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Occupational Safety and Health Hazards in Apparel Processing Factories Posed by Respirable $PM_{2.5}$ in Export Processing Zone, Machakos County, Kenya

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Abstract

Recent epidemiological evidence demonstrates a consistent association of severe health effects with ambient particulate matter. Reduced life expectancy, as well as hospitalization for cardiorespiratory effects, and exacerbation of diseases such as asthma and COPD. Export processing zones (EPZ) employ large number of workers who engage in manufacturing of goods. Apparel processing is a key economic activity in EPZ. Garment cutting and stitching contribute to release of fine particles. This study aimed at assessing exposure to $PM_{2.5}$ among workers in apparel processing companies in EPZ, Machakos County Kenya. The study utilized a cross-sectional descriptive design. Four apparel manufacturing factories were selected. Concentrations of $PM_{2.5}$ were measured using a potable real time PM detector model, Turnkey Osiris Airborne Particulate Monitor with an accuracy of 0.1 μg/m^3. The mean value for $PM_{2.5}$ was 65.61 ± 31.5 with a range of 59.08 - 72.14 μg/m^3. Main $PM_{2.5}$ sources were found to be from Sewing/Embroidery > Cutting/Fusing/pressing > Fabric/relaxing/spreading > Packaging > Office departments respectively. The mean concentrations were above the WHO acceptable levels of 15 μg·m^{-3} for 24-hour exposure. The study reveals that there are significant $PM_{2.5}$ particles in apparel processing companies EPZ, Machakos County. The management should explore engineering control measures, occupational safety practices, and administrative controls to reduce respirable dust exposure.

Keywords

Apparel, Respirable Dust, $PM_{2.5}$, Occupational Exposure Limit, Occupational Safety and Health

1. Introduction

Globally, workers in apparel processing companies are exposed to airborne particulate from natural and synthetic fibrous materials in their work environment [1]. Exposure to cotton dust in the apparel processing industry has been associated with some work specific and non-specific respiratory. Sisal, cotton and moldy hay dust are often contaminated with Gram-negative bacteria, which contain endotoxins (lipopolysaccharide) in their outer cell wall. Endotoxin is released into the air during processing. Exposure to aerosols and respirable particles has been associated with the etiology of respiratory diseases such as chronic bronchitis and chronic obstructive pulmonary disease along with nasal and ocular irritation [2] [3]. The concentrations of Sisal, cotton and moldy hay dust and endotoxin in the working environment are greatly affected by various conditions such as the quality of the materials, the production rate, the ventilation system, the processing method, and the method of dust sampling and analysis [4].

WHO (2021) [5] reports interim target of personal inhalable dust ($PM_{2.5}$) exposure for 24 hours ranging from 25 to 75 μgm^{-3}, air quality guideline of 15 μgm^{-3}. A typical integrated apparel processing factory has four main production process departments (spinning, weaving, finishing, and garment) that are integrated into a single clothing production line. Apparel processing is one of the major manufacturing industries, which is established across the developed and developing countries including Africa.

According to ILO, 2019, over 2.7 million employees yearly miss work due to occupational injury or disease [6]. An estimated 1000 fatalities daily are from workplace accidents and 6500 are from occupational diseases worldwide. Nearly three-quarters of all deaths on the job are attributed to circulatory system disorders (31%), work-related malignancies (26%), and respiratory diseases (17%), according to an ILO report, 2019 [6]. Comparing the causes of death on the job, occupational diseases account for the vast majority at 86.3%, while fatal occupational accidents account for only 13% [6]. The lower the number of injuries accidents and occupational diseases, the higher the competition and productivity. This study assessed the occupational hygiene measurement principally through determination of respirable dust levels exposures and associated health effects in workers in apparel processing companies in Export Processing Zone (EPZ) Athi River, Machakos County. Therefore, the purpose of this study is to assess occupational safety and health hazards posed by respirable $PM_{2.5}$ exposures in apparel processing companies in EPZ, Machakos County Kenya.

2. Materials and Methods

2.1. Study Design

This was a cross-sectional descriptive study aimed at collection of data on exposure to respirable among workers in Apparel processing companies in Export Zone Processing (EPZ), Machakos County, Kenya. The study area was in EPZ Machakos County, Kenya as illustrated in **Figure 1**. According to EPZA (2020),

employ 21,752 employees. Seven of these companies are registered by DOSHS. These had approximately 7800 employees [7]. The four selected factories had clustered department including: Cutting Fusing and pressing; Fabric relaxing and spreading; Midpoint; Office; Packaging; Sewing and Embroidery.

