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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Approximately three thousand plastic goods manufacturing factories (PGMF) are currently operating in Bangladesh involving numerous workers. Associated health problems of these workers are largely unknown. The key objectives of the current study were identifying plastic chemical exposures related health outcomes in these workers and comparing these outcomes before and after their joining in PGMFs. In addition, we aimed to investigate the relationships between work duration and the prevalence of health ailments among workers.

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Method: A cross-sectional study was carried out among factory workers (n=405) at six PGMFs in Gazipur district in Bangladesh. A simple random sampling method had been applied to select participants and data on their self-reported exposures to chemicals and associated respiratory, neurological, and other multiple health outcomes were collected through a validated questionnaire survey. Data were analyzed using different descriptive and inferential statistical tools. The categorical variables and continuous variables were interpreted using frequency distribution and standard deviation (SD) respectively. A Pearson chi-square (χ^2) test was applied to evaluate the correlation between work duration and health outcomes. A *p*-value <0.05 was considered significant statistically.

Results: The average age and work duration of the workers were 25.63±6.85 and 3.49±3.53 years, respectively, implying that most workers were young, and spent over 10% of their lifetime in PGMFs work. Most common health outcomes reported by the workers were nasal discharges: 60 (14.9%), headaches: 76 (18.9%), fatigues: 112 (27.8%), losses of appetites: 108 (26.8%), urination problems: 61 (13.1%), losses of body weights: 102 (25.3%), and nervousness: 70 (17.4%). Among the common health outcomes only headache (*p*=0.005); fatigue (*p*=0.04); urination problem (*p*=<0.0001), and nervousness (*p*=0.004) were significantly associated with the work duration. Furthermore, except for hypertension and tarry stool, all health outcomes among workers differ significantly before and after joining in PGMFs.

Conclusion: This study first time identified important health outcomes of the PGMFs workers and generated baseline information on common health outcomes of the PGMFs workers in developing countries like Bangladesh. However, it might be important to identify potential causes of such health outcomes in PGMFs workers considering both biomarkers of exposures and real-time environmental samples to understand the disease pathology and to recommend mitigation measures to be taken by occupational health policymakers and practitioners in developing countries.

Keywords: Plastic chemical exposures; fatigues; factory; nervousness; worker; Bangladesh.

1. INTRODUCTION

The usage of plastic goods in our daily life is indispensable. Every year the demand is increasing by about 15% spiring demand [1]. The manufacture of plastic goods increased rapidly from 1950 to 2014 from 15 to 311 million metric tons globally [2]. Nowadays plastic pollution is a global issue [3] in developing Asian countries such as Bangladesh, Myanmar, Thailand, and Vietnam [3]. In Bangladesh, the growth in the plastic sector as the industry began in the year 1980. Noticeable gradual growth in the plastic industry in this country was made from the year 1980 to the year 1990 [4]. At the same time, a great number of film grade and injection grade plastic industries were established in Bangladesh [4]. Since then, the growth and development of plastic industries had been commenced to move faster compared to other sectors. Near about 3000 large, medium, and small-sized plastic goods manufacturing factories are currently available in Bangladesh [4]. Millions of people are working in a dusty and hazardous environment in PGMFs around the world [5]. In Bangladesh, approximately one million workforces are directly or indirectly working in this sector. More than 150,000 metric tons of plastic raw materials are imported each year in Bangladesh, and it is increasing continuously. Approximately 6.3 billion tons of plastic goods had been produced worldwide from 1950 to 2018 [6].

The most common uses of chemicals in PGMFs are phenol-formaldehyde, polystyrene, polyvinyl chloride, polyvinyl alcohol, styrene-acrylonitrile, styrene-butadiene, polyethylene, polypropylene, resins, acrylic-fiber, and heavy metal [7]. A range of chemicals used in the plastic factory is known as toxic [8]. Most of the chemicals have a bad impact on public health, animal health, and the ecological environment [9]. These types of toxic, hazardous chemicals can expose to humans through oral, inhalation, and skin penetration route. Scientists got evidence of plastic particles in the food chain [10]. Also, there has evidence of heavy metals and toxicants in the dust of PGMFs [1].

