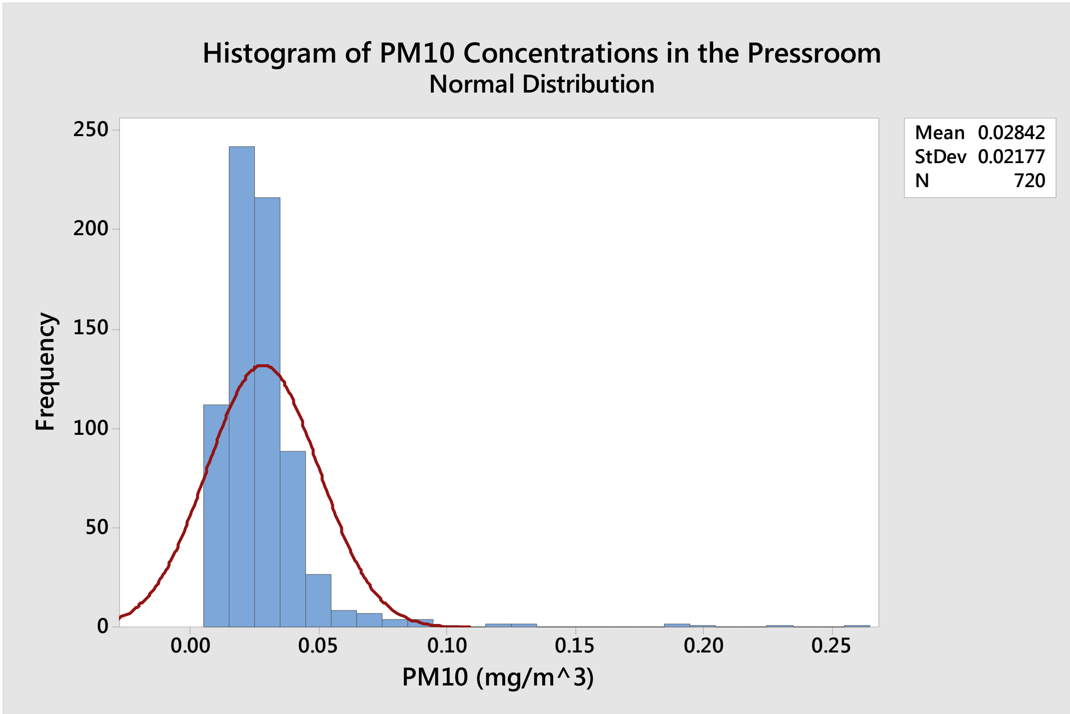

Figure 8. Histogram of PM_{10} data collected in the pressroom

The concentration levels of both $PM_{2.5}$ and PM_{10} followed similar patterns throughout the day. This data indicated generally steady concentrations of both size ranges of dust. Figures 9 and 10 show the time series data of $PM_{2.5}$ and PM_{10}, respectively, in the pressroom throughout the day. The highest concentrations of both sizes were found at around 07:30. This is the time when daily cleaning activities take place; including blowing down equipment with compressed air and sweeping the surrounding floors. Another spike was noted at around 12:00 for lunch and 16:00, signifying a smaller scale cleaning activity in the afternoon. These disturbances accounted for the highest concentrations of the day for both $PM_{2.5}$ and PM_{10} in the pressroom. Other individual spikes represent separate small scale cleaning and maintenance activities that are necessary throughout the day and often require opening equipment and manipulating the interior of the machine, where dust quantities are higher.

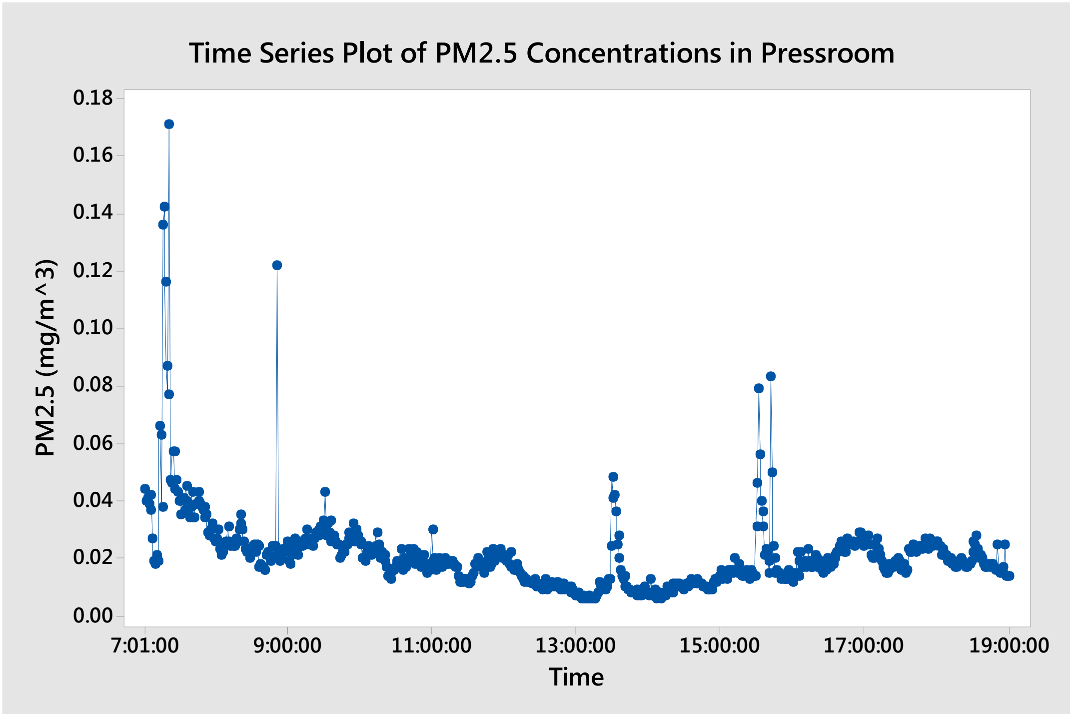

Figure 9. Time series data of $PM_{2.5}$ in the pressroom

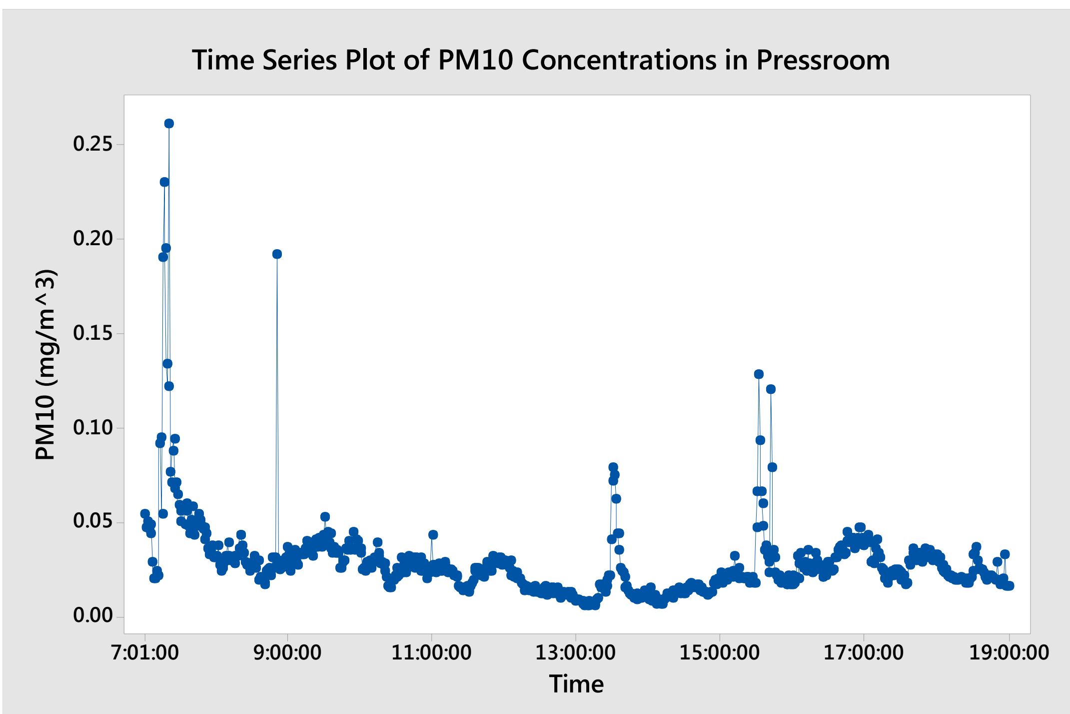

Figure 10. Time series data of PM_{10} in the pressroom

Bindery. Data was collected in the bindery on Tuesday March 14, 2017. 720 samples were collected representing one sample every minute from 07:00 to 19:00. No significant breakdowns or irregular operating conditions existed on the day of collection, representing a standard day of operation. The average concentration of respirable paper dust ($PM_{2.5}$) in the bindery was 0.02629 mg/m^3. The average concentration of inhalable paper dust (PM_{10}) in the bindery was 0.03104 mg/m^3. The maximum concentrations for both size ranges were the lowest of the three observed locations. Both size ranges represent a normal distribution of data as represented in Figures 11 and 12. Basic statistics of data collected in the bindery can be found in Table 4.

Table 4.

Basic statistical data of $PM_{2.5}$ and PM_{10} in the bindery

Particle Size	N	Mean	Standard Deviation	Minimum	Median	Maximum
$PM_{2.5}$ mg/m^3	720	0.02629	0.00986	0.012	0.025	0.082
PM_{10} mg/m^3	720	0.03104	0.01205	0.014	0.03	0.129

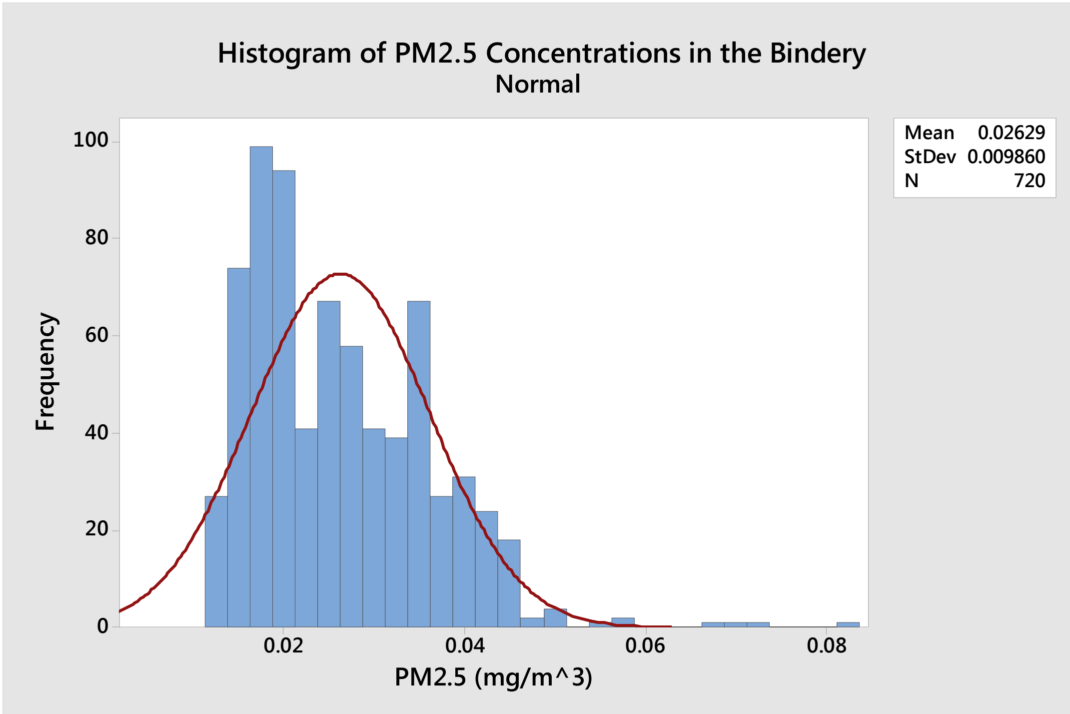

Figure 11. Histogram of $PM_{2.5}$ data collected in the bindery

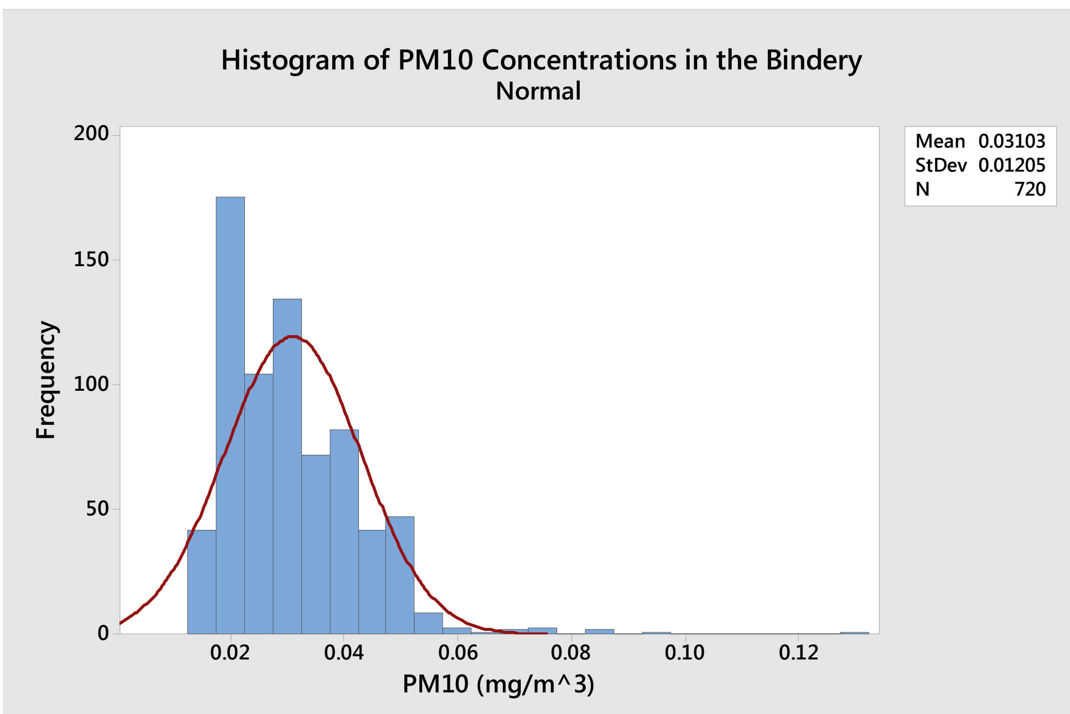

Figure 12. Histogram of PM_{10} data collected in the bindery

The concentration levels of both $PM_{2.5}$ and PM_{10} followed similar patterns throughout the day in the bindery. This data indicated generally steady concentrations of both size ranges of dust. Figures 13 and 14 show the time series data of $PM_{2.5}$ and PM_{10}, respectively, in the bindery throughout the day. The data seems to fluctuate more than the other sampled locations, but on a smaller scale. This signifies a more inconsistent run schedule and more frequent changeover from job to job, requiring entering the equipment for preparing components for different job specifications more often than the other observed processes. This is indicative of the highly transactional environment provided by the digital book production process.

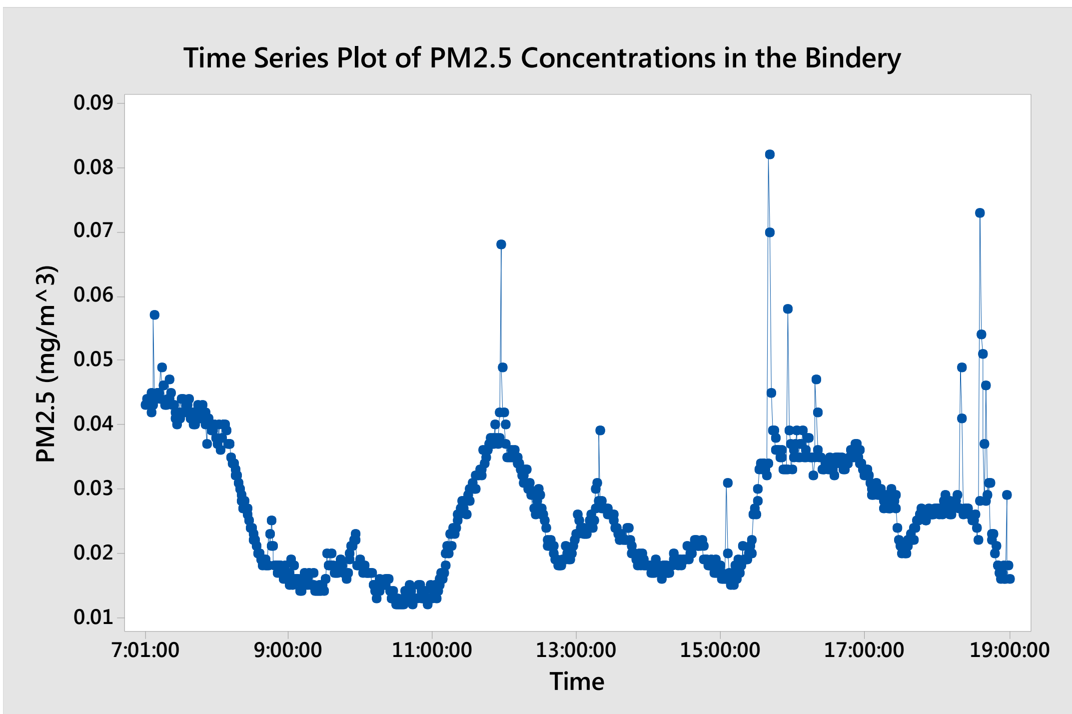

Figure 13. Time series data of $PM_{2.5}$ in the bindery

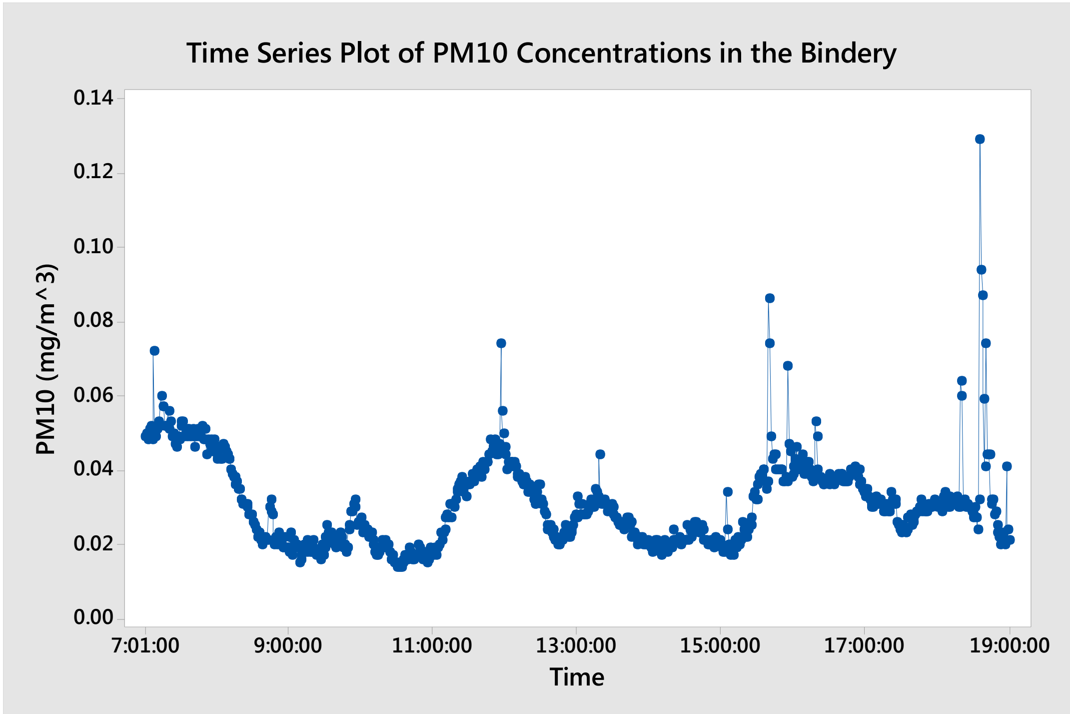

Figure 14. Time series data of PM_{10} in the bindery

Health Implications

Known deleterious dust concentrations from the bookbinding industry and soft tissue paper industry were used as comparisons to each of the processes in the book production facility. These concentrations were derived from the studies focused on paper industries described in chapter two. Dahlqvist (1992), Holm et al. (2011) and Hoffman et al. (2001) were used to determine that inhalable dusts of around 1 mg/m^3 and higher could cause respiratory health concern for surrounding employees. Dahlqvist (1992) was the only study that focused specifically on respirable dust and all concentrations in that size range were measured at under 0.2 mg/m^3. These concentrations were used to determine if employees in the three measured processes were at risk of negative respiratory health implications. Table 5 shows a basic comparison of the figures.