2.2. Respirable Dust Measurement

$PM_{2.5}$ levels were measured using a potable real time PM measurement (Turnkey Osiris Airborne Particulate Monitor). Osiris was positioned vertically in the Lamp Post Box (LPB) and grub screws and two nobs used hold the equipment within the LPB. The LPB which measures approximately (225 × 380 × 210 mm) was then mounted at least 2 meters from the ground on a stable platform across all the six departments. The mounting was undertaken using a banding tool and straps at the midpoint of every department in the factories. In some instances, the LPB was screwed on a wooded platform/post. The departments included: Cutting Fusing and pressing; Fabric relaxing and spreading; Midpoint; Office; Packaging; Sewing and Embroidery. Measurements were done for at least 8 working hours per factory across four months within the 4 selected factories. A total of ninety-six (96) samples were taken for measurement.

2.3. Data Analysis and Presentation

Data analysis was done using Statistical Package for the Social Sciences (SPSS) Version. 25. Data cleaning and validation was performed in order to achieve a clean data set which was then exported into a Statistical Package format (SPSS Version 25 for analysis.

Figure 1. Map of Machakos County (Source: KNBS, 2019) [8].

3. Results and Discussion

Four apparel companies were studied; **Table 1** presents data on attributes of

each of the four companies.

The four companies are located within Export Processing Zone Authority in Athi River Machakos County. The companies had different number of employees as illustrated in Table 1, with machinery mounted across different sections in the workplace. The factories were characterized of different units including Cutting Fusing/pressing, Fabric relaxing/spreading, Office, Sewing/Embroidery and Packaging. All these departments were considered during the study.

3.1. $PM_{2.5}$ Levels in Apparel Processing Companies in EPZ, Machakos County Kenya

The levels of $PM_{2.5}$ are presented in Table 2 below. The companies had variable levels of PMs and these varied from department to department.

The mean dust levels of $PM_{2.5}$ was 68.30 ± 24 with a range of 55.21 - 81.39] in cutting, fusing and pressing department, 62.45 ± 25.8 and a range of 48.70 - 76.19 in the fabric relaxing and spreading department, whereas the midpoint department had a mean of 69.90 ± 27.6 and a range of 55.22 - 84.59 $\mu g \cdot m^{-3}$. The highest concentrations were recorded in the sewing and embroidery department

Table 1. Apparel processing companies in EPZ, Machakos County Kenya.

Company	Company APC1	Company APC2	Company APC3	Company APC4
Size (ft^2)	32291.73	53819.55	258333.85	129166.93
Population	200	600	4500	2500
Working hours	12 - 24	12 - 24	24	24
Humidity (%)	44.4	44.8	45.7	44.5
Temperature (˚C)	26.7	26.8	26.7	26.8

Source: Author (2021).

Table 2. $PM_{2.5}$ levels ($\mu g \cdot m^{-3}$) in apparel processing companies in EPZ, Machakos County Kenya (n = 16).

Departments	APC1		APC2		APC3		APC4	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Cutting Fusing and pressing	71.51 ± 30.9	22.22 - 120.8	65.77 ± 26.3	23.90 - 107.6	56.77 ± 21.4	22.69 - 90.8	79.17 ± 23.4	41.81 - 116.53
Fabric relaxing and spreading	50.23 ± 20.2	18.15 - 82.3	56.59 ± 25.9	15.30 - 97.9	74.16 ± 32.6	22.22 - 126.1	68.83 ± 26.4	26.76 - 110.9
Midpoint	64.30 ± 28.4	19.18 - 109.4	69.52 ± 32.4	17.93 - 121.1	64.69 ± 22.4	28.99 - 100.4	81.13 ± 34.5	26.20 - 136.1
Office	62.20 ± 30.1	21.33 - 90.1	60.20 ± 29.8	12.80 - 107.6	35.80 ± 14.9	11.94 - 59.7	26.70 ± 4.71	19.2 - 34.2
Packaging	65.00 ± 28.3	19.96 - 110.1	54.77 ± 22.7	18.64 - 90.9	55.51 ± 13.4	34.06 - 76.9	58.50 ± 28.2	13.71 - 103.2
Sewing and Embroidery	59.78 ± 30.4	11.38 - 108.2	154.18 ± 17.8	125.88 - 182.5	72.02 ± 26.4	30.03 - 114	63.99 ± 16.2	38.22 - 89.7