Formaldehyde can cause local irritation and acute and chronic toxicity in humans [11]. Scientists got evidence of heavy metals like Lead (Pb), Cadmium (Cd), Nickle (Ni), and Zinc (Zn) in the blood of PGMF workers in Dhaka, Bangladesh [1]. These heavy metal exposures

can cause bronchitis, pneumonia, asthma, chronic dermatitis, back pain, kidney diseases, hypertension, cardiac failure, and even cancer [1]. In Egypt, there is other evidence of DNA damage related to vinyl chloride exposures among PGMF workers [12]. On the other hand, a survey was conducted among the female workers in beverage and plastic manufacturing industries in Indonesia where 63% of the women had reproductive health disorders [13]. Styrene was the most common chemical in plastic industries which can retain in the human body after inhalation and cause serious human health effects [14]. Moreover, styrene causes pneumonia, pneumonitis, asthma with cell injury, and cell death of tracheal, bronchiolar, and alveolar epithelium, and ultimately causes lung damage [15]. Likewise, vinyl chloride exposure through inhalation can affect various tissue and organs [12]. Polystyrene can cause pathology to the Central Nervous System (CNS), and respiratory system and can even cause cancer [16]. Even bisphenols were found to excrete in the urine of the workers of plastic injection molding factories in Malaysia [17].

Plastic polymer is used for producing plastic goods and only synthetic fibers produce 40 million tons per year worldwide [18]. For this reason, the world environment is polluted day by day. However, plastic particles are everywhere in the environmental sample [19]. Improper dumping of plastic goods also causes environmental pollution [20]. Plastic ingredients can pollute all soil, water, and air [21]. Moreover, plastic resin pellet is a raw material that can cause environmental pollution [11]. Poly Vinyl Chloride (PVC) is also a threat to vegetation and human, animal, and environmental health [16,22]. Heavy metals were evidenced in the soil sampled around the plastic metal factories in China [23]. Even plastic particles are also found in the gizzard of seabirds [24]. Due to environmental pollution in Bangladesh, 234,000 people already died, and in urban 80,000 people died [7].

Inhalation of phthalates and polyvinyl chloride have evidence of eye allergy or irritation [25,26]. Likewise, plastic factory workers exposed to polyethylene and polystyrene used plastic factory workers have a high risk of color vision problems [27]. Industrial mercury and toluene exposure affect color perception [28]. The styrene exposure causes headache, fatigue, and color vision problem in PGMF workers [29,30]. Chemical additives and heavy metals used in the plastic product can cause skin allergy, dermatitis, skin vesicle, insomnia, nausea, bone pain, joint pain, and allergy-related nasal discharge with mucosal congestion [26,31-33]. Exposure to Teflon pyrolytic gases in the plastic industry causes pulmonary edema, chest pain, and shortness of breathing [34]. Bisphenol-A exposure can cause hypertension [35]. Factory workers had evidence of a decreased level of consciousness, memory loss, acute toxic encephalopathy, and abdominal pain after exposure to polyvinyl chloride [33]. Formaldehyde exposure can cause urination problems, and loss of appetite [36]. Industry workers with a long time of exposure to Lead (Pb) can show symptoms of constipation [37]. Similarly, fatigue, weight loss, abdominal mail, and tarry stools were evidenced in the industry workers exposed to vinyl chloride [38]. Industrial chemicals like mercury, lead, polychlorinated biphenyl, etc. had been associated with human neurological disorders [39].

Among the worker's groups (according to the work categories) operators and helpers were highly vulnerable to potential exposures to chemicals and related health outcomes. Among the categories of the worker's group, only the operator and helper were directly handling the plastic ingredients, plastic chemicals, and plastic additives. Only these two groups work on the production floor of the PGMFs. However, other worker groups might also be vulnerable because passive or indirect exposures to volatile chemicals and gases are unavoidable for them in the factory. In Egypt, researchers found evidence of polyvinyl chloride and styrene exposure among the workers who worked in the grinding section [40].