Table 5.

Collected average dust concentrations compared to safe studied concentrations

Location	PM2.5 Mean (mg/m^3)	PM10 Mean (mg/m^3)
Recycling Warehouse	0.3873	0.5066
Pressroom	0.020889	0.028415
Bindery	0.026292	0.031035
Safe Studied Concentration	0.2	1

Paper recycling warehouse. The paper recycling warehouse (PRW) had the highest average concentrations of respirable and inhalable dust. The collected averages were compared to the studied safe averages to determine if employees in the paper recycling warehouse are at risk of negative respiratory health implications. When compared to average safe respirable ($PM_{2.5}$) concentrations of 0.2 mg/m^3, the PRW average of 0.3873 mg/m^3 is almost twice of the safe studied average. This was represented graphically in Figure 15. Average concentrations of respirable paper dust in the paper recycling warehouse indicates potential negative respiratory health implications on surrounding employees.

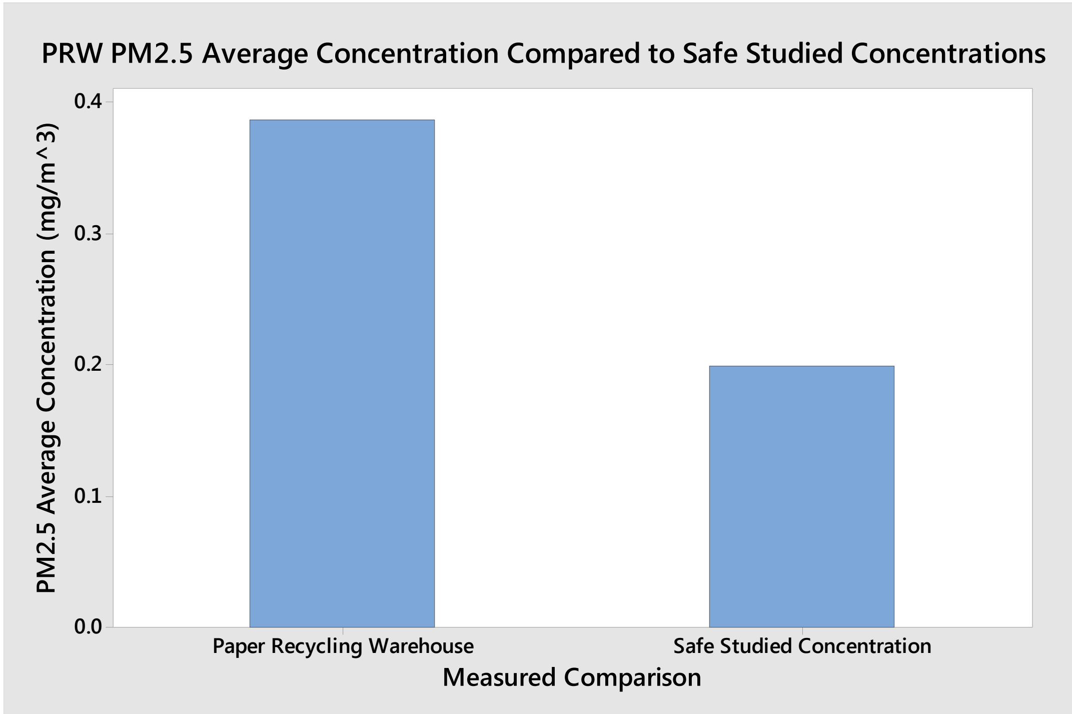

Figure 15. Visual comparison of $PM_{2.5}$ average concentrations in paper recycling warehouse and average safe studied respirable concentrations

Review of PM_{10} concentrations in the PRW compared to safe studied concentrations indicate that employees are not at risk of negative respiratory health implications due to inhalable sized particles. Measured concentrations of PM_{10} in the PRW of 0.5066 mg/m^3 is about half of the safe studied concentration of 1 mg/m^3. Figure 16 shows the PRW measured PM_{10} concentrations and safe studied inhalable dust concentrations graphically.

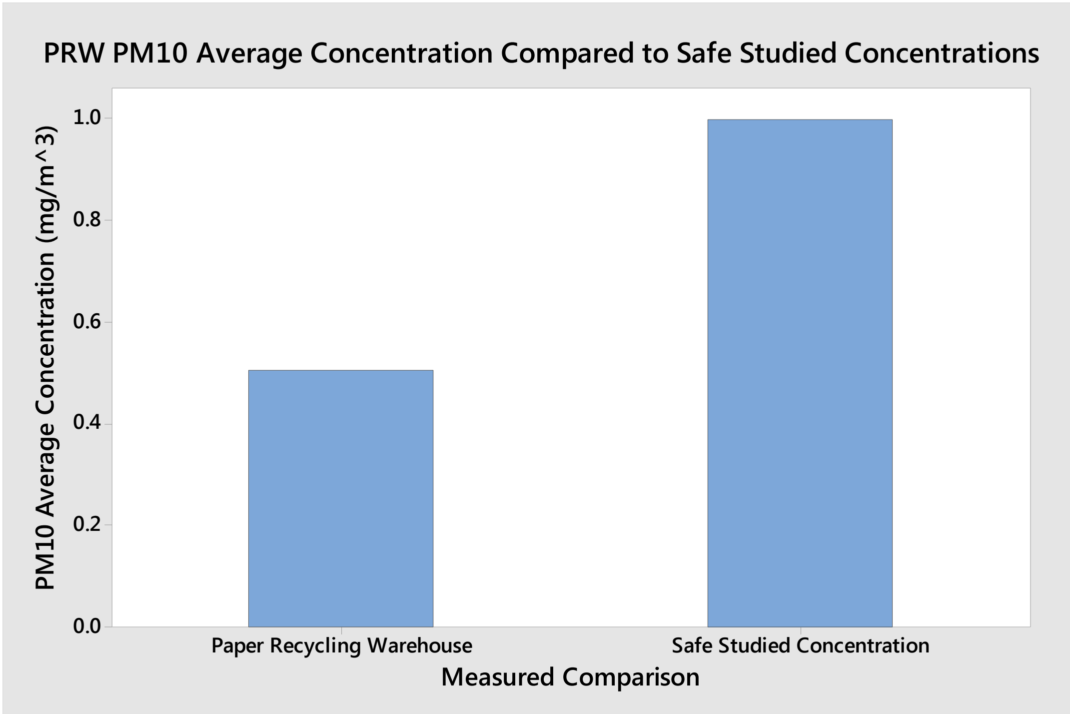

Figure 16. Visual comparison of PM_{10} average concentrations in paper recycling warehouse and average safe studied inhalable concentrations

Pressroom. The pressroom had the lowest average concentrations of respirable and inhalable dust. The collected averages were compared to the studied safe averages to determine if employees in the paper recycling warehouse are at risk of negative respiratory health implications. When compared to average safe respirable ($PM_{2.5}$) concentrations of 0.2 mg/m^3, the pressroom average of 0.020889 mg/m^3 is only about 10% of the safe studied average. This is represented graphically in Figure 17. Average concentrations of respirable paper dust in the pressroom did not indicate negative respiratory health implications on surrounding employees.

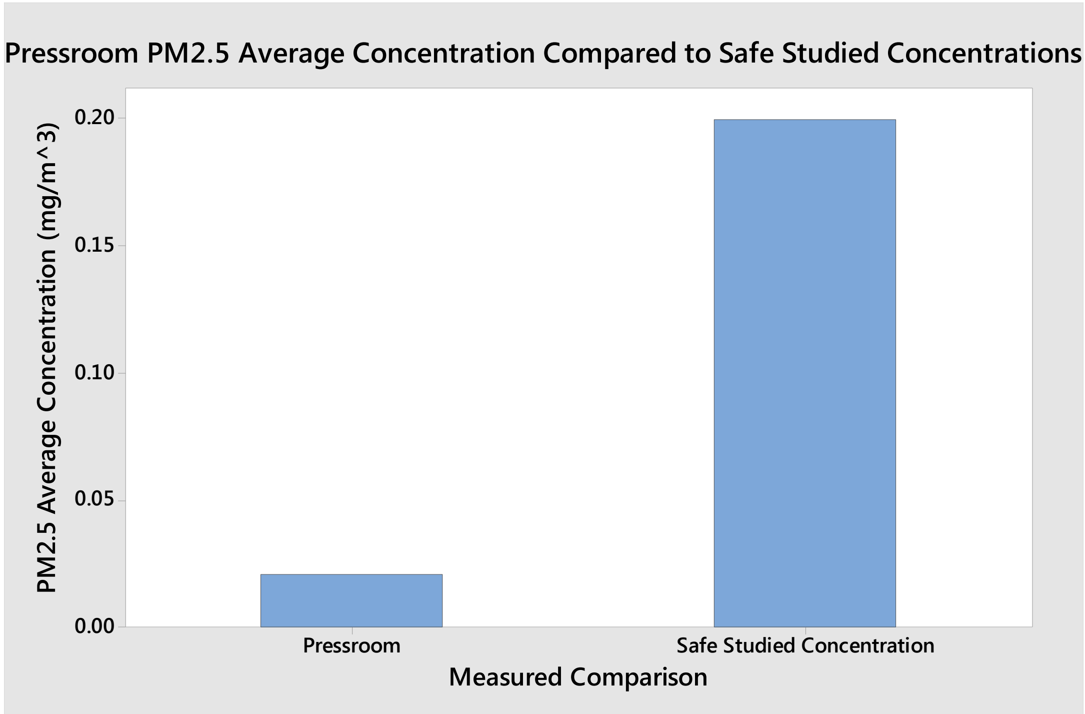

Figure 17. Visual comparison of $PM_{2.5}$ average concentrations in pressroom and average safe studied respirable concentrations

Review of PM_{10} concentrations in the pressroom compared to safe studied concentrations indicate that employees are not at risk of negative respiratory health implications due to inhalable sized particles. Measured concentrations of PM_{10} in the pressroom of 0.028415 mg/m^3 is less than 3% of the safe studied concentration of 1 mg/m^3. Figure 18 compares the pressroom measured PM_{10} concentrations and safe studied inhalable dust concentrations graphically.

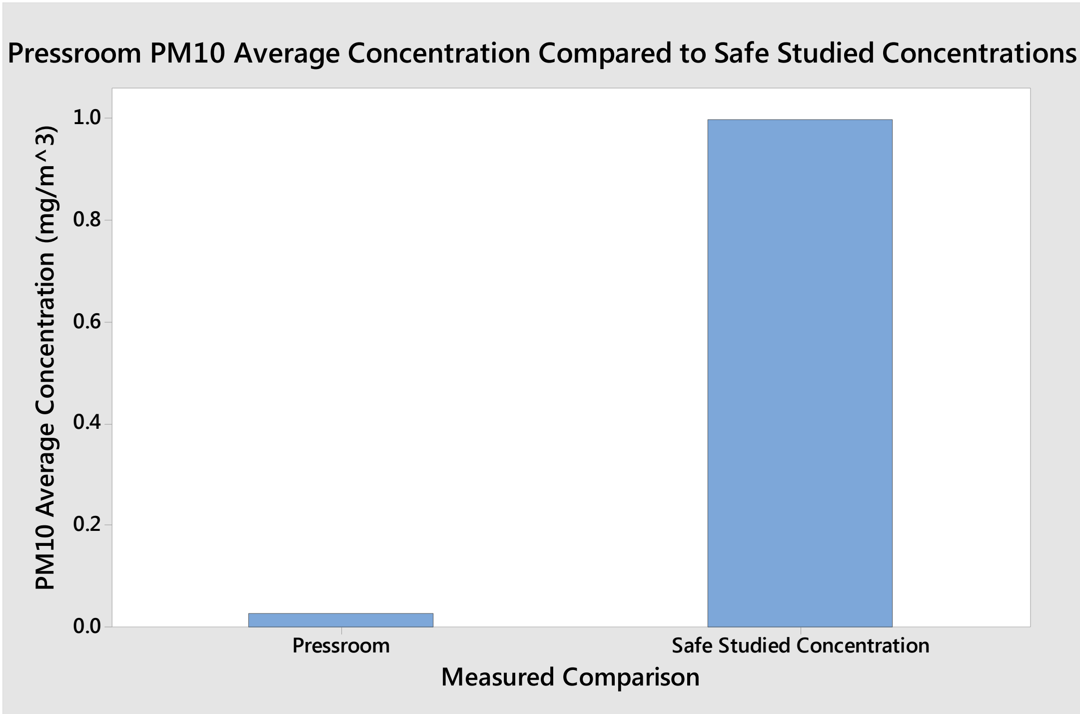

Figure 18. Visual comparison of PM_{10} average concentrations in pressroom and average safe studied inhalable concentrations

Bindery. The bindery had the second lowest average concentrations of both respirable and inhalable dust concentrations. Collected concentration averages were compared to studied safe concentration levels in both respirable and inhalable size ranges. When compared to average safe average respirable ($PM_{2.5}$) concentrations of 0.2 mg/m^3, the bindery average of 0.026292 mg/m^3 was well under the studied safe average at about 13% of the safe studied average. This is represented graphically in Figure 19. Average concentrations of respirable paper dust in the pressroom did not indicate negative respiratory health implications on surrounding employees.

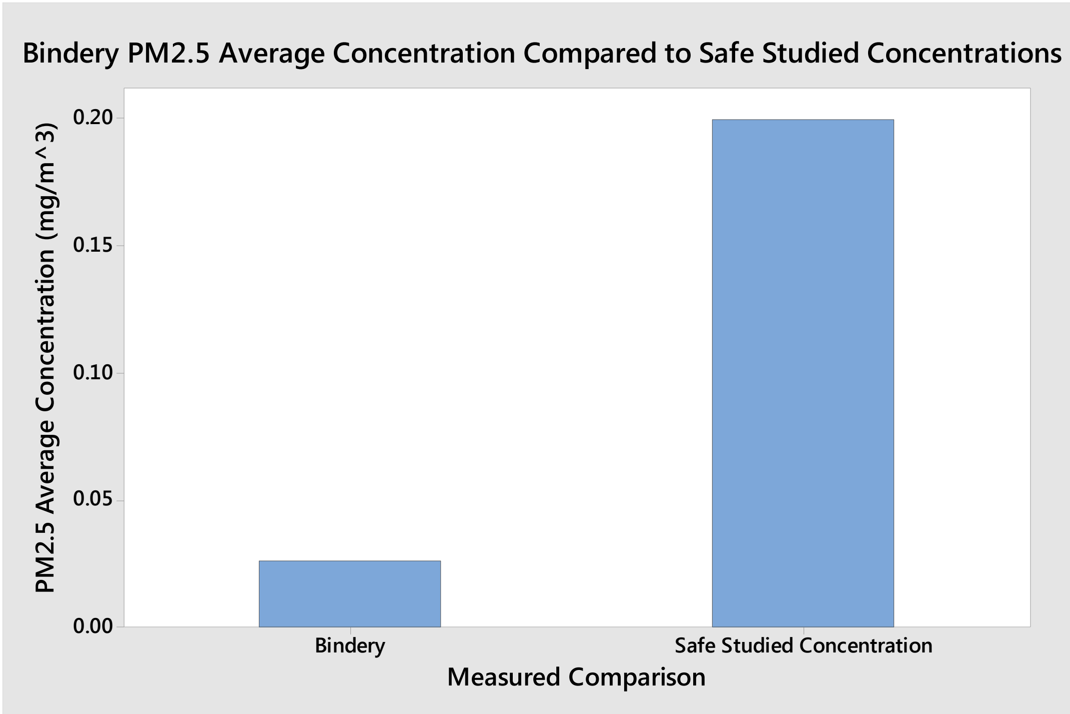

Figure 19. Visual comparison of $PM_{2.5}$ average concentrations in bindery and average safe studied respirable concentrations

Review of PM_{10} concentrations in the bindery compared to safe studied concentrations indicate that employees are not at risk of negative respiratory health implications due to inhalable sized particles. Measured concentrations of PM_{10} in the bindery of 0.031035 mg/m^3 is about 3% of the safe studied concentration of 1 mg/m^3. Figure 20 compares the bindery measured PM_{10} concentrations and safe studied inhalable dust concentrations graphically.