with a mean of 87.49 ± 45.2 and a range of 63.41 - 111.57 whereas offices within the EPZ had a mean of 40.89 ± 24.0 and a range of 6.30 - 55.49 which was lower than levels recorded in the packaging department with a mean of 58.44 ± 21.8 and a range of 46.82 - 70.06 μg·m^{-3}. The overall dust mean level of $PM_{2.5}$ in EPZ was 65.61 ± 31.5 μg·m^{-3}.

The findings are in line with Sangeetha *et al.*, (2013) [9] study conducted in Tirupur India in a textile company thatrevealed levels of $PM_{2.5}$ varied from department to department. According to the findings, those who worked in the Knitting department $PM_{2.5}$ levels were recorded high level at 446.38 μg·m^{-3} while those who worked in the ironing without process section recorded a low of 101.66 μg·m^{-3}. Further, a study done by Mwelange *et al.* (2020) [10] in textile companies in Dar es Salaam, Tanzania, found that there was a lot of dust in the weaving department, with a mean of (SD = 0.32), but there was less dust in the finishing department, with a mean of (SD = 0.09). This was associated with dust release and the worker's exposure to it, especially where work textile processes are ongoing.

3.2. $PM_{2.5}$ Concentrations by Factories and Departments in EPZ, Machakos County Kenya (n = 16)

According to **Figure 2**, APC1 had $PM_{2.5}$ concentration ranging from 50.2 μg·m^{-3} to 71.5 μg·m^{-3} with fabric relaxing/spreading and cutting fusing/pressing departments showing the minimum and maximum values respectively. All departments in APC2 except sewing/embroidery had concentration ranging from 54.8 μg·m^{-3} to 69.5 μg·m^{-3}. Surprisingly, sewing/embroidery had the highest concentration of 154.2 μg·m^{-3}. Similarly, in APC3 the concentration ranged from 35.8 μg·m^{-3} to 72 μg·m^{-3}. Office had the lowest concentration value. APC4 had concentrations ranging from 26.7 μg·m^{-3} to 81.1 μg·m^{-3} with the lowest concentration at office department. In APC3 and APC4 the offices were isolated from the production units, thus the lower concentrations compared to the other departments and factories. The study findings are in line with a study done by Khan *et al.* (2015) [11] in Philippines to investigate the levels of $PM_{2.5}$ concentrations by factories and departments. The findings show that all the departments which include office, fabric relaxing and embroidery and sewing had an average of 58.1 μg·m^{-3}. The high concentration was attributed to the fact that the companies' settings were in one block housing all the departments. However, a study by Tefera *et al.* (2020) [12] conducted in China shows that in the sampled and visited companies under the categories of apparel processing had lower concentrations compared to the other departments. For instance, the sewing/embroidery had the highest concentration of 82.8 μg·m^{-3} while cutting fusing/pressing and fabric relaxing/spreading departments had a low of 25.6 μg·m^{-3} to 21.9 μg·m^{-3} values respectively.

3.3. Statistical Test (ANOVA)

The mean concentration for $PM_{2.5}$ was significantly different between sew-

ing/embroidery and office department (F = 3.808, P-Value = 0.004) as illustrated in Table 3. The mean was higher in sewing/embroidery department than in office department by 46 μg·m^{-3}. However, the mean concentration was not significantly different within the rest of the departments (P > 0.05). The study findings corroborate with a study conducted by Chen *et al.* [13] in Indonesia. This study shows that the mean concentration for $PM_{2.5}$ was significantly different between packaging and front office department (F = 3.517, P-Value = 0.003). The mean was higher in packaging than in front office department by 37 μg·m^{-3}. However, the mean concentration was not significantly different within the rest of the departments (P > 0.05). On divergent views, a study by Pekey *et al.* (2010) [14] in Sydney that shows that the mean concentration for $PM_{2.5}$ was significantly different between front office and sewing and embroidery department (F = 3.274, P-Value = 0.008). The mean was higher in front office than in sewing and embroidery department by 25 μg·m^{-3}. The mean concentration was significantly different within the rest of the departments as standardized by the P-value (P > 0.05).