Although the above-described health outcomes related to acute and chronic plastic-related chemical exposures are highly feasible, they were rarely systematically studied among PGMF workers in Bangladesh. As the workers in this work setting are not well educated and not properly trained for personal protective equipment use, they are supposed to be more vulnerable to potential adverse health outcomes unlike the workers of developed countries. The current study was undertaken to address this gap of knowledge. To our knowledge, the current study of plastic chemicals exposures and related health impacts through a validated survey is for the first time conducted in Bangladesh. Hence, our main objectives were the identification plastic chemical exposures related to health outcomes

among these workers and to compare these outcomes before and after their joining in PGMFs. We also aimed to investigate the relationships between work duration and the prevalence of health disorders among workers.

2. MATERIALS AND METHODS

2.1 Study Design and Study Area Selection

A cross-sectional survey was designed and carried out to determine the health outcomes among the PGMFs workers in the Gazipur district of Bangladesh (see the Appendix). As introduced in the existing literature above, most of these outcomes could be related to plastic-related chemical exposures. The study area was geographically located from North 24.22; 90.40 to South 23.28; 90.39 Latitude and Longitude, respectively, which is very close to the northern part of the capital city Dhaka. All types of factories are operating in the Gazipur district and this is a large industrial area in the country. The study period was from October 2020 to December 2020. For the study, six PGMFs had been randomly selected where daily necessary goods like utensils, pipes, doors, and water tanks were manufactured. The numbers of workers employed in the selected factories ranged approximately between 200 and 500.

2.2 Participants' Selection

Some eligibility criteria had been followed during the recruitment of participants for data collection. First, the participant must be a PGMF employee with at least one year of work experience. Second, the participant must be an adult who works full-time. Moreover, the study considered both male and female workers.

2.3 Sample Size and Sampling Design

Infinite population formula [$S = (Z)^2 \times P \times (1\text{-}P) \div (M)^2$] was used to calculate the sample size (S) where Z-score was 1.96 at a 95% confidence level, and population proportion [3] and margin of error (M) were 50% (0.50) and 5% (0.05) respectively [41]. Therefore, the sample size (S) was 384.16 ≈ 385. However, a slight modification in the sample size (S) was made considering a non-response proportion of 5% by using the formula, $N = 385 \times [100 / (100\text{-}5)]$. Thus, the final sample size was 405. A simple random sampling method had been applied to select participants from six factories.

2.4 Study Tool, Data Collection and Study Variables

A structured and validated questionnaire was used to collect data from the selected PGMF workers through a face-to-face interview method. The base questions were adopted and modified according to the socio-demographical aspects of Bangladeshi workers following the assessment of health disorders of plastic factory workers in Egypt [40]. A total of thirty-five (35) questions were accommodated in the questionnaire under two sections (Section-A and Section-B; see Appendix). Eight questions on socio-demographical characteristics of the workers' age, gender, marital status, education, work experience, etc. were included in Section-A. Section-B included twenty-seven questions related to the possible chemical exposure-related health outcomes including the respiratory system, nervous system, digestive system, cardiovascular system, renal system, skeletal system, etc. related symptoms. During data collection on twenty-seven health outcomes, we first asked the workers about the current state of a specific symptom, whether it was present or absent; at the same time, we asked if they had this symptom before joining this factory. Among the 27 health outcomes, we shorted out the top seven common health outcomes which percentage were fifteen or above. Then we calculated the statistical relation with work duration. Data collection was performed inside the factory during the work time of the workers without hampering anybody. Each interview lasted between 10-12 minutes. A few interviews were taken in a private room to ensure the participant's confidence regarding their answers. Clinical data were not collected from the participants. Data collection had been completed by seven trips to the selected PGMFs within 90 days. Before data collection, the questionnaire and consent forms were translated into Bengali (native language) and the survey was conducted in Bengali. Other hand, we selected the possible health outcomes based on our study on the common chemicals used for plastic goods manufacturing. There were so many outcomes for the workers. We took only those health outcomes which can be reported by the workers without any clinical test. However, we only counted those symptoms which can easily be felt or seen by the workers themselves. Plastic chemical exposure can cause human cancer, but we did not count this type of outcome. In these ways, we ensured twenty-seven health outcomes for the workers.