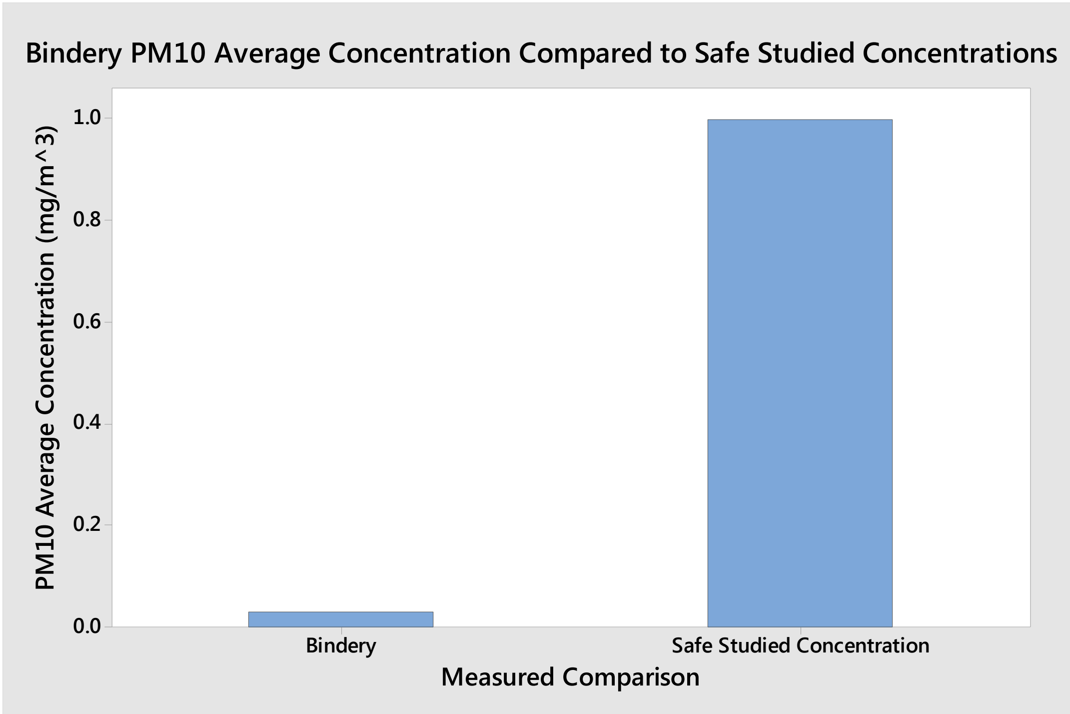

Figure 20. Visual comparison of PM_{10} average concentrations in bindery and average safe studied inhalable concentrations

OSHA. Until 1987, paper dust was regulated by OSHA with limits of 5 mg/m^3 for respirable dust and 15 mg/m^3 for inhalable dust under the list of particulates not otherwise regulated (OSHA, 1987). Comparison to OSHA figures were examined briefly in Table 6.

Table 6.

Collected paper dust average concentrations compared to previous OSHA standard regulating paper dust

Location	PM2.5 Mean (mg/m^3)	PM2.5 Max (mg/m^3)	PM10 Mean (mg/m^3)	PM10 Max (mg/m^3)
Recycling Warehouse	0.3873	3.84	0.5066	6.03
Pressroom	0.020889	0.171	0.028415	0.261
Bindery	0.026292	0.082	0.031035	0.129
Previous OSHA Standard	5	NA	15	NA

Additional comparison to previous OSHA standards were concluded to be unnecessary because of the significant difference between recorded averages and the OSHA average exposure limits for employees. It was notable that even the maximum recordings in both size ranges at all sampled locations in the book production facility were lower than the OSHA average concentration exposure limits.

Process Comparison

Average concentrations in the paper recycling warehouse were significantly higher than the pressroom and bindery as seen in Figure 21. The average $PM_{2.5}$ concentration in the PRW was 18.5 times larger than the average $PM_{2.5}$ in the pressroom and 14.7 times larger than the average $PM_{2.5}$ in the bindery. The average PM_{10} concentration in the PRW was 17.8 times larger than the average PM_{10} concentration in the pressroom and 16.3 times larger than the average PM_{10} concentration in the bindery.

Figure 22 shows a time series of sampling of $PM_{2.5}$ in each process. Figure 23 shows a time series of sampling of PM_{10} in each process.

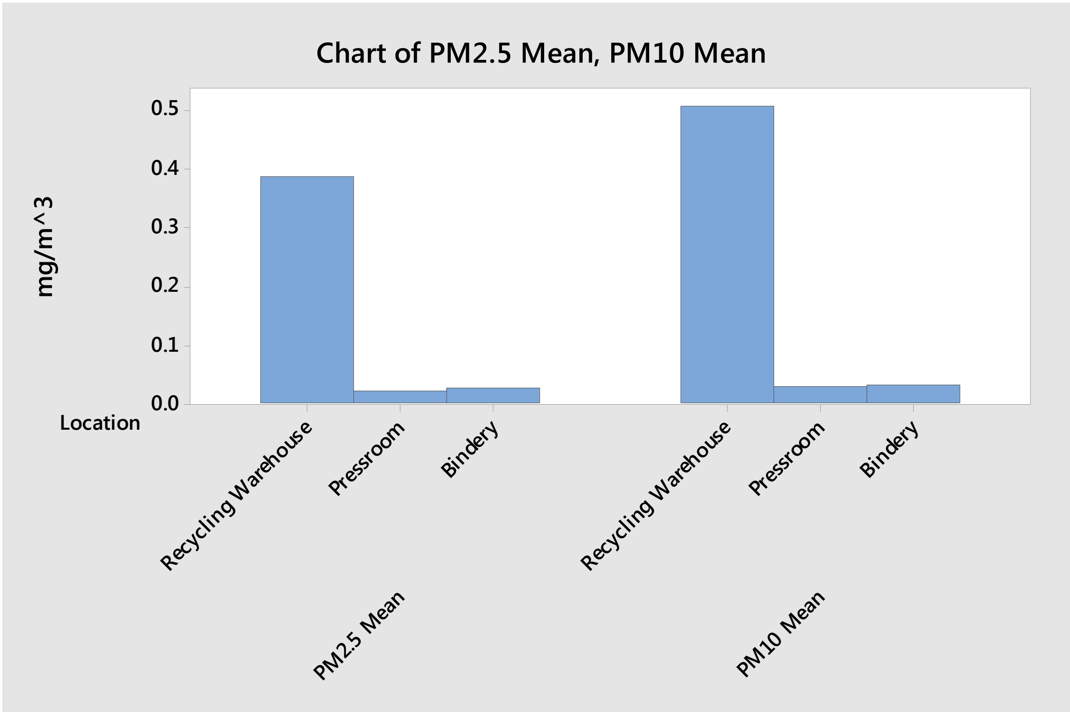

Figure 21. Mean concentrations of all processes compared

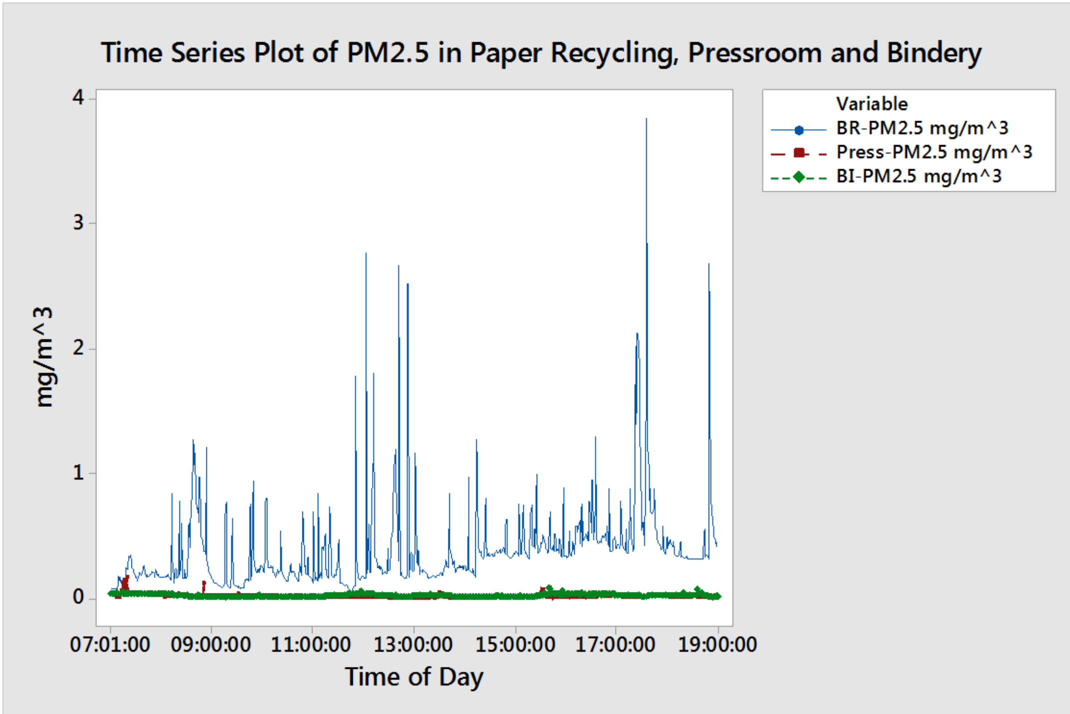

Figure 22. Time series of $PM_{2.5}$ data collected in all processes

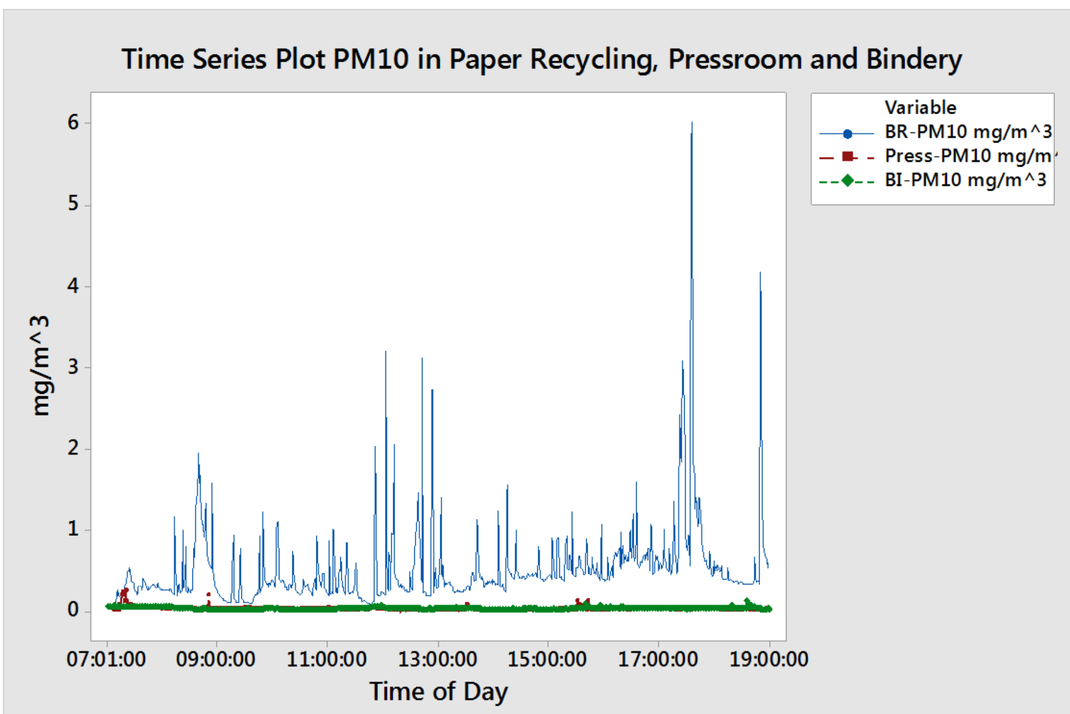

Figure 23. Time series of PM_{10} data collected in all processes

The pressroom and bindery had a much more comparable average concentration of both $PM_{2.5}$ and PM_{10} data. The average concentration of 0.026292 of $PM_{2.5}$ dust in the bindery was 0.005403 mg/m^3 higher than the average concentration of 0.020889 mg/m^3 in the pressroom. The average concentration of 0.031035 mg/m^3 of PM_{10} dust in the bindery was 0.00262 mg/m^3 larger than the average concentration of 0.028415 mg/m^3 in the pressroom. While the pressroom showed a lower overall average concentration of both $PM_{2.5}$ and PM_{10} than the bindery, there were higher individual recordings of both size ranges found in the pressroom than the bindery. The pressroom also had a lower minimum in both size ranges than the bindery, showing a larger range of particle dispersion in the pressroom than the bindery. Figure 24 shows the time series data of the bindery and the pressroom for $PM_{2.5}$ and Figure 25 represents the same data for PM_{10}.

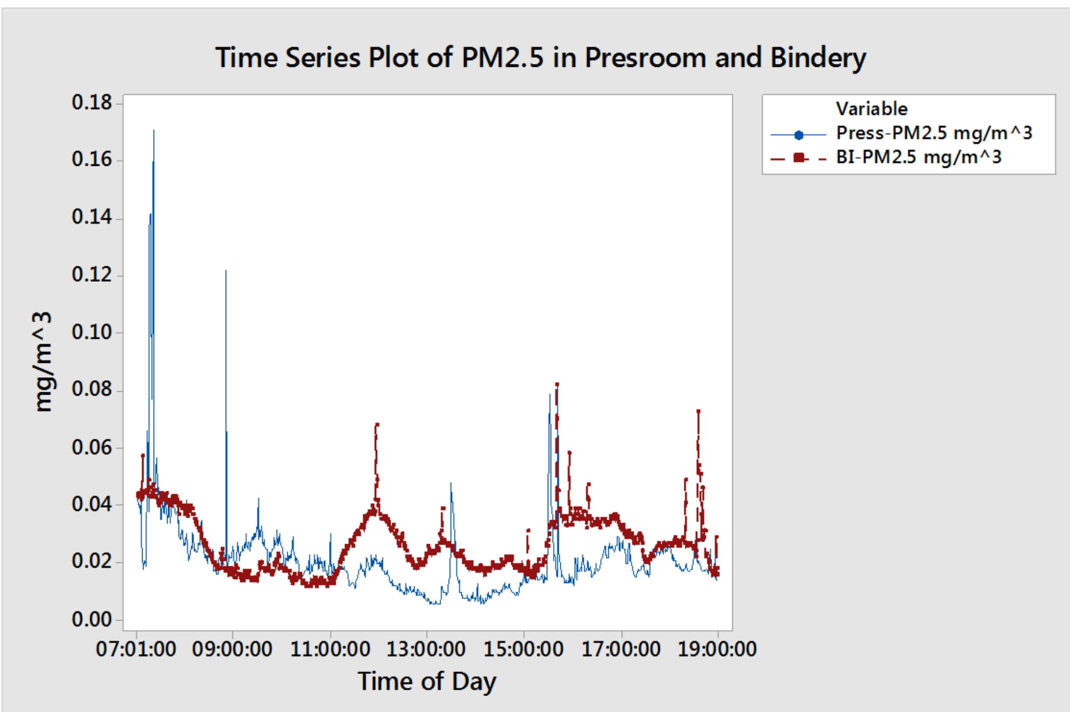

Figure 24. Time series of $PM_{2.5}$ data collected in the pressroom and bindery

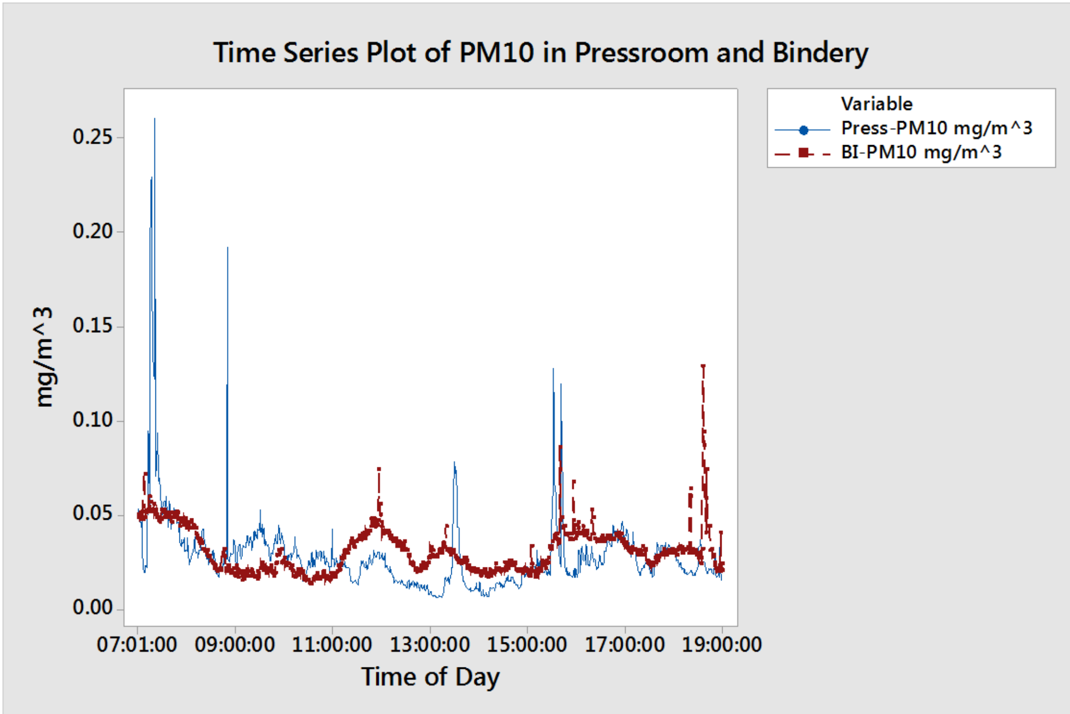

Figure 25. Time series of PM_{10} data collected in the pressroom and bindery

Summary

Collection and interpretation. Data collection in each location was representative of a normal operating day for each process. Basic statistics revealed average, maximum and minimum concentrations for each location throughout the 12 hour shift. The average concentration throughout the shift was used as the primary figure of comparison between each process and to pre-determined safe concentrations for employees. The pressroom and bindery showed averages of both respirable and inhalable paper dusts much lower than the safe concentration levels determined by the researcher and can be designated as processes that do not have negative respiratory health implications on surrounding employees. The paper recycling warehouse had concentration levels of respiratory dusts that slightly exceeded the concentration levels determined by the research to be safe, although larger, inhalable dust particle concentrations were significantly lower than safe levels as determined by the researcher. The bailing process in the paper recycling warehouse is a process that could have negative respiratory health implications on surrounding employees.

All three processes were directly affected by the employees working around them. Most spikes in concentration reading could be linked to an operator activity causing the disturbance of dust from the machine, primarily cleaning. The paper recycling warehouse has significantly higher concentrations than both other processes and is most susceptible to excessive paper dust. The bindery and pressroom had similar concentration levels and all levels were negligible when compared to minimum safe operating concentrations. Overall, the primary book production processes in the facility show dust concentration levels that do not lead the researcher to believe there is an improvement needed on dust collection systems, but additional research may need to be conducted to verify the concentration levels reported in the paper recycling warehouse and how those levels effect the surrounding employees.

Summary and Discussion

Summary

The purpose of this quantitative single subject research was to determine the average concentration levels of inhalable dust ($PM_{2.5}$ and PM_{10}) in suspected problematic areas of a book production facility (Creswell, 2009). The research questions sought to understand if any of the three measured processes; printing, binding or recycling were susceptible to excessive paper dust and if any of these processes could have negative respiratory health implications on surrounding employees. The researcher collected dust concentration data in each location for $PM_{2.5}$ and PM_{10} in one minute increments for one full 12 hour shift at each process. The sampling equipment, a DustTrak DRX 8533, was set up within 3 meters of each piece of equipment involved in the measured process at a height of around 1-2 meters off of the floor. Each day of collection was free of any significant breakdowns or uncommon activities and provided a good sample of a standard operating day in each process.

The pressroom and bindery showed very low average concentration levels for both $PM_{2.5}$ and PM_{10} particle sizes. When compared to average concentrations derived from other paper dust studies, these two process were determined to not reach concentration levels that could have negative respiratory health implications on surrounding employees. The paper recycling warehouse had a much higher average concentration level than the other two processes. When compared to average concentrations derived from other paper dust studies, the respirable concentration of paper dust showed potential for negative respiratory health implications on surrounding employees.