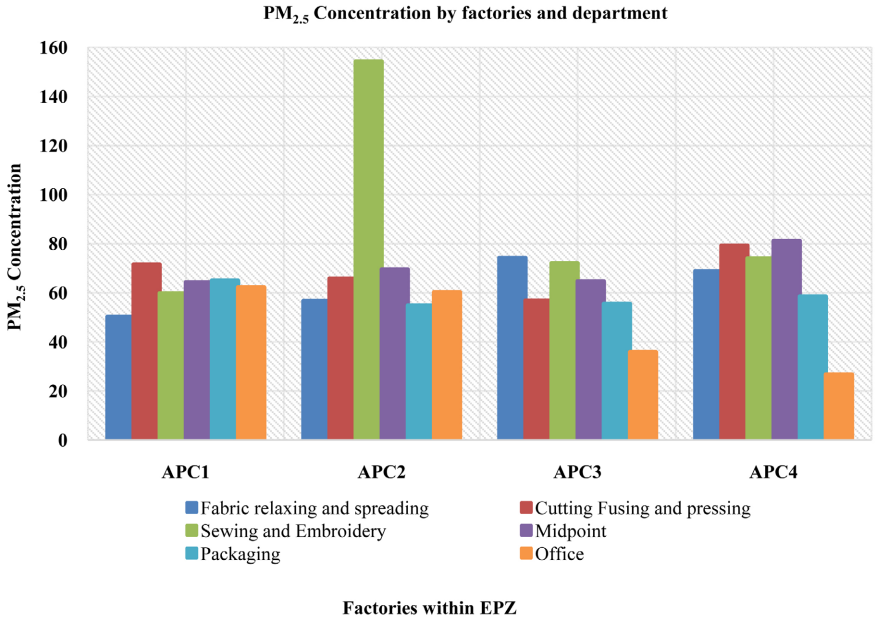

Figure 2. $PM_{2.5}$ concentrations by factories and Departments in EPZ, Machakos County Kenya (n = 16).

Table 3. Statistical test (ANOVA) within departments in EPZ, Machakos County Kenya.

ANOVA					
$PM_{2.5}$					
	Sum of Squares	df	Mean Square	F	Sig.
Between departments	16380.946	5	3276.189	3.808	0.004
Within departments	73985.692	86	860.299		
Total	90366.639	91			

4. Conclusions

The highest $PM_{2.5}$ dust concentrations were recorded in the sewing and embroidery department with a mean of 87.49 ± 45.2 and a range of 63.41 - 111.57 whereas offices within the EPZ had the lowest $PM_{2.5}$ concentrations with a mean of 40.89 ± 24.0 and a range of 6.30 - 55.49. The overall dust mean levels of $PM_{2.5}$ in EPZ was 65.61 ± 31.5 $\mu g \cdot m^{-3}$. The mean concentration for $PM_{2.5}$ was significantly different between sewing/embroidery and office department ($F = 3.808$, P-Value = 0.004). The mean was higher in sewing/embroidery department than in office department by 46 $\mu g \cdot m^{-3}$. However, the mean concentration was not significantly different within the rest of the departments ($P > 0.05$).

The study finding on dust concentration failed to meet WHO $PM_{2.5}$ air quality guidelines levels of 15 $\mu g \cdot m^{-3}$ 2021 [15]. However, the findings below the recommended occupational exposure limit set by Factories and Other Places of Work Act (Hazardous Substances Rules) 2007 [16]. In addition to this, the research established that most of the respondents were exposed to dust for more than 8 hours.

5. Recommendation

There is a need to develop mechanisms for reducing employee dust exposure. Developing engineering controls, training and supervision should be an effective strategy to adopt in the industry. All practicable measures shall be taken to protect the persons employed against inhalation of the dust and to prevent its accumulating in any workroom.

Ethical Approval and Consideration

Approvals were sought from the Jomo Kenyatta University of Agriculture and Technology (JKUAT), National Commission for Science, Technology and Innovation (NACOSTI) and the management of the Export Processing Zone Authority (EPZA).

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Conflicts of Interest

The authors declare no competing interest.

Authors' Contributions

Owino conceptualized the study design, did literature review, obtained ethical approvals, carried out data collection/analysis, discussion and manuscript preparation.

Paul Njogu and Dennis Magu analyzed and verified the study proposal, guided the research progress. Both the supervisors have reviewed and approved this manuscript.

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