2.5 Analysis of Data

Statistical analysis of data was accomplished using IBM SPSS version 25. Interpretation of the categorical variables and continuous variables was made using frequency distribution including the percentage and mean (M) and standard deviation (SD) respectively. A Pearson chi-square (χ^2) test was applied to evaluate the correlation between work duration and health outcomes. Moreover, using 2 × 2 contingency tables, a McNemar's test was used to assess the difference in health outcomes before and after joining the job. A p-value <0.05 was considered significant statistically.

3. RESULTS

3.1 Demographic Characteristics of Participants

Workers of eight categories participated in the current study. Out of 405 workers most of them were operator (n = 231; 57.0%) followed by helpers (n = 148, 36.50%), quality controller (n=12, 3.00%), electrician (n=4, 1.00%), manager (n=4, 1.00%), loader (n=2, 0.50%), production officer (n=2, 0.50%), and supervisor (n=2, 0.50%). The Socio-demographic characteristics of these workers are stated in Table 1. The average age of the workers was 25.63±6.85 years and the average work duration was 3.49±3.53 years in PGMFs. The majority (n=217, 53.60%) of the workers were between 21 to 30 years of age group. There were few (n=12, 3.0%) workers above the 40 years age group. A maximum of 335 (82.70%) of the workers had below 6 years of work experience in PGMFs. Among all workers, a majority (n=398, 98.30%) had been appointed as permanent workers and the rest of them were daily wage workers. Only 118 (29.1%) of workers had previous job experience from PGMFs. Regarding the education levels of the workers, the maximum (n = 162, 40.0%) had secondary school level education. Majority of the workers (n = 329, 81.20%) were male and (n=76, 18.80%) workers were female. In terms of marital status, 200 workers (49.4%) were married.

Table 1. Socio-demographic characteristics of workers

Characteristics	n=405	%
1. Gender		
Male	272	67.2
Female	133	32.8
2. Marital status of the participants		
Married	200	49.4
Unmarried	205	50.6
3. Education level of the participants		
Primary	132	32.6
Secondary School	162	40.0
Higher secondary school	63	15.6
University	48	11.9
4. Job types of the participants		
Permanent	398	98.3
Daily Wager	7	1.7
5. Previous same job experience		
Yes	118	29.1
No	287	70.9
6. The age group of the participants		
Below 21 years	108	26.7
21 to 30 years	217	53.6
31 to 40 years	68	16.8
Above 40 years	12	3.0
	M	SD
	25.63	6.85
7. Total work duration in the present plastic manufacturing factory		
Below 6 years	335	82.7
6 to 10 years	46	11.4
Above 10years	24	5.9
	M	SD
	3.49	3.53

Table 2. Health status before and after joining in the factory

All health outcomes		Before joining		After joining		*p*-value*
		N	%	N	%	
Eye allergy	Yes	4	1.0	24	6.0	<0.0001
	No	401	99.0	379	94.0	
Vision problem	Yes	6	1.5	36	8.9	<0.0001
	No	399	98.5	367	91.1	
Nasal discharge	Yes	6	1.5	60	14.9	<0.0001
	No	399	98.5	343	85.1	
Short breathing	Yes	6	1.5	28	6.9	<0.0001
	No	399	98.5	375	93.1	
Body allergy	Yes	10	2.5	57	14.1	<0.0001
	No	395	97.5	346	85.9	
Body burning	Yes	8	2.0	28	6.9	0.001
	No	397	98.0	375	93.1	
Dermatitis	Yes	4	1.0	34	8.4	<0.0001
	No	401	99.0	369	91.6	
Skin vesicles	Yes	6	1.5	48	11.9	<0.0001
	No	399	98.5	355	88.1	
Headache	Yes	10	2.5	76	18.9	<0.0001
	No	395	97.5	327	81.1	
Insomnia	Yes	8	2.0	46	11.4	<0.0001
	No	397	98.0	357	88.6	
Nausea	Yes	4	1.0	26	6.5	<0.0001
	No	401	99.0	377	93.5	
Coughing	Yes	4	1.0	42	10.4	<0.0001
	No	401	99.0	361	89.6	
Chest pain	Yes	4	1.0	44	10.9	<0.0001
	No	401	99.0	359	89.1	
Hypertension	Yes	4	1.0	10	2.5	0.180
	No	401	99.0	393	97.5	
Low blood pressure	Yes	8	2.0	52	12.9	<0.0001
	No	397	98.0	351	87.1	
Memory loss	Yes	2	0.5	40	9.9	<0.0001
	No	403	99.5	363	90.1	
Fatigue	Yes	16	4.0	112	27.8	<0.0001
	No	389	96.0	291	72.2	
Loss of appetite	Yes	14	3.5	108	26.8	<0.0001
	No	391	96.5	295	73.2	
Abdominal pain	Yes	2	0.5	36	8.9	<0.0001
	No	403	99.5	367	91.1	
Constipation	Yes	6	1.5	29	7.2	<0.0001
	No	399	98.5	374	92.8	
Tarry stool	Yes	4	1.0	10	2.5	0.109
	No	401	99.0	393	97.5	
Urination problem	Yes	12	3.0	61	15.1	<0.0001
	No	393	97.0	342	84.9	
Edema	Yes	2	0.5	20	5.0	<0.0001
	No	403	99.5	383	95.0	
Joint pain	Yes	10	2.5	57	14.1	<0.0001
	No	395	97.5	346	85.9	
Bone pain	Yes	10	2.5	52	12.9	<0.0001
	No	395	97.5	351	87.1	
Loss of body weight	Yes	18	4.4	102	25.3	<0.0001
	No	387	95.6	301	74.7	
Nervousness	Yes	14	3.5	70	17.4	<0.0001
	No	391	96.5	333	82.6	