Discussion

Data collected in the bindery and pressroom showed concentration levels so low that it was difficult to draw comparisons to average levels in studies that had shown negative respiratory implications on surrounding employees. The data collected in the paper recycling warehouse showed concentrations much higher than the other processes and made the second research question easy to answer. The first research question proved to be the more difficult question to answer due to lack of previous research as described in the summary of limitations. Most findings were unsurprising to the researcher. The concentrations of the press and bindery were lower than expected, but concentrations under safe limits were expected throughout. The concentrations in the paper recycling warehouse were also mostly unsurprising. The only unexpected portion of the research was that respiratory concentration levels in the paper recycling warehouse proved to be high enough to consider the potential of negative respiratory health implications to surrounding employees. These results prompted further reading into potential safe respirable concentration levels of paper dust by the researcher. No data was found in previously summarized research to indicate a better concentration level to use as a safe respirable level.

Limitations. Data collection could have been improved by spanning over a longer period of time. Although the researcher was not interested in seeing trends over a large span of time, an extended collection period would give a more accurate average daily concentration level to use for comparison and would have balanced out variables such as temperature, humidity, amount of production and special periodic activities that cause levels to rise significantly for short periods of time. The financial ability to have multiple pieces of equipment monitoring for long periods of time was the limiting factor.

Previous research on paper dust was limited, specifically in the book production industry. More reliable data studying potentially harmful concentrations of respirable paper dust would have allowed for a more reliable figure of comparison to data collected in this research. The concentration of 0.2 mg/m^3 was selected from a pilot study (Dahlqvist, 1992) that references that number as the minimum recordable concentration and determined employees had minor respiratory health problems from a combination of inhalable and respirable concentrations of dust. The 0.2 mg/m^3 could be a low estimate to use for a safe concentration level, but a more accurate ulterior concentration level could not be found.

One additional limitation is the difference in the amount of time employees spend around each process. The paper recycling warehouse is only occupied by employees occasionally passing through on forklifts to move material. The exception to this is the one hour spent each shift cleaning the equipment. Time of occupancy in the recorded area could be included in further research and considered in a time weighted average calculation.

Further research. A better understanding of safe concentration levels of paper dust could be gained by incorporating a respiratory health survey to employees working in the sampled processes, specifically the paper recycling warehouse. Comparing employee concentration levels and duration of exposure to reported respiratory health effects could give improved insight to safe concentration levels of respirable and inhalable dusts. This additional research could fill in some of the gaps that the review of literature identified.

Additional detailed research could be conducted on the data collected in each process to compare daily activities to concentration levels. This would require a visual observance of the processes throughout recording. While the data would be valuable, this would also improve employee awareness and enable them to correct any action that may cause additional dust dispersion in the air.

It will be suggested to the studied facility to investigate potential additional mitigation in the paper recycling warehouse. This research should include the verification that offered dust masks and respirators are capable of protecting the employees from the concentrations of paper dust identified in the study. The study should also attempt to identify improved dust control in that process of the book production facility.

APPENDIX

Table_A 1.

Complete set of all collected data for $PM_{2.5}$ and PM_{10} paper dust concentrations

Date (PRW)	Time of Day (all)	PM2.5 mg/m^3 (PRW)	PM10 mg/m^3 (PRW)	Date (Press)	PM2.5 mg/m^3 (Press)	PM10 mg/m^3 (Press)	Date (Binder)	PM2.5 mg/m^3 (Binder)	PM10 mg/m^3 (Binder)
3/9/2017	7:01	0.078	0.087	3/13/2017	0.044	0.054	3/14/2017	0.043	0.049
3/9/2017	7:02	0.08	0.091	3/13/2017	0.04	0.047	3/14/2017	0.044	0.05
3/9/2017	7:03	0.078	0.088	3/13/2017	0.041	0.05	3/14/2017	0.043	0.048
3/9/2017	7:04	0.078	0.087	3/13/2017	0.039	0.046	3/14/2017	0.044	0.051
3/9/2017	7:05	0.079	0.088	3/13/2017	0.037	0.044	3/14/2017	0.045	0.052
3/9/2017	7:06	0.084	0.093	3/13/2017	0.042	0.049	3/14/2017	0.042	0.049
3/9/2017	7:07	0.081	0.091	3/13/2017	0.027	0.029	3/14/2017	0.043	0.048
3/9/2017	7:08	0.078	0.088	3/13/2017	0.019	0.02	3/14/2017	0.057	0.072
3/9/2017	7:09	0.098	0.108	3/13/2017	0.018	0.02	3/14/2017	0.044	0.049
3/9/2017	7:10	0.1	0.114	3/13/2017	0.021	0.024	3/14/2017	0.045	0.051
3/9/2017	7:11	0.194	0.259	3/13/2017	0.02	0.022	3/14/2017	0.045	0.051
3/9/2017	7:12	0.145	0.182	3/13/2017	0.019	0.022	3/14/2017	0.045	0.053
3/9/2017	7:13	0.172	0.218	3/13/2017	0.066	0.092	3/14/2017	0.044	0.052
3/9/2017	7:14	0.135	0.181	3/13/2017	0.063	0.095	3/14/2017	0.049	0.06
3/9/2017	7:15	0.126	0.174	3/13/2017	0.038	0.054	3/14/2017	0.046	0.057
3/9/2017	7:16	0.123	0.168	3/13/2017	0.136	0.19	3/14/2017	0.046	0.057
3/9/2017	7:17	0.138	0.192	3/13/2017	0.142	0.23	3/14/2017	0.043	0.052
3/9/2017	7:18	0.164	0.228	3/13/2017	0.116	0.195	3/14/2017	0.043	0.052
3/9/2017	7:19	0.153	0.211	3/13/2017	0.087	0.134	3/14/2017	0.044	0.052
3/9/2017	7:20	0.244	0.328	3/13/2017	0.077	0.122	3/14/2017	0.047	0.056
3/9/2017	7:21	0.237	0.351	3/13/2017	0.171	0.261	3/14/2017	0.044	0.051
3/9/2017	7:22	0.254	0.372	3/13/2017	0.047	0.077	3/14/2017	0.045	0.053
3/9/2017	7:23	0.347	0.495	3/13/2017	0.046	0.071	3/14/2017	0.043	0.049
3/9/2017	7:24	0.33	0.492	3/13/2017	0.057	0.088	3/14/2017	0.043	0.05
3/9/2017	7:25	0.362	0.548	3/13/2017	0.057	0.094	3/14/2017	0.042	0.049
3/9/2017	7:26	0.297	0.439	3/13/2017	0.044	0.068	3/14/2017	0.041	0.047
3/9/2017	7:27	0.246	0.369	3/13/2017	0.047	0.071	3/14/2017	0.04	0.046
3/9/2017	7:28	0.232	0.35	3/13/2017	0.043	0.065	3/14/2017	0.042	0.049
3/9/2017	7:29	0.229	0.357	3/13/2017	0.04	0.059	3/14/2017	0.041	0.048
3/9/2017	7:30	0.206	0.31	3/13/2017	0.04	0.056	3/14/2017	0.044	0.053
3/9/2017	7:31	0.171	0.246	3/13/2017	0.035	0.05	3/14/2017	0.042	0.052
3/9/2017	7:32	0.172	0.254	3/13/2017	0.041	0.057	3/14/2017	0.044	0.053
3/9/2017	7:33	0.143	0.21	3/13/2017	0.041	0.058	3/14/2017	0.042	0.049

3/9/2017	7:34	0.162	0.232	3/13/2017	0.037	0.049	3/14/2017	0.043	0.05
3/9/2017	7:35	0.205	0.301	3/13/2017	0.045	0.06	3/14/2017	0.042	0.049
3/9/2017	7:36	0.215	0.324	3/13/2017	0.04	0.056	3/14/2017	0.043	0.051
3/9/2017	7:37	0.206	0.297	3/13/2017	0.036	0.048	3/14/2017	0.044	0.051
3/9/2017	7:38	0.187	0.273	3/13/2017	0.034	0.044	3/14/2017	0.041	0.049
3/9/2017	7:39	0.208	0.321	3/13/2017	0.038	0.051	3/14/2017	0.042	0.05
3/9/2017	7:40	0.268	0.405	3/13/2017	0.043	0.058	3/14/2017	0.042	0.051
3/9/2017	7:41	0.268	0.383	3/13/2017	0.034	0.045	3/14/2017	0.04	0.049
3/9/2017	7:42	0.219	0.329	3/13/2017	0.034	0.043	3/14/2017	0.04	0.046
3/9/2017	7:43	0.204	0.313	3/13/2017	0.039	0.048	3/14/2017	0.041	0.049
3/9/2017	7:44	0.172	0.265	3/13/2017	0.039	0.048	3/14/2017	0.043	0.051
3/9/2017	7:45	0.2	0.305	3/13/2017	0.043	0.054	3/14/2017	0.042	0.05
3/9/2017	7:46	0.181	0.268	3/13/2017	0.04	0.052	3/14/2017	0.041	0.049
3/9/2017	7:47	0.184	0.279	3/13/2017	0.039	0.051	3/14/2017	0.041	0.049
3/9/2017	7:48	0.198	0.295	3/13/2017	0.038	0.048	3/14/2017	0.043	0.052
3/9/2017	7:49	0.205	0.316	3/13/2017	0.037	0.046	3/14/2017	0.041	0.048
3/9/2017	7:50	0.223	0.33	3/13/2017	0.038	0.047	3/14/2017	0.042	0.051
3/9/2017	7:51	0.213	0.32	3/13/2017	0.034	0.041	3/14/2017	0.04	0.048
3/9/2017	7:52	0.219	0.322	3/13/2017	0.035	0.044	3/14/2017	0.037	0.044
3/9/2017	7:53	0.219	0.316	3/13/2017	0.029	0.036	3/14/2017	0.041	0.048
3/9/2017	7:54	0.181	0.278	3/13/2017	0.028	0.033	3/14/2017	0.04	0.047
3/9/2017	7:55	0.232	0.348	3/13/2017	0.03	0.037	3/14/2017	0.04	0.048
3/9/2017	7:56	0.192	0.293	3/13/2017	0.03	0.035	3/14/2017	0.039	0.046
3/9/2017	7:57	0.196	0.298	3/13/2017	0.032	0.038	3/14/2017	0.039	0.045
3/9/2017	7:58	0.201	0.305	3/13/2017	0.027	0.031	3/14/2017	0.04	0.048
3/9/2017	7:59	0.176	0.269	3/13/2017	0.026	0.031	3/14/2017	0.038	0.046
3/9/2017	8:00	0.181	0.275	3/13/2017	0.027	0.032	3/14/2017	0.037	0.044
3/9/2017	8:01	0.181	0.265	3/13/2017	0.026	0.031	3/14/2017	0.037	0.043
3/9/2017	8:02	0.183	0.265	3/13/2017	0.03	0.038	3/14/2017	0.04	0.046
3/9/2017	8:03	0.183	0.271	3/13/2017	0.023	0.027	3/14/2017	0.036	0.043
3/9/2017	8:04	0.182	0.269	3/13/2017	0.021	0.024	3/14/2017	0.038	0.043
3/9/2017	8:05	0.18	0.256	3/13/2017	0.022	0.026	3/14/2017	0.04	0.046
3/9/2017	8:06	0.179	0.265	3/13/2017	0.022	0.026	3/14/2017	0.04	0.047
3/9/2017	8:07	0.187	0.27	3/13/2017	0.025	0.029	3/14/2017	0.04	0.046
3/9/2017	8:08	0.173	0.248	3/13/2017	0.026	0.032	3/14/2017	0.039	0.045
3/9/2017	8:09	0.198	0.283	3/13/2017	0.025	0.031	3/14/2017	0.037	0.044
3/9/2017	8:10	0.189	0.271	3/13/2017	0.031	0.039	3/14/2017	0.037	0.043
3/9/2017	8:11	0.172	0.246	3/13/2017	0.026	0.032	3/14/2017	0.037	0.043
3/9/2017	8:12	0.157	0.229	3/13/2017	0.024	0.03	3/14/2017	0.035	0.04
3/9/2017	8:13	0.153	0.209	3/13/2017	0.025	0.031	3/14/2017	0.034	0.039
3/9/2017	8:14	0.843	1.17	3/13/2017	0.024	0.03	3/14/2017	0.034	0.038
3/9/2017	8:15	0.302	0.428	3/13/2017	0.024	0.028	3/14/2017	0.033	0.038

3/9/2017	8:16	0.17	0.248	3/13/2017	0.026	0.032	3/14/2017	0.032	0.036
3/9/2017	8:17	0.133	0.189	3/13/2017	0.027	0.032	3/14/2017	0.032	0.037
3/9/2017	8:18	0.247	0.345	3/13/2017	0.026	0.032	3/14/2017	0.031	0.035
3/9/2017	8:19	0.232	0.325	3/13/2017	0.03	0.036	3/14/2017	0.03	0.035
3/9/2017	8:20	0.169	0.233	3/13/2017	0.035	0.043	3/14/2017	0.029	0.032
3/9/2017	8:21	0.182	0.245	3/13/2017	0.032	0.043	3/14/2017	0.028	0.032
3/9/2017	8:22	0.189	0.266	3/13/2017	0.03	0.038	3/14/2017	0.027	0.031
3/9/2017	8:23	0.794	0.994	3/13/2017	0.026	0.034	3/14/2017	0.028	0.031
3/9/2017	8:24	0.2	0.28	3/13/2017	0.023	0.029	3/14/2017	0.027	0.031
3/9/2017	8:25	0.331	0.435	3/13/2017	0.022	0.028	3/14/2017	0.026	0.03
3/9/2017	8:26	0.606	0.793	3/13/2017	0.022	0.027	3/14/2017	0.027	0.031
3/9/2017	8:27	0.171	0.246	3/13/2017	0.023	0.027	3/14/2017	0.025	0.028
3/9/2017	8:28	0.168	0.235	3/13/2017	0.02	0.024	3/14/2017	0.024	0.028
3/9/2017	8:29	0.232	0.298	3/13/2017	0.022	0.026	3/14/2017	0.024	0.028
3/9/2017	8:30	0.181	0.254	3/13/2017	0.024	0.029	3/14/2017	0.023	0.026
3/9/2017	8:31	0.17	0.234	3/13/2017	0.023	0.028	3/14/2017	0.022	0.026
3/9/2017	8:32	0.187	0.257	3/13/2017	0.025	0.032	3/14/2017	0.022	0.025
3/9/2017	8:33	0.184	0.255	3/13/2017	0.022	0.026	3/14/2017	0.021	0.024
3/9/2017	8:34	0.611	0.788	3/13/2017	0.025	0.03	3/14/2017	0.02	0.022
3/9/2017	8:35	0.421	0.62	3/13/2017	0.024	0.03	3/14/2017	0.02	0.023
3/9/2017	8:36	0.596	0.903	3/13/2017	0.017	0.019	3/14/2017	0.02	0.023
3/9/2017	8:37	0.821	1.27	3/13/2017	0.018	0.021	3/14/2017	0.019	0.021
3/9/2017	8:38	0.906	1.4	3/13/2017	0.017	0.02	3/14/2017	0.018	0.02
3/9/2017	8:39	1.12	1.72	3/13/2017	0.017	0.019	3/14/2017	0.019	0.021
3/9/2017	8:40	1.28	1.95	3/13/2017	0.016	0.017	3/14/2017	0.018	0.021
3/9/2017	8:41	1.02	1.58	3/13/2017	0.016	0.018	3/14/2017	0.019	0.022
3/9/2017	8:42	1.17	1.68	3/13/2017	0.021	0.024	3/14/2017	0.018	0.021
3/9/2017	8:43	0.761	1.16	3/13/2017	0.022	0.025	3/14/2017	0.018	0.021
3/9/2017	8:44	0.706	1.06	3/13/2017	0.021	0.026	3/14/2017	0.023	0.03
3/9/2017	8:45	0.724	1.08	3/13/2017	0.019	0.022	3/14/2017	0.021	0.029
3/9/2017	8:46	0.607	0.918	3/13/2017	0.02	0.024	3/14/2017	0.025	0.032
3/9/2017	8:47	0.985	1.34	3/13/2017	0.024	0.031	3/14/2017	0.021	0.028
3/9/2017	8:48	0.706	0.98	3/13/2017	0.024	0.031	3/14/2017	0.018	0.02
3/9/2017	8:49	0.497	0.737	3/13/2017	0.024	0.031	3/14/2017	0.018	0.022
3/9/2017	8:50	0.474	0.697	3/13/2017	0.021	0.027	3/14/2017	0.017	0.02
3/9/2017	8:51	0.408	0.602	3/13/2017	0.122	0.192	3/14/2017	0.018	0.021
3/9/2017	8:52	0.383	0.557	3/13/2017	0.022	0.027	3/14/2017	0.018	0.023
3/9/2017	8:53	0.378	0.568	3/13/2017	0.019	0.025	3/14/2017	0.018	0.021
3/9/2017	8:54	0.359	0.515	3/13/2017	0.021	0.026	3/14/2017	0.017	0.02
3/9/2017	8:55	1.22	1.57	3/13/2017	0.023	0.03	3/14/2017	0.016	0.019
3/9/2017	8:56	0.305	0.429	3/13/2017	0.022	0.029	3/14/2017	0.017	0.019
3/9/2017	8:57	0.247	0.338	3/13/2017	0.022	0.029	3/14/2017	0.018	0.022

3/9/2017	8:58	0.229	0.32	3/13/2017	0.023	0.031	3/14/2017	0.016	0.019
3/9/2017	8:59	0.203	0.287	3/13/2017	0.026	0.037	3/14/2017	0.016	0.019
3/9/2017	9:00	0.172	0.242	3/13/2017	0.025	0.033	3/14/2017	0.015	0.018
3/9/2017	9:01	0.167	0.226	3/13/2017	0.019	0.026	3/14/2017	0.017	0.022
3/9/2017	9:02	0.153	0.205	3/13/2017	0.018	0.024	3/14/2017	0.019	0.023
3/9/2017	9:03	0.14	0.188	3/13/2017	0.021	0.028	3/14/2017	0.015	0.017
3/9/2017	9:04	0.131	0.172	3/13/2017	0.023	0.033	3/14/2017	0.018	0.021
3/9/2017	9:05	0.126	0.158	3/13/2017	0.025	0.033	3/14/2017	0.016	0.019
3/9/2017	9:06	0.126	0.158	3/13/2017	0.027	0.035	3/14/2017	0.016	0.019
3/9/2017	9:07	0.118	0.145	3/13/2017	0.023	0.029	3/14/2017	0.016	0.02
3/9/2017	9:08	0.112	0.138	3/13/2017	0.021	0.027	3/14/2017	0.016	0.019
3/9/2017	9:09	0.108	0.13	3/13/2017	0.024	0.034	3/14/2017	0.014	0.015
3/9/2017	9:10	0.104	0.122	3/13/2017	0.024	0.033	3/14/2017	0.015	0.017
3/9/2017	9:11	0.101	0.123	3/13/2017	0.026	0.034	3/14/2017	0.014	0.016
3/9/2017	9:12	0.1	0.122	3/13/2017	0.024	0.033	3/14/2017	0.015	0.018
3/9/2017	9:13	0.097	0.115	3/13/2017	0.025	0.033	3/14/2017	0.017	0.02
3/9/2017	9:14	0.096	0.115	3/13/2017	0.027	0.036	3/14/2017	0.016	0.019
3/9/2017	9:15	0.104	0.121	3/13/2017	0.025	0.036	3/14/2017	0.016	0.021
3/9/2017	9:16	0.124	0.157	3/13/2017	0.03	0.04	3/14/2017	0.015	0.018
3/9/2017	9:17	0.661	0.783	3/13/2017	0.026	0.035	3/14/2017	0.017	0.02
3/9/2017	9:18	0.772	0.942	3/13/2017	0.025	0.034	3/14/2017	0.015	0.018
3/9/2017	9:19	0.13	0.154	3/13/2017	0.027	0.039	3/14/2017	0.015	0.018
3/9/2017	9:20	0.107	0.128	3/13/2017	0.027	0.036	3/14/2017	0.017	0.021
3/9/2017	9:21	0.101	0.12	3/13/2017	0.024	0.032	3/14/2017	0.015	0.019
3/9/2017	9:22	0.097	0.114	3/13/2017	0.027	0.037	3/14/2017	0.014	0.018
3/9/2017	9:23	0.099	0.118	3/13/2017	0.029	0.041	3/14/2017	0.014	0.017
3/9/2017	9:24	0.096	0.11	3/13/2017	0.028	0.037	3/14/2017	0.014	0.017
3/9/2017	9:25	0.649	0.774	3/13/2017	0.03	0.042	3/14/2017	0.015	0.018
3/9/2017	9:26	0.393	0.507	3/13/2017	0.028	0.038	3/14/2017	0.014	0.017
3/9/2017	9:27	0.136	0.157	3/13/2017	0.031	0.04	3/14/2017	0.014	0.016
3/9/2017	9:28	0.115	0.135	3/13/2017	0.029	0.037	3/14/2017	0.015	0.02
3/9/2017	9:29	0.106	0.125	3/13/2017	0.033	0.043	3/14/2017	0.014	0.017
3/9/2017	9:30	0.107	0.124	3/13/2017	0.031	0.042	3/14/2017	0.016	0.019
3/9/2017	9:31	0.103	0.119	3/13/2017	0.043	0.053	3/14/2017	0.016	0.022
3/9/2017	9:32	0.098	0.115	3/13/2017	0.028	0.041	3/14/2017	0.02	0.025
3/9/2017	9:33	0.101	0.118	3/13/2017	0.032	0.045	3/14/2017	0.018	0.023
3/9/2017	9:34	0.095	0.109	3/13/2017	0.029	0.039	3/14/2017	0.018	0.021
3/9/2017	9:35	0.083	0.095	3/13/2017	0.033	0.044	3/14/2017	0.02	0.023
3/9/2017	9:36	0.088	0.101	3/13/2017	0.026	0.036	3/14/2017	0.018	0.022
3/9/2017	9:37	0.089	0.101	3/13/2017	0.026	0.034	3/14/2017	0.018	0.021
3/9/2017	9:38	0.094	0.107	3/13/2017	0.028	0.037	3/14/2017	0.017	0.02
3/9/2017	9:39	0.089	0.102	3/13/2017	0.026	0.034	3/14/2017	0.017	0.019

3/9/2017	9:40	0.127	0.163	3/13/2017	0.025	0.034	3/14/2017	0.018	0.022
3/9/2017	9:41	0.161	0.212	3/13/2017	0.025	0.035	3/14/2017	0.017	0.02
3/9/2017	9:42	0.154	0.201	3/13/2017	0.025	0.034	3/14/2017	0.018	0.021
3/9/2017	9:43	0.162	0.216	3/13/2017	0.02	0.026	3/14/2017	0.019	0.023
3/9/2017	9:44	0.163	0.218	3/13/2017	0.021	0.026	3/14/2017	0.018	0.022
3/9/2017	9:45	0.145	0.202	3/13/2017	0.024	0.03	3/14/2017	0.017	0.019
3/9/2017	9:46	0.759	0.937	3/13/2017	0.023	0.029	3/14/2017	0.017	0.019
3/9/2017	9:47	0.158	0.22	3/13/2017	0.022	0.03	3/14/2017	0.017	0.02
3/9/2017	9:48	0.196	0.283	3/13/2017	0.025	0.036	3/14/2017	0.016	0.018
3/9/2017	9:49	0.224	0.319	3/13/2017	0.025	0.035	3/14/2017	0.017	0.019
3/9/2017	9:50	0.948	1.23	3/13/2017	0.029	0.04	3/14/2017	0.02	0.024
3/9/2017	9:51	0.35	0.482	3/13/2017	0.027	0.037	3/14/2017	0.019	0.025
3/9/2017	9:52	0.281	0.4	3/13/2017	0.026	0.035	3/14/2017	0.021	0.029
3/9/2017	9:53	0.256	0.354	3/13/2017	0.027	0.036	3/14/2017	0.021	0.029
3/9/2017	9:54	0.217	0.313	3/13/2017	0.032	0.045	3/14/2017	0.022	0.031
3/9/2017	9:55	0.239	0.342	3/13/2017	0.026	0.035	3/14/2017	0.023	0.03
3/9/2017	9:56	0.212	0.31	3/13/2017	0.026	0.036	3/14/2017	0.022	0.032
3/9/2017	9:57	0.247	0.353	3/13/2017	0.03	0.041	3/14/2017	0.018	0.025
3/9/2017	9:58	0.217	0.312	3/13/2017	0.028	0.04	3/14/2017	0.018	0.026
3/9/2017	9:59	0.273	0.39	3/13/2017	0.026	0.036	3/14/2017	0.019	0.026
3/9/2017	10:00	0.273	0.39	3/13/2017	0.026	0.036	3/14/2017	0.018	0.025
3/9/2017	10:01	0.258	0.383	3/13/2017	0.025	0.034	3/14/2017	0.018	0.027
3/9/2017	10:02	0.208	0.305	3/13/2017	0.02	0.025	3/14/2017	0.017	0.023
3/9/2017	10:03	0.241	0.373	3/13/2017	0.02	0.026	3/14/2017	0.018	0.025
3/9/2017	10:04	0.324	0.485	3/13/2017	0.019	0.024	3/14/2017	0.017	0.024
3/9/2017	10:05	0.777	1.02	3/13/2017	0.022	0.029	3/14/2017	0.017	0.024
3/9/2017	10:06	0.81	1.11	3/13/2017	0.021	0.026	3/14/2017	0.017	0.024
3/9/2017	10:07	0.342	0.465	3/13/2017	0.024	0.029	3/14/2017	0.017	0.022
3/9/2017	10:08	0.268	0.386	3/13/2017	0.022	0.03	3/14/2017	0.017	0.022
3/9/2017	10:09	0.253	0.369	3/13/2017	0.021	0.026	3/14/2017	0.017	0.023
3/9/2017	10:10	0.251	0.364	3/13/2017	0.023	0.029	3/14/2017	0.015	0.021
3/9/2017	10:11	0.273	0.396	3/13/2017	0.022	0.029	3/14/2017	0.015	0.02
3/9/2017	10:12	0.248	0.363	3/13/2017	0.022	0.031	3/14/2017	0.014	0.018
3/9/2017	10:13	0.259	0.368	3/13/2017	0.024	0.031	3/14/2017	0.013	0.017
3/9/2017	10:14	0.219	0.308	3/13/2017	0.029	0.039	3/14/2017	0.014	0.017
3/9/2017	10:15	0.209	0.304	3/13/2017	0.025	0.034	3/14/2017	0.016	0.019
3/9/2017	10:16	0.197	0.273	3/13/2017	0.023	0.032	3/14/2017	0.014	0.018
3/9/2017	10:17	0.183	0.264	3/13/2017	0.02	0.028	3/14/2017	0.015	0.019
3/9/2017	10:18	0.228	0.316	3/13/2017	0.022	0.029	3/14/2017	0.015	0.021
3/9/2017	10:19	0.239	0.33	3/13/2017	0.021	0.027	3/14/2017	0.015	0.019
3/9/2017	10:20	0.203	0.287	3/13/2017	0.021	0.028	3/14/2017	0.015	0.02
3/9/2017	10:21	0.221	0.314	3/13/2017	0.019	0.024	3/14/2017	0.016	0.021

3/9/2017	10:22	0.221	0.312	3/13/2017	0.017	0.021	3/14/2017	0.016	0.019
3/9/2017	10:23	0.544	0.747	3/13/2017	0.014	0.016	3/14/2017	0.016	0.02
3/9/2017	10:24	0.255	0.359	3/13/2017	0.014	0.015	3/14/2017	0.014	0.018
3/9/2017	10:25	0.227	0.331	3/13/2017	0.013	0.015	3/14/2017	0.013	0.016
3/9/2017	10:26	0.192	0.272	3/13/2017	0.015	0.019	3/14/2017	0.013	0.016
3/9/2017	10:27	0.165	0.24	3/13/2017	0.016	0.019	3/14/2017	0.014	0.017
3/9/2017	10:28	0.161	0.235	3/13/2017	0.016	0.019	3/14/2017	0.013	0.015
3/9/2017	10:29	0.156	0.221	3/13/2017	0.017	0.022	3/14/2017	0.012	0.015
3/9/2017	10:30	0.142	0.206	3/13/2017	0.018	0.021	3/14/2017	0.013	0.015
3/9/2017	10:31	0.143	0.216	3/13/2017	0.019	0.026	3/14/2017	0.012	0.014
3/9/2017	10:32	0.16	0.228	3/13/2017	0.017	0.022	3/14/2017	0.012	0.014
3/9/2017	10:33	0.202	0.294	3/13/2017	0.017	0.023	3/14/2017	0.012	0.014
3/9/2017	10:34	0.283	0.387	3/13/2017	0.023	0.031	3/14/2017	0.012	0.014
3/9/2017	10:35	0.213	0.297	3/13/2017	0.016	0.023	3/14/2017	0.012	0.015
3/9/2017	10:36	0.214	0.303	3/13/2017	0.017	0.023	3/14/2017	0.013	0.016
3/9/2017	10:37	0.228	0.323	3/13/2017	0.02	0.028	3/14/2017	0.014	0.017
3/9/2017	10:38	0.224	0.329	3/13/2017	0.017	0.023	3/14/2017	0.013	0.016
3/9/2017	10:39	0.215	0.306	3/13/2017	0.019	0.026	3/14/2017	0.013	0.016
3/9/2017	10:40	0.198	0.29	3/13/2017	0.02	0.027	3/14/2017	0.014	0.018
3/9/2017	10:41	0.183	0.257	3/13/2017	0.023	0.032	3/14/2017	0.015	0.019
3/9/2017	10:42	0.171	0.239	3/13/2017	0.02	0.027	3/14/2017	0.014	0.018
3/9/2017	10:43	0.142	0.196	3/13/2017	0.02	0.03	3/14/2017	0.012	0.016
3/9/2017	10:44	0.165	0.234	3/13/2017	0.023	0.031	3/14/2017	0.013	0.016
3/9/2017	10:45	0.244	0.346	3/13/2017	0.021	0.031	3/14/2017	0.013	0.017
3/9/2017	10:46	0.291	0.415	3/13/2017	0.018	0.026	3/14/2017	0.013	0.017
3/9/2017	10:47	0.203	0.288	3/13/2017	0.022	0.031	3/14/2017	0.013	0.017
3/9/2017	10:48	0.19	0.266	3/13/2017	0.02	0.028	3/14/2017	0.015	0.02
3/9/2017	10:49	0.702	0.93	3/13/2017	0.02	0.028	3/14/2017	0.015	0.019
3/9/2017	10:50	0.374	0.506	3/13/2017	0.021	0.031	3/14/2017	0.013	0.018
3/9/2017	10:51	0.262	0.369	3/13/2017	0.017	0.024	3/14/2017	0.014	0.018
3/9/2017	10:52	0.268	0.371	3/13/2017	0.018	0.024	3/14/2017	0.013	0.016
3/9/2017	10:53	0.2	0.292	3/13/2017	0.021	0.028	3/14/2017	0.014	0.018
3/9/2017	10:54	0.205	0.302	3/13/2017	0.017	0.025	3/14/2017	0.013	0.017
3/9/2017	10:55	0.333	0.473	3/13/2017	0.018	0.025	3/14/2017	0.013	0.016
3/9/2017	10:56	0.347	0.476	3/13/2017	0.015	0.02	3/14/2017	0.012	0.015
3/9/2017	10:57	0.195	0.28	3/13/2017	0.016	0.023	3/14/2017	0.013	0.016
3/9/2017	10:58	0.182	0.256	3/13/2017	0.016	0.023	3/14/2017	0.015	0.019
3/9/2017	10:59	0.167	0.243	3/13/2017	0.018	0.026	3/14/2017	0.013	0.017
3/9/2017	11:00	0.165	0.223	3/13/2017	0.03	0.043	3/14/2017	0.014	0.018
3/9/2017	11:01	0.134	0.187	3/13/2017	0.019	0.027	3/14/2017	0.014	0.017
3/9/2017	11:02	0.708	0.865	3/13/2017	0.02	0.027	3/14/2017	0.015	0.019
3/9/2017	11:03	0.153	0.211	3/13/2017	0.016	0.023	3/14/2017	0.013	0.017

3/9/2017	11:04	0.158	0.22	3/13/2017	0.018	0.025	3/14/2017	0.014	0.019
3/9/2017	11:05	0.181	0.238	3/13/2017	0.02	0.028	3/14/2017	0.015	0.02
3/9/2017	11:06	0.145	0.202	3/13/2017	0.018	0.025	3/14/2017	0.016	0.02
3/9/2017	11:07	0.849	1.02	3/13/2017	0.018	0.024	3/14/2017	0.017	0.023
3/9/2017	11:08	0.416	0.517	3/13/2017	0.017	0.024	3/14/2017	0.016	0.021
3/9/2017	11:09	0.17	0.225	3/13/2017	0.019	0.026	3/14/2017	0.017	0.023
3/9/2017	11:10	0.208	0.284	3/13/2017	0.02	0.029	3/14/2017	0.018	0.024
3/9/2017	11:11	0.207	0.279	3/13/2017	0.019	0.028	3/14/2017	0.02	0.027
3/9/2017	11:12	0.167	0.219	3/13/2017	0.018	0.026	3/14/2017	0.021	0.028
3/9/2017	11:13	0.415	0.523	3/13/2017	0.018	0.023	3/14/2017	0.02	0.027
3/9/2017	11:14	0.397	0.513	3/13/2017	0.019	0.024	3/14/2017	0.023	0.031
3/9/2017	11:15	0.52	0.664	3/13/2017	0.019	0.025	3/14/2017	0.021	0.027
3/9/2017	11:16	0.236	0.298	3/13/2017	0.018	0.023	3/14/2017	0.023	0.031
3/9/2017	11:17	0.241	0.3	3/13/2017	0.019	0.024	3/14/2017	0.024	0.031
3/9/2017	11:18	0.195	0.251	3/13/2017	0.018	0.022	3/14/2017	0.023	0.03
3/9/2017	11:19	0.16	0.202	3/13/2017	0.017	0.022	3/14/2017	0.024	0.032
3/9/2017	11:20	0.171	0.218	3/13/2017	0.017	0.022	3/14/2017	0.025	0.034
3/9/2017	11:21	0.737	0.862	3/13/2017	0.017	0.021	3/14/2017	0.026	0.035
3/9/2017	11:22	0.307	0.354	3/13/2017	0.014	0.016	3/14/2017	0.026	0.036
3/9/2017	11:23	0.207	0.242	3/13/2017	0.012	0.015	3/14/2017	0.027	0.037
3/9/2017	11:24	0.173	0.209	3/13/2017	0.012	0.015	3/14/2017	0.028	0.038
3/9/2017	11:25	0.179	0.221	3/13/2017	0.012	0.014	3/14/2017	0.028	0.035
3/9/2017	11:26	0.18	0.22	3/13/2017	0.013	0.015	3/14/2017	0.027	0.034
3/9/2017	11:27	0.196	0.241	3/13/2017	0.013	0.015	3/14/2017	0.028	0.036
3/9/2017	11:28	0.19	0.231	3/13/2017	0.013	0.015	3/14/2017	0.026	0.033
3/9/2017	11:29	0.239	0.291	3/13/2017	0.013	0.016	3/14/2017	0.029	0.036
3/9/2017	11:30	0.234	0.286	3/13/2017	0.012	0.014	3/14/2017	0.028	0.036
3/9/2017	11:31	0.478	0.589	3/13/2017	0.011	0.013	3/14/2017	0.03	0.037
3/9/2017	11:32	0.315	0.393	3/13/2017	0.012	0.016	3/14/2017	0.03	0.037
3/9/2017	11:33	0.198	0.244	3/13/2017	0.014	0.018	3/14/2017	0.031	0.039
3/9/2017	11:34	0.133	0.161	3/13/2017	0.015	0.019	3/14/2017	0.03	0.037
3/9/2017	11:35	0.135	0.166	3/13/2017	0.018	0.026	3/14/2017	0.03	0.038
3/9/2017	11:36	0.126	0.152	3/13/2017	0.018	0.024	3/14/2017	0.032	0.039
3/9/2017	11:37	0.121	0.148	3/13/2017	0.018	0.026	3/14/2017	0.032	0.04
3/9/2017	11:38	0.103	0.122	3/13/2017	0.02	0.026	3/14/2017	0.032	0.039
3/9/2017	11:39	0.106	0.128	3/13/2017	0.018	0.024	3/14/2017	0.033	0.041
3/9/2017	11:40	0.12	0.14	3/13/2017	0.017	0.023	3/14/2017	0.033	0.041
3/9/2017	11:41	0.113	0.132	3/13/2017	0.017	0.022	3/14/2017	0.032	0.038
3/9/2017	11:42	0.1	0.119	3/13/2017	0.018	0.025	3/14/2017	0.036	0.042
3/9/2017	11:43	0.096	0.112	3/13/2017	0.015	0.021	3/14/2017	0.034	0.04
3/9/2017	11:44	0.087	0.101	3/13/2017	0.018	0.025	3/14/2017	0.035	0.042
3/9/2017	11:45	0.082	0.097	3/13/2017	0.019	0.027	3/14/2017	0.036	0.042