**p-value from Chi-square test*

Table 3. Cross-tabulation including Chi-square test of seven common health outcomes after joining in factory

Common health outcomes			Work duration (Years)			N	
			Below 6	6 to 10	Above 10		*p*-value*
Nasal discharge	Yes	Count (%)	48 (80.0)	8 (13.3)	4 (6.7)	60	0.83
	No	Count (%)	287 (83.2)	38 (11.0)	20 (5.8)	345	
Headache	Yes	Count (%)	56 (71.8)	12 (15.4)	10 (12.8)	78	0.005
	No	Count (%)	279 (85.3)	34 (10.4)	14 (4.3)	327	
Fatigue	Yes	Count (%)	88 (77.2)	14 (12.3)	12 (10.5)	114	0.04
	No	Count (%)	247 (84.9)	32 (11.0)	12 (4.1)	291	
Loss of appetite	Yes	Count (%)	86 (78.2)	14 (12.7)	10 (9.1)	110	0.20
	No	Count (%)	249 (84.4)	32 (10.8)	14 (4.7)	295	
Urination problem	Yes	Count (%)	37 (58.7)	16 (25.4)	10 (15.9)	63	<0.0001
	No	Count (%)	298 (87.1)	30 (8.8)	14 (4.1)	342	
Bodyweight loss	Yes	Count (%)	84 (80.8)	12 (11.5)	8 (7.7)	104	0.66
	No	Count (%)	251 (83.4)	34 (11.3)	16 (5.3)	301	
Nervousness	Yes	Count (%)	54 (77.1)	6 (8.6)	10 (14.3)	70	0.004
	No	Count (%)	281 (83.9)	40 (11.9)	14 (4.2)	335	

**p-value from Chi-square test*

Table 4. Previous same work experience and common health outcomes after joining in factory

Common health outcomes		Previous same work experience				*p*-value*
		Yes		No		
		N	%	N	%	
Nasal discharge	Yes	18	30.0	42	70.0	<0.0001
	No	100	29.0	245	71.0	
Headache	Yes	20	25.6	58	74.4	0.002
	No	98	30.0	229	70.0	
Fatigue	Yes	30	26.3	84	73.7	0.81
	No	88	30.2	203	69.8	
Loss of appetite	Yes	26	23.6	84	76.4	0.59
	No	92	31.2	203	68.8	
Urination problem	Yes	27	42.9	36	57.1	<0.0001
	No	91	26.6	251	73.4	
Bodyweight loss	Yes	22	21.2	82	78.8	0.33
	No	96	31.9	205	68.1	
Nervousness	Yes	14	20.0	56	80.0	<0.0001
	No	104	31.0	231	69.0	