3/9/2017	11:46	0.075	0.088	3/13/2017	0.022	0.029	3/14/2017	0.036	0.042
3/9/2017	11:47	0.063	0.072	3/13/2017	0.02	0.027	3/14/2017	0.037	0.044
3/9/2017	11:48	0.08	0.091	3/13/2017	0.017	0.024	3/14/2017	0.038	0.048
3/9/2017	11:49	0.096	0.11	3/13/2017	0.018	0.024	3/14/2017	0.037	0.045
3/9/2017	11:50	0.106	0.127	3/13/2017	0.019	0.028	3/14/2017	0.037	0.046
3/9/2017	11:51	0.101	0.123	3/13/2017	0.023	0.032	3/14/2017	0.038	0.046
3/9/2017	11:52	1.78	2.04	3/13/2017	0.019	0.029	3/14/2017	0.04	0.048
3/9/2017	11:53	0.295	0.361	3/13/2017	0.021	0.029	3/14/2017	0.038	0.044
3/9/2017	11:54	0.166	0.203	3/13/2017	0.02	0.028	3/14/2017	0.037	0.044
3/9/2017	11:55	0.167	0.2	3/13/2017	0.022	0.031	3/14/2017	0.038	0.045
3/9/2017	11:56	0.158	0.195	3/13/2017	0.021	0.03	3/14/2017	0.042	0.047
3/9/2017	11:57	0.153	0.196	3/13/2017	0.023	0.031	3/14/2017	0.068	0.074
3/9/2017	11:58	0.176	0.229	3/13/2017	0.02	0.027	3/14/2017	0.049	0.056
3/9/2017	11:59	0.178	0.237	3/13/2017	0.02	0.028	3/14/2017	0.042	0.05
3/9/2017	12:00	0.185	0.234	3/13/2017	0.02	0.028	3/14/2017	0.04	0.046
3/9/2017	12:01	0.182	0.23	3/13/2017	0.021	0.03	3/14/2017	0.037	0.044
3/9/2017	12:02	0.169	0.211	3/13/2017	0.019	0.027	3/14/2017	0.035	0.04
3/9/2017	12:03	0.165	0.202	3/13/2017	0.021	0.028	3/14/2017	0.035	0.042
3/9/2017	12:04	2.76	3.2	3/13/2017	0.018	0.026	3/14/2017	0.035	0.041
3/9/2017	12:05	0.258	0.307	3/13/2017	0.022	0.03	3/14/2017	0.035	0.042
3/9/2017	12:06	0.196	0.237	3/13/2017	0.017	0.022	3/14/2017	0.036	0.042
3/9/2017	12:07	0.593	0.719	3/13/2017	0.017	0.024	3/14/2017	0.035	0.041
3/9/2017	12:08	0.493	0.595	3/13/2017	0.016	0.021	3/14/2017	0.036	0.042
3/9/2017	12:09	0.219	0.266	3/13/2017	0.016	0.021	3/14/2017	0.035	0.041
3/9/2017	12:10	0.812	0.971	3/13/2017	0.016	0.02	3/14/2017	0.035	0.039
3/9/2017	12:11	0.796	0.941	3/13/2017	0.018	0.023	3/14/2017	0.034	0.038
3/9/2017	12:12	1.11	1.28	3/13/2017	0.016	0.02	3/14/2017	0.034	0.039
3/9/2017	12:13	1.81	2.06	3/13/2017	0.015	0.02	3/14/2017	0.033	0.038
3/9/2017	12:14	0.387	0.459	3/13/2017	0.014	0.018	3/14/2017	0.032	0.037
3/9/2017	12:15	0.33	0.392	3/13/2017	0.013	0.017	3/14/2017	0.031	0.036
3/9/2017	12:16	0.327	0.394	3/13/2017	0.014	0.017	3/14/2017	0.032	0.036
3/9/2017	12:17	0.268	0.33	3/13/2017	0.012	0.014	3/14/2017	0.033	0.038
3/9/2017	12:18	0.25	0.304	3/13/2017	0.013	0.016	3/14/2017	0.033	0.037
3/9/2017	12:19	0.273	0.331	3/13/2017	0.012	0.015	3/14/2017	0.03	0.034
3/9/2017	12:20	0.251	0.303	3/13/2017	0.012	0.014	3/14/2017	0.03	0.034
3/9/2017	12:21	0.233	0.279	3/13/2017	0.012	0.015	3/14/2017	0.031	0.036
3/9/2017	12:22	0.265	0.316	3/13/2017	0.012	0.015	3/14/2017	0.029	0.035
3/9/2017	12:23	0.24	0.292	3/13/2017	0.011	0.015	3/14/2017	0.029	0.035
3/9/2017	12:24	0.202	0.245	3/13/2017	0.011	0.013	3/14/2017	0.027	0.032
3/9/2017	12:25	0.219	0.264	3/13/2017	0.012	0.015	3/14/2017	0.027	0.031
3/9/2017	12:26	0.225	0.265	3/13/2017	0.013	0.016	3/14/2017	0.026	0.031
3/9/2017	12:27	0.212	0.252	3/13/2017	0.01	0.013	3/14/2017	0.028	0.034

3/9/2017	12:28	0.203	0.237	3/13/2017	0.011	0.013	3/14/2017	0.03	0.036
3/9/2017	12:29	0.215	0.248	3/13/2017	0.01	0.013	3/14/2017	0.029	0.036
3/9/2017	12:30	0.41	0.493	3/13/2017	0.01	0.013	3/14/2017	0.027	0.032
3/9/2017	12:31	0.229	0.274	3/13/2017	0.01	0.012	3/14/2017	0.026	0.031
3/9/2017	12:32	0.232	0.269	3/13/2017	0.009	0.012	3/14/2017	0.026	0.031
3/9/2017	12:33	0.417	0.496	3/13/2017	0.011	0.015	3/14/2017	0.025	0.029
3/9/2017	12:34	0.484	0.586	3/13/2017	0.013	0.016	3/14/2017	0.024	0.028
3/9/2017	12:35	0.551	0.649	3/13/2017	0.009	0.011	3/14/2017	0.022	0.025
3/9/2017	12:36	0.806	0.97	3/13/2017	0.011	0.014	3/14/2017	0.021	0.024
3/9/2017	12:37	0.947	1.15	3/13/2017	0.01	0.013	3/14/2017	0.021	0.024
3/9/2017	12:38	1.08	1.3	3/13/2017	0.01	0.013	3/14/2017	0.022	0.025
3/9/2017	12:39	1.19	1.46	3/13/2017	0.012	0.015	3/14/2017	0.021	0.023
3/9/2017	12:40	0.934	1.13	3/13/2017	0.011	0.015	3/14/2017	0.021	0.024
3/9/2017	12:41	0.672	0.788	3/13/2017	0.01	0.012	3/14/2017	0.02	0.022
3/9/2017	12:42	0.306	0.365	3/13/2017	0.011	0.014	3/14/2017	0.019	0.021
3/9/2017	12:43	2.67	3.12	3/13/2017	0.01	0.012	3/14/2017	0.019	0.022
3/9/2017	12:44	0.256	0.3	3/13/2017	0.012	0.015	3/14/2017	0.018	0.02
3/9/2017	12:45	0.193	0.225	3/13/2017	0.01	0.013	3/14/2017	0.018	0.02
3/9/2017	12:46	0.208	0.241	3/13/2017	0.01	0.013	3/14/2017	0.018	0.02
3/9/2017	12:47	0.193	0.221	3/13/2017	0.009	0.01	3/14/2017	0.018	0.021
3/9/2017	12:48	0.173	0.198	3/13/2017	0.009	0.011	3/14/2017	0.019	0.021
3/9/2017	12:49	0.165	0.187	3/13/2017	0.011	0.013	3/14/2017	0.019	0.023
3/9/2017	12:50	0.166	0.197	3/13/2017	0.01	0.012	3/14/2017	0.021	0.025
3/9/2017	12:51	0.164	0.191	3/13/2017	0.009	0.012	3/14/2017	0.019	0.023
3/9/2017	12:52	0.164	0.198	3/13/2017	0.009	0.011	3/14/2017	0.02	0.024
3/9/2017	12:53	0.224	0.259	3/13/2017	0.01	0.013	3/14/2017	0.019	0.022
3/9/2017	12:54	2.52	2.74	3/13/2017	0.009	0.011	3/14/2017	0.019	0.022
3/9/2017	12:55	0.354	0.408	3/13/2017	0.008	0.01	3/14/2017	0.02	0.023
3/9/2017	12:56	0.181	0.225	3/13/2017	0.01	0.013	3/14/2017	0.02	0.024
3/9/2017	12:57	0.375	0.497	3/13/2017	0.009	0.011	3/14/2017	0.021	0.025
3/9/2017	12:58	0.362	0.532	3/13/2017	0.008	0.01	3/14/2017	0.022	0.027
3/9/2017	12:59	0.22	0.289	3/13/2017	0.007	0.008	3/14/2017	0.023	0.028
3/9/2017	13:00	0.22	0.301	3/13/2017	0.007	0.009	3/14/2017	0.023	0.027
3/9/2017	13:01	0.259	0.357	3/13/2017	0.007	0.009	3/14/2017	0.026	0.033
3/9/2017	13:02	0.448	0.544	3/13/2017	0.008	0.009	3/14/2017	0.025	0.031
3/9/2017	13:03	1.17	1.41	3/13/2017	0.007	0.008	3/14/2017	0.024	0.028
3/9/2017	13:04	0.3	0.467	3/13/2017	0.006	0.008	3/14/2017	0.024	0.031
3/9/2017	13:05	0.272	0.427	3/13/2017	0.006	0.007	3/14/2017	0.023	0.028
3/9/2017	13:06	0.396	0.57	3/13/2017	0.007	0.008	3/14/2017	0.024	0.028
3/9/2017	13:07	0.2	0.31	3/13/2017	0.006	0.006	3/14/2017	0.023	0.028
3/9/2017	13:08	0.233	0.36	3/13/2017	0.006	0.007	3/14/2017	0.023	0.028
3/9/2017	13:09	0.222	0.346	3/13/2017	0.006	0.006	3/14/2017	0.024	0.029

3/9/2017	13:10	0.223	0.342	3/13/2017	0.006	0.006	3/14/2017	0.024	0.03
3/9/2017	13:11	0.219	0.331	3/13/2017	0.007	0.008	3/14/2017	0.025	0.031
3/9/2017	13:12	0.234	0.356	3/13/2017	0.006	0.007	3/14/2017	0.026	0.032
3/9/2017	13:13	0.227	0.352	3/13/2017	0.006	0.007	3/14/2017	0.024	0.03
3/9/2017	13:14	0.212	0.316	3/13/2017	0.006	0.007	3/14/2017	0.025	0.03
3/9/2017	13:15	0.217	0.327	3/13/2017	0.006	0.006	3/14/2017	0.027	0.032
3/9/2017	13:16	0.202	0.294	3/13/2017	0.006	0.007	3/14/2017	0.03	0.035
3/9/2017	13:17	0.174	0.249	3/13/2017	0.007	0.009	3/14/2017	0.031	0.034
3/9/2017	13:18	0.173	0.24	3/13/2017	0.008	0.01	3/14/2017	0.028	0.033
3/9/2017	13:19	0.168	0.229	3/13/2017	0.012	0.017	3/14/2017	0.039	0.044
3/9/2017	13:20	0.175	0.243	3/13/2017	0.01	0.015	3/14/2017	0.027	0.031
3/9/2017	13:21	0.18	0.256	3/13/2017	0.01	0.015	3/14/2017	0.028	0.032
3/9/2017	13:22	0.182	0.245	3/13/2017	0.01	0.017	3/14/2017	0.027	0.031
3/9/2017	13:23	0.194	0.262	3/13/2017	0.01	0.016	3/14/2017	0.027	0.032
3/9/2017	13:24	0.184	0.25	3/13/2017	0.009	0.013	3/14/2017	0.027	0.031
3/9/2017	13:25	0.178	0.242	3/13/2017	0.01	0.016	3/14/2017	0.026	0.029
3/9/2017	13:26	0.179	0.25	3/13/2017	0.012	0.019	3/14/2017	0.027	0.031
3/9/2017	13:27	0.181	0.249	3/13/2017	0.013	0.022	3/14/2017	0.026	0.03
3/9/2017	13:28	0.184	0.252	3/13/2017	0.013	0.022	3/14/2017	0.026	0.03
3/9/2017	13:29	0.186	0.263	3/13/2017	0.024	0.041	3/14/2017	0.026	0.031
3/9/2017	13:30	0.19	0.267	3/13/2017	0.048	0.079	3/14/2017	0.026	0.03
3/9/2017	13:31	0.195	0.279	3/13/2017	0.041	0.072	3/14/2017	0.025	0.028
3/9/2017	13:32	0.208	0.301	3/13/2017	0.042	0.075	3/14/2017	0.024	0.027
3/9/2017	13:33	0.215	0.317	3/13/2017	0.036	0.062	3/14/2017	0.024	0.027
3/9/2017	13:34	0.202	0.289	3/13/2017	0.025	0.044	3/14/2017	0.023	0.026
3/9/2017	13:35	0.191	0.269	3/13/2017	0.028	0.044	3/14/2017	0.022	0.025
3/9/2017	13:36	0.232	0.354	3/13/2017	0.02	0.035	3/14/2017	0.022	0.025
3/9/2017	13:37	0.27	0.409	3/13/2017	0.016	0.026	3/14/2017	0.023	0.026
3/9/2017	13:38	0.319	0.477	3/13/2017	0.014	0.024	3/14/2017	0.022	0.025
3/9/2017	13:39	0.281	0.41	3/13/2017	0.013	0.023	3/14/2017	0.022	0.024
3/9/2017	13:40	0.267	0.373	3/13/2017	0.014	0.021	3/14/2017	0.022	0.025
3/9/2017	13:41	0.265	0.392	3/13/2017	0.01	0.015	3/14/2017	0.022	0.025
3/9/2017	13:42	0.254	0.375	3/13/2017	0.01	0.016	3/14/2017	0.024	0.027
3/9/2017	13:43	0.849	1.13	3/13/2017	0.009	0.014	3/14/2017	0.024	0.027
3/9/2017	13:44	0.399	0.555	3/13/2017	0.009	0.012	3/14/2017	0.022	0.025
3/9/2017	13:45	0.361	0.497	3/13/2017	0.008	0.012	3/14/2017	0.02	0.022
3/9/2017	13:46	0.287	0.408	3/13/2017	0.008	0.011	3/14/2017	0.021	0.026
3/9/2017	13:47	0.269	0.385	3/13/2017	0.008	0.011	3/14/2017	0.02	0.023
3/9/2017	13:48	0.311	0.428	3/13/2017	0.008	0.01	3/14/2017	0.02	0.023
3/9/2017	13:49	0.268	0.378	3/13/2017	0.008	0.01	3/14/2017	0.019	0.022
3/9/2017	13:50	0.217	0.306	3/13/2017	0.009	0.012	3/14/2017	0.019	0.021
3/9/2017	13:51	0.214	0.302	3/13/2017	0.007	0.009	3/14/2017	0.018	0.02

3/9/2017	13:52	0.249	0.35	3/13/2017	0.008	0.01	3/14/2017	0.02	0.022
3/9/2017	13:53	0.248	0.346	3/13/2017	0.007	0.01	3/14/2017	0.018	0.021
3/9/2017	13:54	0.273	0.372	3/13/2017	0.007	0.01	3/14/2017	0.02	0.022
3/9/2017	13:55	0.247	0.336	3/13/2017	0.009	0.012	3/14/2017	0.019	0.021
3/9/2017	13:56	0.278	0.381	3/13/2017	0.008	0.011	3/14/2017	0.018	0.02
3/9/2017	13:57	0.246	0.347	3/13/2017	0.01	0.014	3/14/2017	0.018	0.02
3/9/2017	13:58	0.252	0.356	3/13/2017	0.008	0.011	3/14/2017	0.018	0.02
3/9/2017	13:59	0.276	0.395	3/13/2017	0.008	0.011	3/14/2017	0.018	0.021
3/9/2017	14:00	0.24	0.342	3/13/2017	0.007	0.01	3/14/2017	0.018	0.02
3/9/2017	14:01	0.27	0.374	3/13/2017	0.008	0.009	3/14/2017	0.018	0.02
3/9/2017	14:02	0.244	0.337	3/13/2017	0.013	0.015	3/14/2017	0.017	0.019
3/9/2017	14:03	0.226	0.32	3/13/2017	0.007	0.008	3/14/2017	0.017	0.018
3/9/2017	14:04	0.244	0.336	3/13/2017	0.007	0.008	3/14/2017	0.017	0.019
3/9/2017	14:05	0.239	0.326	3/13/2017	0.007	0.008	3/14/2017	0.018	0.02
3/9/2017	14:06	0.984	1.25	3/13/2017	0.009	0.011	3/14/2017	0.019	0.021
3/9/2017	14:07	0.243	0.35	3/13/2017	0.006	0.007	3/14/2017	0.018	0.021
3/9/2017	14:08	0.224	0.32	3/13/2017	0.007	0.008	3/14/2017	0.018	0.02
3/9/2017	14:09	0.209	0.293	3/13/2017	0.008	0.009	3/14/2017	0.017	0.018
3/9/2017	14:10	0.246	0.333	3/13/2017	0.007	0.008	3/14/2017	0.017	0.019
3/9/2017	14:11	0.223	0.308	3/13/2017	0.006	0.007	3/14/2017	0.016	0.017
3/9/2017	14:12	0.202	0.281	3/13/2017	0.007	0.007	3/14/2017	0.018	0.019
3/9/2017	14:13	0.194	0.271	3/13/2017	0.008	0.009	3/14/2017	0.018	0.021
3/9/2017	14:14	0.172	0.241	3/13/2017	0.007	0.01	3/14/2017	0.018	0.02
3/9/2017	14:15	1.28	1.55	3/13/2017	0.01	0.012	3/14/2017	0.017	0.018
3/9/2017	14:16	0.46	0.578	3/13/2017	0.009	0.011	3/14/2017	0.017	0.019
3/9/2017	14:17	0.414	0.504	3/13/2017	0.008	0.011	3/14/2017	0.017	0.02
3/9/2017	14:18	0.385	0.469	3/13/2017	0.009	0.012	3/14/2017	0.018	0.02
3/9/2017	14:19	0.369	0.452	3/13/2017	0.008	0.011	3/14/2017	0.018	0.019
3/9/2017	14:20	0.379	0.472	3/13/2017	0.008	0.01	3/14/2017	0.019	0.021
3/9/2017	14:21	0.344	0.424	3/13/2017	0.011	0.014	3/14/2017	0.02	0.024
3/9/2017	14:22	0.338	0.41	3/13/2017	0.01	0.014	3/14/2017	0.019	0.021
3/9/2017	14:23	0.326	0.39	3/13/2017	0.011	0.014	3/14/2017	0.019	0.021
3/9/2017	14:24	0.351	0.419	3/13/2017	0.01	0.014	3/14/2017	0.018	0.021
3/9/2017	14:25	0.816	1	3/13/2017	0.01	0.013	3/14/2017	0.019	0.022
3/9/2017	14:26	0.401	0.497	3/13/2017	0.011	0.015	3/14/2017	0.019	0.021
3/9/2017	14:27	0.403	0.487	3/13/2017	0.01	0.012	3/14/2017	0.018	0.02
3/9/2017	14:28	0.349	0.416	3/13/2017	0.01	0.014	3/14/2017	0.019	0.021
3/9/2017	14:29	0.365	0.439	3/13/2017	0.009	0.012	3/14/2017	0.019	0.021
3/9/2017	14:30	0.351	0.418	3/13/2017	0.01	0.013	3/14/2017	0.019	0.021
3/9/2017	14:31	0.341	0.404	3/13/2017	0.01	0.012	3/14/2017	0.019	0.021
3/9/2017	14:32	0.358	0.427	3/13/2017	0.011	0.015	3/14/2017	0.021	0.025
3/9/2017	14:33	0.359	0.433	3/13/2017	0.01	0.014	3/14/2017	0.019	0.021

3/9/2017	14:34	0.354	0.427	3/13/2017	0.012	0.017	3/14/2017	0.02	0.024
3/9/2017	14:35	0.342	0.402	3/13/2017	0.012	0.016	3/14/2017	0.02	0.022
3/9/2017	14:36	0.347	0.406	3/13/2017	0.013	0.018	3/14/2017	0.02	0.023
3/9/2017	14:37	0.371	0.438	3/13/2017	0.011	0.015	3/14/2017	0.021	0.024
3/9/2017	14:38	0.384	0.459	3/13/2017	0.012	0.016	3/14/2017	0.022	0.026
3/9/2017	14:39	0.397	0.464	3/13/2017	0.012	0.015	3/14/2017	0.022	0.026
3/9/2017	14:40	0.368	0.439	3/13/2017	0.011	0.015	3/14/2017	0.021	0.025
3/9/2017	14:41	0.381	0.457	3/13/2017	0.013	0.017	3/14/2017	0.021	0.024
3/9/2017	14:42	0.383	0.456	3/13/2017	0.012	0.017	3/14/2017	0.021	0.023
3/9/2017	14:43	0.405	0.473	3/13/2017	0.011	0.014	3/14/2017	0.021	0.023
3/9/2017	14:44	0.368	0.436	3/13/2017	0.011	0.015	3/14/2017	0.022	0.025
3/9/2017	14:45	0.384	0.452	3/13/2017	0.01	0.013	3/14/2017	0.021	0.024
3/9/2017	14:46	0.394	0.472	3/13/2017	0.01	0.013	3/14/2017	0.019	0.021
3/9/2017	14:47	0.417	0.485	3/13/2017	0.01	0.013	3/14/2017	0.019	0.021
3/9/2017	14:48	0.354	0.41	3/13/2017	0.01	0.013	3/14/2017	0.019	0.021
3/9/2017	14:49	0.59	0.721	3/13/2017	0.009	0.011	3/14/2017	0.018	0.02
3/9/2017	14:50	0.645	0.8	3/13/2017	0.009	0.012	3/14/2017	0.018	0.02
3/9/2017	14:51	0.353	0.416	3/13/2017	0.009	0.012	3/14/2017	0.018	0.02
3/9/2017	14:52	0.35	0.409	3/13/2017	0.01	0.013	3/14/2017	0.019	0.021
3/9/2017	14:53	0.343	0.396	3/13/2017	0.009	0.013	3/14/2017	0.018	0.021
3/9/2017	14:54	0.338	0.387	3/13/2017	0.012	0.018	3/14/2017	0.017	0.019
3/9/2017	14:55	0.333	0.382	3/13/2017	0.013	0.019	3/14/2017	0.017	0.02
3/9/2017	14:56	0.331	0.381	3/13/2017	0.013	0.018	3/14/2017	0.019	0.022
3/9/2017	14:57	0.349	0.395	3/13/2017	0.012	0.017	3/14/2017	0.017	0.02
3/9/2017	14:58	0.347	0.4	3/13/2017	0.013	0.02	3/14/2017	0.018	0.02
3/9/2017	14:59	0.368	0.43	3/13/2017	0.014	0.019	3/14/2017	0.018	0.021
3/9/2017	15:00	0.363	0.428	3/13/2017	0.015	0.021	3/14/2017	0.017	0.02
3/9/2017	15:01	0.383	0.454	3/13/2017	0.016	0.023	3/14/2017	0.016	0.019
3/9/2017	15:02	0.38	0.444	3/13/2017	0.013	0.018	3/14/2017	0.016	0.018
3/9/2017	15:03	0.369	0.423	3/13/2017	0.015	0.022	3/14/2017	0.016	0.018
3/9/2017	15:04	0.35	0.4	3/13/2017	0.014	0.021	3/14/2017	0.016	0.019
3/9/2017	15:05	0.765	0.912	3/13/2017	0.013	0.019	3/14/2017	0.031	0.034
3/9/2017	15:06	0.455	0.545	3/13/2017	0.014	0.02	3/14/2017	0.02	0.024
3/9/2017	15:07	0.357	0.411	3/13/2017	0.016	0.023	3/14/2017	0.017	0.02
3/9/2017	15:08	0.362	0.414	3/13/2017	0.016	0.023	3/14/2017	0.015	0.017
3/9/2017	15:09	0.364	0.419	3/13/2017	0.016	0.023	3/14/2017	0.016	0.019
3/9/2017	15:10	0.741	0.865	3/13/2017	0.015	0.021	3/14/2017	0.015	0.017
3/9/2017	15:11	0.748	0.912	3/13/2017	0.016	0.024	3/14/2017	0.017	0.019
3/9/2017	15:12	0.397	0.471	3/13/2017	0.02	0.032	3/14/2017	0.018	0.021
3/9/2017	15:13	0.355	0.414	3/13/2017	0.016	0.022	3/14/2017	0.016	0.019
3/9/2017	15:14	0.365	0.429	3/13/2017	0.015	0.022	3/14/2017	0.019	0.022
3/9/2017	15:15	0.341	0.398	3/13/2017	0.018	0.026	3/14/2017	0.018	0.021

3/9/2017	15:16	0.337	0.389	3/13/2017	0.015	0.02	3/14/2017	0.017	0.02
3/9/2017	15:17	0.325	0.375	3/13/2017	0.015	0.021	3/14/2017	0.018	0.021
3/9/2017	15:18	0.352	0.413	3/13/2017	0.014	0.021	3/14/2017	0.021	0.026
3/9/2017	15:19	0.688	0.832	3/13/2017	0.014	0.02	3/14/2017	0.019	0.024
3/9/2017	15:20	0.748	0.931	3/13/2017	0.015	0.02	3/14/2017	0.019	0.023
3/9/2017	15:21	0.43	0.525	3/13/2017	0.015	0.02	3/14/2017	0.019	0.022
3/9/2017	15:22	0.412	0.497	3/13/2017	0.016	0.021	3/14/2017	0.019	0.022
3/9/2017	15:23	0.56	0.682	3/13/2017	0.015	0.021	3/14/2017	0.02	0.024
3/9/2017	15:24	0.564	0.689	3/13/2017	0.013	0.018	3/14/2017	0.021	0.026
3/9/2017	15:25	0.401	0.475	3/13/2017	0.016	0.02	3/14/2017	0.02	0.025
3/9/2017	15:26	1	1.22	3/13/2017	0.014	0.019	3/14/2017	0.022	0.027
3/9/2017	15:27	0.503	0.6	3/13/2017	0.015	0.021	3/14/2017	0.026	0.033
3/9/2017	15:28	0.374	0.441	3/13/2017	0.014	0.018	3/14/2017	0.027	0.034
3/9/2017	15:29	0.375	0.432	3/13/2017	0.014	0.018	3/14/2017	0.026	0.032
3/9/2017	15:30	0.376	0.437	3/13/2017	0.031	0.047	3/14/2017	0.028	0.032
3/9/2017	15:31	0.456	0.538	3/13/2017	0.046	0.066	3/14/2017	0.03	0.036
3/9/2017	15:32	0.446	0.54	3/13/2017	0.079	0.128	3/14/2017	0.033	0.038
3/9/2017	15:33	0.465	0.584	3/13/2017	0.056	0.093	3/14/2017	0.034	0.039
3/9/2017	15:34	0.518	0.685	3/13/2017	0.04	0.066	3/14/2017	0.033	0.038
3/9/2017	15:35	0.48	0.619	3/13/2017	0.036	0.06	3/14/2017	0.034	0.04
3/9/2017	15:36	0.432	0.54	3/13/2017	0.031	0.048	3/14/2017	0.034	0.04
3/9/2017	15:37	0.408	0.516	3/13/2017	0.021	0.035	3/14/2017	0.033	0.037
3/9/2017	15:38	0.392	0.485	3/13/2017	0.023	0.038	3/14/2017	0.032	0.035
3/9/2017	15:39	0.372	0.451	3/13/2017	0.022	0.032	3/14/2017	0.034	0.037
3/9/2017	15:40	0.38	0.465	3/13/2017	0.019	0.029	3/14/2017	0.082	0.086
3/9/2017	15:41	0.469	0.562	3/13/2017	0.015	0.023	3/14/2017	0.07	0.074
3/9/2017	15:42	0.708	0.884	3/13/2017	0.083	0.12	3/14/2017	0.045	0.049
3/9/2017	15:43	0.401	0.475	3/13/2017	0.05	0.079	3/14/2017	0.039	0.043
3/9/2017	15:44	0.394	0.467	3/13/2017	0.024	0.035	3/14/2017	0.039	0.044
3/9/2017	15:45	0.429	0.54	3/13/2017	0.02	0.031	3/14/2017	0.038	0.044
3/9/2017	15:46	0.395	0.474	3/13/2017	0.015	0.023	3/14/2017	0.036	0.04
3/9/2017	15:47	0.377	0.451	3/13/2017	0.016	0.022	3/14/2017	0.036	0.04
3/9/2017	15:48	0.526	0.678	3/13/2017	0.015	0.019	3/14/2017	0.036	0.04
3/9/2017	15:49	0.467	0.587	3/13/2017	0.015	0.022	3/14/2017	0.035	0.04
3/9/2017	15:50	0.385	0.472	3/13/2017	0.014	0.018	3/14/2017	0.036	0.04
3/9/2017	15:51	0.4	0.487	3/13/2017	0.013	0.019	3/14/2017	0.035	0.04
3/9/2017	15:52	0.372	0.449	3/13/2017	0.014	0.02	3/14/2017	0.033	0.037
3/9/2017	15:53	0.489	0.588	3/13/2017	0.013	0.018	3/14/2017	0.033	0.037
3/9/2017	15:54	0.43	0.516	3/13/2017	0.013	0.018	3/14/2017	0.033	0.038
3/9/2017	15:55	0.351	0.404	3/13/2017	0.014	0.017	3/14/2017	0.033	0.037
3/9/2017	15:56	0.344	0.397	3/13/2017	0.013	0.017	3/14/2017	0.058	0.068
3/9/2017	15:57	0.331	0.378	3/13/2017	0.016	0.022	3/14/2017	0.039	0.047

3/9/2017	15:58	0.891	1.08	3/13/2017	0.013	0.017	3/14/2017	0.037	0.045
3/9/2017	15:59	0.35	0.408	3/13/2017	0.014	0.017	3/14/2017	0.033	0.038
3/9/2017	16:00	0.343	0.391	3/13/2017	0.015	0.022	3/14/2017	0.035	0.039
3/9/2017	16:01	0.349	0.401	3/13/2017	0.012	0.017	3/14/2017	0.036	0.041
3/9/2017	16:02	0.333	0.379	3/13/2017	0.014	0.018	3/14/2017	0.037	0.043
3/9/2017	16:03	0.347	0.389	3/13/2017	0.015	0.021	3/14/2017	0.039	0.046
3/9/2017	16:04	0.343	0.388	3/13/2017	0.022	0.032	3/14/2017	0.035	0.041
3/9/2017	16:05	0.553	0.664	3/13/2017	0.019	0.028	3/14/2017	0.035	0.04
3/9/2017	16:06	0.367	0.414	3/13/2017	0.014	0.02	3/14/2017	0.037	0.04
3/9/2017	16:07	0.342	0.381	3/13/2017	0.022	0.034	3/14/2017	0.037	0.042
3/9/2017	16:08	0.418	0.49	3/13/2017	0.017	0.027	3/14/2017	0.039	0.044
3/9/2017	16:09	0.459	0.553	3/13/2017	0.017	0.026	3/14/2017	0.035	0.039
3/9/2017	16:10	0.375	0.456	3/13/2017	0.018	0.026	3/14/2017	0.035	0.039
3/9/2017	16:11	0.356	0.415	3/13/2017	0.019	0.029	3/14/2017	0.036	0.041
3/9/2017	16:12	0.531	0.635	3/13/2017	0.017	0.024	3/14/2017	0.038	0.042
3/9/2017	16:13	0.59	0.723	3/13/2017	0.023	0.035	3/14/2017	0.038	0.042
3/9/2017	16:14	0.585	0.704	3/13/2017	0.019	0.028	3/14/2017	0.035	0.04
3/9/2017	16:15	0.542	0.667	3/13/2017	0.017	0.024	3/14/2017	0.035	0.038
3/9/2017	16:16	0.591	0.727	3/13/2017	0.017	0.024	3/14/2017	0.035	0.038
3/9/2017	16:17	0.632	0.779	3/13/2017	0.017	0.023	3/14/2017	0.032	0.037
3/9/2017	16:18	0.442	0.543	3/13/2017	0.019	0.028	3/14/2017	0.035	0.038
3/9/2017	16:19	0.768	0.976	3/13/2017	0.021	0.034	3/14/2017	0.047	0.053
3/9/2017	16:20	0.422	0.518	3/13/2017	0.02	0.03	3/14/2017	0.042	0.049
3/9/2017	16:21	0.621	0.816	3/13/2017	0.017	0.025	3/14/2017	0.036	0.04
3/9/2017	16:22	0.469	0.597	3/13/2017	0.019	0.027	3/14/2017	0.035	0.038
3/9/2017	16:23	0.494	0.641	3/13/2017	0.019	0.027	3/14/2017	0.035	0.038
3/9/2017	16:24	0.524	0.692	3/13/2017	0.016	0.025	3/14/2017	0.033	0.037
3/9/2017	16:25	0.511	0.647	3/13/2017	0.015	0.021	3/14/2017	0.033	0.036
3/9/2017	16:26	0.469	0.607	3/13/2017	0.016	0.021	3/14/2017	0.033	0.036
3/9/2017	16:27	0.541	0.715	3/13/2017	0.017	0.023	3/14/2017	0.034	0.037
3/9/2017	16:28	0.466	0.608	3/13/2017	0.016	0.022	3/14/2017	0.034	0.037
3/9/2017	16:29	0.791	1	3/13/2017	0.02	0.029	3/14/2017	0.033	0.037
3/9/2017	16:30	0.656	0.852	3/13/2017	0.019	0.029	3/14/2017	0.033	0.036
3/9/2017	16:31	0.521	0.657	3/13/2017	0.017	0.024	3/14/2017	0.035	0.039
3/9/2017	16:32	0.951	1.2	3/13/2017	0.017	0.025	3/14/2017	0.034	0.038
3/9/2017	16:33	0.559	0.714	3/13/2017	0.018	0.024	3/14/2017	0.033	0.037
3/9/2017	16:34	0.474	0.616	3/13/2017	0.018	0.025	3/14/2017	0.032	0.036
3/9/2017	16:35	0.68	0.87	3/13/2017	0.02	0.031	3/14/2017	0.034	0.037
3/9/2017	16:36	1.3	1.6	3/13/2017	0.021	0.031	3/14/2017	0.035	0.038
3/9/2017	16:37	0.609	0.744	3/13/2017	0.022	0.031	3/14/2017	0.035	0.038
3/9/2017	16:38	0.477	0.587	3/13/2017	0.022	0.035	3/14/2017	0.035	0.039
3/9/2017	16:39	0.438	0.543	3/13/2017	0.024	0.037	3/14/2017	0.034	0.038

3/9/2017	16:40	0.453	0.58	3/13/2017	0.026	0.038	3/14/2017	0.035	0.039
3/9/2017	16:41	0.47	0.609	3/13/2017	0.023	0.036	3/14/2017	0.034	0.039
3/9/2017	16:42	0.456	0.594	3/13/2017	0.023	0.035	3/14/2017	0.033	0.037
3/9/2017	16:43	0.466	0.606	3/13/2017	0.022	0.033	3/14/2017	0.033	0.037
3/9/2017	16:44	0.518	0.684	3/13/2017	0.022	0.034	3/14/2017	0.034	0.037
3/9/2017	16:45	0.512	0.692	3/13/2017	0.025	0.04	3/14/2017	0.034	0.038
3/9/2017	16:46	0.487	0.633	3/13/2017	0.027	0.045	3/14/2017	0.034	0.037
3/9/2017	16:47	0.525	0.722	3/13/2017	0.025	0.039	3/14/2017	0.035	0.038
3/9/2017	16:48	0.47	0.625	3/13/2017	0.026	0.042	3/14/2017	0.036	0.04
3/9/2017	16:49	0.583	0.777	3/13/2017	0.025	0.041	3/14/2017	0.035	0.04
3/9/2017	16:50	0.589	0.771	3/13/2017	0.026	0.042	3/14/2017	0.035	0.04
3/9/2017	16:51	0.411	0.509	3/13/2017	0.025	0.042	3/14/2017	0.036	0.039
3/9/2017	16:52	0.888	1.08	3/13/2017	0.024	0.036	3/14/2017	0.037	0.041
3/9/2017	16:53	0.507	0.619	3/13/2017	0.025	0.038	3/14/2017	0.037	0.039
3/9/2017	16:54	0.375	0.449	3/13/2017	0.026	0.042	3/14/2017	0.035	0.038
3/9/2017	16:55	0.382	0.472	3/13/2017	0.026	0.041	3/14/2017	0.036	0.04
3/9/2017	16:56	0.392	0.498	3/13/2017	0.029	0.047	3/14/2017	0.034	0.036
3/9/2017	16:57	0.473	0.682	3/13/2017	0.029	0.047	3/14/2017	0.034	0.037
3/9/2017	16:58	0.484	0.632	3/13/2017	0.025	0.042	3/14/2017	0.033	0.035
3/9/2017	16:59	0.504	0.684	3/13/2017	0.024	0.038	3/14/2017	0.032	0.034
3/9/2017	17:00	0.417	0.563	3/13/2017	0.027	0.04	3/14/2017	0.033	0.035
3/9/2017	17:01	0.399	0.509	3/13/2017	0.027	0.04	3/14/2017	0.032	0.033
3/9/2017	17:02	0.437	0.599	3/13/2017	0.025	0.039	3/14/2017	0.033	0.035
3/9/2017	17:03	0.423	0.559	3/13/2017	0.028	0.043	3/14/2017	0.032	0.033
3/9/2017	17:04	0.406	0.527	3/13/2017	0.025	0.04	3/14/2017	0.031	0.032
3/9/2017	17:05	0.442	0.571	3/13/2017	0.025	0.039	3/14/2017	0.03	0.031
3/9/2017	17:06	0.794	1.03	3/13/2017	0.021	0.029	3/14/2017	0.029	0.03
3/9/2017	17:07	0.467	0.644	3/13/2017	0.02	0.03	3/14/2017	0.029	0.03
3/9/2017	17:08	0.443	0.59	3/13/2017	0.02	0.028	3/14/2017	0.03	0.032
3/9/2017	17:09	0.412	0.533	3/13/2017	0.024	0.036	3/14/2017	0.031	0.033
3/9/2017	17:10	0.408	0.51	3/13/2017	0.027	0.041	3/14/2017	0.03	0.032
3/9/2017	17:11	0.396	0.493	3/13/2017	0.021	0.032	3/14/2017	0.029	0.031
3/9/2017	17:12	0.563	0.776	3/13/2017	0.023	0.034	3/14/2017	0.029	0.031
3/9/2017	17:13	0.373	0.471	3/13/2017	0.021	0.031	3/14/2017	0.03	0.032
3/9/2017	17:14	0.364	0.447	3/13/2017	0.019	0.026	3/14/2017	0.029	0.031
3/9/2017	17:15	0.389	0.497	3/13/2017	0.018	0.025	3/14/2017	0.028	0.03
3/9/2017	17:16	0.629	0.941	3/13/2017	0.017	0.024	3/14/2017	0.027	0.029
3/9/2017	17:17	0.88	1.35	3/13/2017	0.016	0.02	3/14/2017	0.028	0.029
3/9/2017	17:18	0.5	0.712	3/13/2017	0.015	0.02	3/14/2017	0.029	0.031
3/9/2017	17:19	0.423	0.563	3/13/2017	0.015	0.018	3/14/2017	0.027	0.029
3/9/2017	17:20	0.378	0.467	3/13/2017	0.016	0.022	3/14/2017	0.027	0.029
3/9/2017	17:21	0.402	0.497	3/13/2017	0.018	0.021	3/14/2017	0.027	0.029