**p-value detected from Chi-square test*

3.2 Health Status Before and after Joining the Factory

Before joining the PGMFs, only 18 (4.4%) of the workers reported losing body weight, but after joining the factories, 102 (25.3%) reported losing body weight, which was statistically significant (p<0.0001). Likewise, symptom fatigue 16(4.0%) leads to 112(27.8%) after joining the factory. Similarly, loss of appetite 14 (3.5%) leads to 108(26.8%); nervousness 14 (3.5%) leads to 70(17.4%); nasal discharge 6 (6.5%) leads to 60 (14.9%); headache 10 (2.5%) leads to 76 (18.9%); urination problem 12 (3%) leads to 61(15.1%) with *p,*<0.0001 level of significant. However, no significant changes were observed in the case of hypertension (*p*=0.18) and tarry stool (*p*=0.10). The remarkable point was that frequency of all health outcomes was higher after joining factories than in previous health outcomes (Table 2; see Supplementary Fig. S1 in the online edition).

3.3 Health Outcomes Compared with Work Duration

Table 3 presents seven common health outcomes after joining a factory. A chi-square test for independence had been applied to assess whether the work duration was related to

symptoms. The chi-square test of headache (p=0.005); fatigue (p=0.04); urination problem (p=<0.0001), and nervousness (p=0.004) were statistically significant and had a small to moderate relationship with work duration (see supplementary Table S1 in the online edition).

3.4 Health Outcomes Compared to the Previous PGMF Work Experience

Among the seven common health outcomes comparing with the previous PGMF work experience only nasal discharge (n=18, 30.0%); headache (n=20, 25.6%; p=0.002); urination problem (n=27, 42.9%), and nervousness (n=14, 20.0%; p=<0.0001) were statistically significant whereas, fatigue (n=30, 26.3%; p=0.81); loss of appetite (n=26, 23.6%; p=0.59); body weight loss (n=22, 21.2%; p=0.33) were statistically insignificant (Table 4).

4. DISCUSSION

In this study, we investigated the plastic chemical exposures related to twenty-seven health outcomes (e.g., respiratory, neurological, cardiovascular, digestive tract, etc. related) of the workers and compared these outcomes before and after their joining in PGMFs including their work duration in this sector. We found that seven out of the twenty-seven chemical exposure-related health outcomes were commonly present among the workers. All the symptoms increased among the workers after joining the factory. Apart from hypertension and tarry stool, all health outcomes among workers increased after they joined the PGMFs and the differences in each period were statistically significant. Log time work in the PGMFs had a significant impact on headache, fatigue, urination problem, and nervousness of the workers. The workers who had the previous same work experience showed significantly prominent respiratory, nervous, and renal system symptoms.

Fatigue (n=112, 27.8%) was the topmost common health outcome of the PGMFs workers. High exposure to styrene causes the acute reversible effect of fatigue [30]. Styrene can be absorbed into the blood by all routes like orally, inhalation, percutaneous absorption, subcutaneous, and intraperitoneal administration. The most common route of absorption of styrene among the PGMFs workers is inhalation and percutaneous. After absorption in the blood, it can produce toxicity and produce fatigue symptoms in humans [42]. Loss of appetite (n=108, 26.8%) was the second most common health outcome among the workers. Formaldehyde exposure can cause the loss of appetite [36]. Formaldehyde is a water-soluble volatile gas mainly absorbed in blood by the inhalation route [43]. In the case of acute formaldehyde poisoning, it can produce a loss of appetite [44]. Loss of body weight (n=102, 25.3%) was the third common symptom among the workers. Vinyl chloride exposure can reduce the body weight of factory workers [38]. Occupational exposure to vinyl chloride causes digestive tract disorder which may lead to body weight loss [45]. Vinyl chloride is a colorless, sweet odor gas generally used in industries and laboratories [45]. The workers got vinyl chloride exposure through oral and inhalation routes [46]. Reduction of body weight was reported in rats, mice, and hamsters after experimental administration of vinyl chloride through oral and inhalation routes [47]. Headache (n=76, 18.9%) was the fourth most common exposure health outcome. Exposure to styrene causes the acute reversible effect of headache[30], Nervousness (n=70, 17.4%) symptom was also a very common health outcome among the workers. A recent report showed evidence that some industrial chemicals like mercury, lead, polychlorinated biphenyl, etc. had the health outcome of neurological disorders in humans [39]. The nasal discharge (n=60, 14.9%) and urination problem (n=61, 13.1%) were also significant among the workers; formaldehyde exposure can affect both the respiratory and renal systems [36]. Besides these, chemical exposure to kids' toys has evidence of childhood cancer [48]. Working a long time in PGMFs with dust can cause diabetes [5]. However, fine particles released from the plastic can passes the blood-brain barrier and human placenta and thus can cause serious human health effects [49].