3/9/2017	17:22	0.517	0.657	3/13/2017	0.017	0.022	3/14/2017	0.03	0.034
3/9/2017	17:23	2.02	2.43	3/13/2017	0.018	0.024	3/14/2017	0.028	0.032
3/9/2017	17:24	1.4	1.84	3/13/2017	0.017	0.022	3/14/2017	0.028	0.031
3/9/2017	17:25	1.6	2.11	3/13/2017	0.018	0.024	3/14/2017	0.029	0.032
3/9/2017	17:26	2.13	3.03	3/13/2017	0.019	0.025	3/14/2017	0.027	0.031
3/9/2017	17:27	2.05	3.1	3/13/2017	0.019	0.025	3/14/2017	0.024	0.026
3/9/2017	17:28	1.71	2.59	3/13/2017	0.02	0.025	3/14/2017	0.022	0.025
3/9/2017	17:29	1.22	1.73	3/13/2017	0.019	0.024	3/14/2017	0.021	0.024
3/9/2017	17:30	0.663	0.918	3/13/2017	0.018	0.023	3/14/2017	0.021	0.025
3/9/2017	17:31	0.544	0.747	3/13/2017	0.016	0.019	3/14/2017	0.02	0.023
3/9/2017	17:32	0.618	0.91	3/13/2017	0.016	0.019	3/14/2017	0.021	0.025
3/9/2017	17:33	0.613	0.955	3/13/2017	0.018	0.022	3/14/2017	0.02	0.024
3/9/2017	17:34	0.434	0.565	3/13/2017	0.015	0.017	3/14/2017	0.02	0.023
3/9/2017	17:35	1.61	2.45	3/13/2017	0.016	0.018	3/14/2017	0.021	0.024
3/9/2017	17:36	3.84	6.03	3/13/2017	0.016	0.018	3/14/2017	0.022	0.027
3/9/2017	17:37	1.77	2.82	3/13/2017	0.023	0.03	3/14/2017	0.022	0.027
3/9/2017	17:38	1.19	1.84	3/13/2017	0.022	0.027	3/14/2017	0.023	0.028
3/9/2017	17:39	1.04	1.68	3/13/2017	0.022	0.03	3/14/2017	0.022	0.025
3/9/2017	17:40	0.787	1.26	3/13/2017	0.025	0.036	3/14/2017	0.022	0.026
3/9/2017	17:41	0.88	1.41	3/13/2017	0.024	0.034	3/14/2017	0.024	0.027
3/9/2017	17:42	0.69	1.08	3/13/2017	0.023	0.031	3/14/2017	0.024	0.028
3/9/2017	17:43	0.682	1.04	3/13/2017	0.022	0.03	3/14/2017	0.025	0.029
3/9/2017	17:44	0.717	1.12	3/13/2017	0.023	0.032	3/14/2017	0.025	0.029
3/9/2017	17:45	0.884	1.41	3/13/2017	0.024	0.034	3/14/2017	0.026	0.03
3/9/2017	17:46	0.735	1.18	3/13/2017	0.024	0.034	3/14/2017	0.026	0.029
3/9/2017	17:47	0.575	0.881	3/13/2017	0.024	0.032	3/14/2017	0.027	0.032
3/9/2017	17:48	0.545	0.811	3/13/2017	0.023	0.029	3/14/2017	0.026	0.029
3/9/2017	17:49	0.489	0.694	3/13/2017	0.024	0.032	3/14/2017	0.026	0.03
3/9/2017	17:50	0.449	0.611	3/13/2017	0.027	0.036	3/14/2017	0.025	0.029
3/9/2017	17:51	0.438	0.606	3/13/2017	0.025	0.034	3/14/2017	0.025	0.029
3/9/2017	17:52	0.446	0.636	3/13/2017	0.024	0.031	3/14/2017	0.026	0.029
3/9/2017	17:53	0.416	0.574	3/13/2017	0.023	0.032	3/14/2017	0.027	0.031
3/9/2017	17:54	0.397	0.526	3/13/2017	0.027	0.035	3/14/2017	0.026	0.03
3/9/2017	17:55	0.401	0.52	3/13/2017	0.024	0.033	3/14/2017	0.026	0.03
3/9/2017	17:56	0.59	0.748	3/13/2017	0.025	0.032	3/14/2017	0.026	0.03
3/9/2017	17:57	0.381	0.469	3/13/2017	0.024	0.03	3/14/2017	0.026	0.031
3/9/2017	17:58	0.38	0.461	3/13/2017	0.026	0.033	3/14/2017	0.027	0.032
3/9/2017	17:59	0.357	0.424	3/13/2017	0.025	0.032	3/14/2017	0.027	0.031
3/9/2017	18:00	0.501	0.607	3/13/2017	0.026	0.033	3/14/2017	0.027	0.03
3/9/2017	18:01	0.4	0.474	3/13/2017	0.026	0.032	3/14/2017	0.027	0.031
3/9/2017	18:02	0.458	0.551	3/13/2017	0.024	0.029	3/14/2017	0.026	0.03
3/9/2017	18:03	0.426	0.507	3/13/2017	0.024	0.031	3/14/2017	0.027	0.03

3/9/2017	18:04	0.481	0.577	3/13/2017	0.021	0.026	3/14/2017	0.026	0.029
3/9/2017	18:05	0.455	0.541	3/13/2017	0.023	0.027	3/14/2017	0.027	0.031
3/9/2017	18:06	0.438	0.52	3/13/2017	0.021	0.024	3/14/2017	0.028	0.033
3/9/2017	18:07	0.415	0.487	3/13/2017	0.021	0.023	3/14/2017	0.029	0.034
3/9/2017	18:08	0.469	0.551	3/13/2017	0.021	0.025	3/14/2017	0.027	0.032
3/9/2017	18:09	0.37	0.427	3/13/2017	0.019	0.022	3/14/2017	0.027	0.03
3/9/2017	18:10	0.352	0.399	3/13/2017	0.02	0.022	3/14/2017	0.028	0.033
3/9/2017	18:11	0.349	0.394	3/13/2017	0.019	0.021	3/14/2017	0.026	0.03
3/9/2017	18:12	0.35	0.397	3/13/2017	0.02	0.022	3/14/2017	0.026	0.031
3/9/2017	18:13	0.351	0.396	3/13/2017	0.018	0.02	3/14/2017	0.027	0.031
3/9/2017	18:14	0.344	0.389	3/13/2017	0.019	0.021	3/14/2017	0.028	0.032
3/9/2017	18:15	0.359	0.404	3/13/2017	0.017	0.019	3/14/2017	0.028	0.032
3/9/2017	18:16	0.462	0.534	3/13/2017	0.018	0.02	3/14/2017	0.028	0.032
3/9/2017	18:17	0.335	0.375	3/13/2017	0.017	0.019	3/14/2017	0.029	0.033
3/9/2017	18:18	0.346	0.386	3/13/2017	0.018	0.019	3/14/2017	0.027	0.03
3/9/2017	18:19	0.349	0.393	3/13/2017	0.018	0.02	3/14/2017	0.027	0.03
3/9/2017	18:20	0.339	0.374	3/13/2017	0.018	0.02	3/14/2017	0.049	0.064
3/9/2017	18:21	0.336	0.373	3/13/2017	0.02	0.021	3/14/2017	0.041	0.06
3/9/2017	18:22	0.332	0.365	3/13/2017	0.019	0.02	3/14/2017	0.026	0.031
3/9/2017	18:23	0.342	0.379	3/13/2017	0.018	0.02	3/14/2017	0.027	0.032
3/9/2017	18:24	0.339	0.374	3/13/2017	0.017	0.018	3/14/2017	0.027	0.03
3/9/2017	18:25	0.339	0.371	3/13/2017	0.017	0.018	3/14/2017	0.027	0.03
3/9/2017	18:26	0.327	0.357	3/13/2017	0.018	0.02	3/14/2017	0.027	0.031
3/9/2017	18:27	0.319	0.343	3/13/2017	0.018	0.018	3/14/2017	0.026	0.03
3/9/2017	18:28	0.321	0.348	3/13/2017	0.018	0.02	3/14/2017	0.026	0.03
3/9/2017	18:29	0.323	0.351	3/13/2017	0.019	0.021	3/14/2017	0.025	0.029
3/9/2017	18:30	0.327	0.352	3/13/2017	0.022	0.024	3/14/2017	0.025	0.027
3/9/2017	18:31	0.325	0.352	3/13/2017	0.026	0.033	3/14/2017	0.025	0.028
3/9/2017	18:32	0.321	0.343	3/13/2017	0.025	0.034	3/14/2017	0.026	0.03
3/9/2017	18:33	0.321	0.345	3/13/2017	0.028	0.037	3/14/2017	0.024	0.027
3/9/2017	18:34	0.316	0.338	3/13/2017	0.023	0.03	3/14/2017	0.022	0.024
3/9/2017	18:35	0.317	0.339	3/13/2017	0.021	0.026	3/14/2017	0.028	0.032
3/9/2017	18:36	0.321	0.342	3/13/2017	0.02	0.025	3/14/2017	0.073	0.129
3/9/2017	18:37	0.317	0.338	3/13/2017	0.021	0.025	3/14/2017	0.054	0.094
3/9/2017	18:38	0.318	0.338	3/13/2017	0.02	0.025	3/14/2017	0.051	0.087
3/9/2017	18:39	0.323	0.342	3/13/2017	0.018	0.023	3/14/2017	0.037	0.059
3/9/2017	18:40	0.317	0.334	3/13/2017	0.018	0.022	3/14/2017	0.028	0.041
3/9/2017	18:41	0.32	0.34	3/13/2017	0.017	0.021	3/14/2017	0.046	0.074
3/9/2017	18:42	0.32	0.338	3/13/2017	0.017	0.019	3/14/2017	0.029	0.044
3/9/2017	18:43	0.316	0.335	3/13/2017	0.018	0.022	3/14/2017	0.031	0.044
3/9/2017	18:44	0.371	0.408	3/13/2017	0.017	0.021	3/14/2017	0.031	0.044
3/9/2017	18:45	0.557	0.665	3/13/2017	0.018	0.021	3/14/2017	0.022	0.031

3/9/2017	18:46	0.335	0.356	3/13/2017	0.018	0.022	3/14/2017	0.023	0.032
3/9/2017	18:47	0.353	0.376	3/13/2017	0.018	0.021	3/14/2017	0.023	0.032
3/9/2017	18:48	0.348	0.372	3/13/2017	0.017	0.02	3/14/2017	0.02	0.028
3/9/2017	18:49	0.345	0.37	3/13/2017	0.016	0.019	3/14/2017	0.021	0.029
3/9/2017	18:50	0.321	0.342	3/13/2017	0.016	0.019	3/14/2017	0.018	0.025
3/9/2017	18:51	2.68	4.18	3/13/2017	0.025	0.029	3/14/2017	0.018	0.023
3/9/2017	18:52	0.842	1.3	3/13/2017	0.016	0.019	3/14/2017	0.017	0.022
3/9/2017	18:53	0.807	1.19	3/13/2017	0.015	0.017	3/14/2017	0.016	0.02
3/9/2017	18:54	0.674	1	3/13/2017	0.016	0.018	3/14/2017	0.017	0.021
3/9/2017	18:55	0.554	0.781	3/13/2017	0.017	0.02	3/14/2017	0.018	0.023
3/9/2017	18:56	0.498	0.687	3/13/2017	0.015	0.017	3/14/2017	0.016	0.021
3/9/2017	18:57	0.48	0.656	3/13/2017	0.025	0.033	3/14/2017	0.016	0.02
3/9/2017	18:58	0.44	0.578	3/13/2017	0.014	0.016	3/14/2017	0.029	0.041
3/9/2017	18:59	0.454	0.59	3/13/2017	0.014	0.016	3/14/2017	0.018	0.024
3/9/2017	19:00	0.411	0.517	3/13/2017	0.014	0.016	3/14/2017	0.016	0.021

REFERENCES

Application Notes. Research papers involving the TSI DustTrak Aerosol Monitor. TSI Inc. (2016). Retrieved January, 2017 from http://www.tsi.com/uploadedFiles/_Site_Root/Products/Literature/Application_Notes/ITI-079-Research_Papers_DustTrak_A4.pdf

Bickis, U. (1998). Hazard prevention and control in the work environment: airborne dust. *World Health*, *13*, 16. Retrieved from http://cdrwww.who.int/occupational_health/publications/en/oehairbornedust5.pdf

Bruno, M. H. (Ed.). (2000). *Pocket pal: Graphic arts production handbook* (18th ed.). Memphis, TN: International Paper Co.

Buekens, A. (2009). Dust particle formation and characteristics. In *Pollution control technologies* (Vol. 1). Retrieved January 8, 2017, from https://www.eolss.net/Sample-Chapters/C09/E4-14-01-04.pdf

Center for Disease Control [CDC] (2017). National Institute for Occupational Safety and Health pocket guide to particulate not otherwise regulated. Retrieved from https://www.cdc.gov/niosh/npg/npgd0480.html

Creswell, J. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). California: Sage Publications.

Cross, L. (2012). The age of digital printing. *Publishers Weekly*, *259*(44), 18. Retrieved from http://eds.a.ebscohost.com.libsrv.wku.edu/ehost/detail/detail?sid=4ba20768-435d-4c81-a8c0-0d608b7c87a6%40sessionmgr4009&vid=0&hid=4111&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#AN=82991538&db=ulh

Dahlqvist, M. (1992) Lung function and exposure to paper dust in bookbinders - A pilot study. *Upsala Journal of Medical Sciences 97*(1), 49-54. http://dx.doi.org/10.3109/03009739209179281

Davis, R. H. (2014). Business economics and the printing industry. *Business Economics*, *49*(2), 122-126. http://dx.doi.org/10.1057/be.2014.9

DustTrak II Aerosol Monitor 8533. (2017). Shoreview, MN: TSI, Inc.

EPA. (2016, September 12). Size Comparisons for PM Particles [Visual depiction of a micron.]. Retrieved February 8, 2017, from https://www.epa.gov/sites/production/files/2016-09/pm2.5_scale_graphic-color_2.jpg

Esworthy, R. (2015). *Air quality: EPA's 2013 changes to the particulate matter (PM) standard* (CRS Report No. R42934). Retrieved from Congressional Research Service. https://fas.org/sgp/crs/misc/R42934.pdf

Groves, W., Hahne, R., Levine, S., & Schork, M. (1994). A field comparison of respirable dust samplers. *American Industrial Hygiene Association Journal, 55*(8), 748-755. Retrieved from http://search.proquest.com.libsrv.wku.edu/docview/236321334?OpenUrlRefId=info:xri/sid:primo&accountid=15150

Hoffman, C., Toren, K., Sallsten, G., & Henneberger, P. K. (2001). Exposure to paper dust and the onset of asthma and chronic bronchitis. American Journal of Epidemiology, 153(11), 137.

Holm, M., Dahlman-Höglund, A., & Torén, K. (2011). Respiratory health effects and exposure to superabsorbent polymer and paper dust - an epidemiological study. *BMC Public Health,* 11, 557. doi:10.1186/1471-2458-11-557

Industrial ventilation: A manual of recommended practice (2004). Cincinnati, OH: American Conference of Governmental and Industrial Hygenists [ACGIH].

Kraus, T., Pfahlberg, A., Zöbelein, P., Gefeller, O., & Raithel, H.J. (2004). Lung function among workers in the soft tissue paper-producing industry. *Chest, 125*(2), 731-736. doi: 10.1378/chest.125.2.731

Lewis, M., & Strebel, M. (2016). Dust management in bulk-material-handling operations. *Chemical Engineering, 123*(11), 48-57. Retrieved from http://libsrv.wku.edu:2048/login?url=http://search.proquest.com/docview/1837160398?accountid=15150

Lyman, R. (1993). *Binding and finishing*. Pittsburgh, PA: Graphic Arts Technical Foundation.

Michelson, M. (2015). Inkjet altering book printing paradigms. *In - Plant Graphics, 65*(7), 34. Retrieved from http://libsrv.wku.edu:2048/login?url=http://search.proquest.com/docview/1700395295?accountid=15150

Minitab (Version 17) [Computer software]. State College, PA: Minitab Inc.

Occupational Safety and Health Administration [OSHA]. (1987). Interpretations (Standard 1910.1000 TABLE Z-3). Retrieved from https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=19546

Occupational Safety and Health Administration [OSHA]. (2017). Regulations (Standard 1910.1000). Retrieved from https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9991

Pagliari, L., & Maurer, Ruth. (2005). *Implementation of a dust control system for hazardous respirable dust in a hygiene paper facility* (Doctoral dissertation). Retrieved from http://search.proquest.com.libsrv.wku.edu/docview/305361451/fulltextPDF/249E5B710E144D92PQ/1?accountid=15150

Robinson, W. (1986). *The Solid waste handbook: A practical guide*. New York: Wiley.

Sakunkoo, P., Chaiear, N., Chaikittiporn, C., & Sadhra, S. (2011). Concentrations and size distribution of inhalable and respirable dust among sugar industry workers. *Asia-Pacific Journal of Public Health, 23*(6), 967-979. doi: 10.1177/1010539510365099

Sayer, H. (1922). *Engineering principles and practical data relating to dust and refuse removal from woodworking machines*. Albany, N.Y.: State of New York, Department of Labor.

Sittig, M. (1977). *Particulates and fine dust removal: Processes and equipment*. Park Ridge, N.J.: Noyes Data.

Technical library. System equipment details & performance data. G.F. Puhl. (2017). Retrieved January 10, 2017, from http://www.gfpuhl.com/technical-library

Wallace, L. A., Wheeler, A. J., Kearney J., Van Ryswyk, K., You, H., Kulka R. H., . . . Xu, X. (2010). Validation of continuous particle monitors for personal, indoor, and outdoor exposures. *Journal of Exposure Science and Environmental Epidemiology, 21*(1), 49.