So far, this type of research on plastic chemical exposures related to the health outcomes of PGMF workers in Bangladesh is conducted for the first time. Conducting this type of survey and getting unbiased data was challenging because employers were often reluctant to allow their workers in participating such surveys for various reasons. Firstly, midlevel management thinks that workers will pass all kinds of inside information about the factory to the interviewer. Sometimes they thought that workers have the affinity to pass the wrong message against the factory. However, most of the mid-level management cannot recognize the benefit of the

research. Even they think the survey may negatively affect the business. On the other hand, workers are often afraid to provide the right information due to their job security. As most of the workers had secondary school level education, their answering quality was according to their education level. Also, self-reported exposure or information on health outcomes in the study could be erroneous. We have overcome all the challenges through public motivation. Firstly, we contacted the individual midlevel management of the factory. Then we showed them the questionnaire and consent paper and introduced them to our research objectives. After getting permission from the higher authority, they provided us the time and date for taking an interview. Without fettering the manufacturing, we took the interview. Thus, we tried our best to collect accurate and unbiased data in this study. Due to the lower education of the workers sometimes they did not provide the answer to the point. Some workers felt very shy during asking about a particular physical symptom present or absent. Overall, data collection from the workers for this study was very challenging and we tried to overcome such challenges and collected unbiased data. We studied health outcomes in 405 workers of six PGMFs in a local area out of thousands of factories in the whole country which might limit the scope of the study. Another limitation of the study was face-to-face interviewing of the PGMFs worker as some workers felt very shy when they were asked about a particular symptom whether present or absent. Sometimes, the workers forgot their previous health status before joining the PGMFs. We could not make a direct causal association between exposure to chemicals and health outcomes in PGMFs workers as we did not conduct an accurate exposure assessment through laboratory analysis of environmental samples of PGMFs for the presence of toxic and hazardous chemicals in our current study. As the education level of most of the workers was lower, the objectives of the research seemed to them unimportant or irrelevant and data collection from the workers was therefore very challenging. In the future, health outcomes of PGMFs workers need to be evaluated on a large scale in Bangladesh and a questionnaire survey along with personal exposure assessment combined with an analysis of environmental samples and biological samples from the workers should be included in a future study to identify hazardous and toxic chemicals associated with major health outcomes in PGMFs workers and also to identify potential risk factors of such health outcomes to provide useful guidelines to control or minimize health outcomes in PGMFs workers.

5. CONCLUSION

In this study, we evaluated the health outcomes among the PGMFs workers in Bangladesh related to plastic chemical exposures at their work and compared those outcomes before and after their joining in PGMFs. Based on our study results, at least one of the studied twenty-seven health outcomes was increased among the workers after joining the PGMF. Fatigue, loss of appetite, nervousness, and body weight loss were the top work-related health disorders among the workers. Work-related increases in all these health outcomes were statistically significant. We first time identified important health outcomes of the PGMFs workers in Bangladesh and generated baseline information on common health outcomes of the PGMFs workers, which can be utilized later as pilot data for a large-scale study among these workers. Future studies should be directed towards the identification of potential causes and pathology of such health outcomes and diseases considering both specific biomarkers and real-time environmental samples to better recommend mitigation of adverse health outcomes among workers in PGMFs in developing countries.

ETHICAL APPROVAL AND CONSENT

The study design was approved by the ethical committee of Sylhet Agricultural University before implementation. Written consent was taken from the workers before data collection. The research objectives were introduced clearly to the selected participants and written consent from the participants was taken before interviewing.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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SUPPLEMENTARY MATERIALS

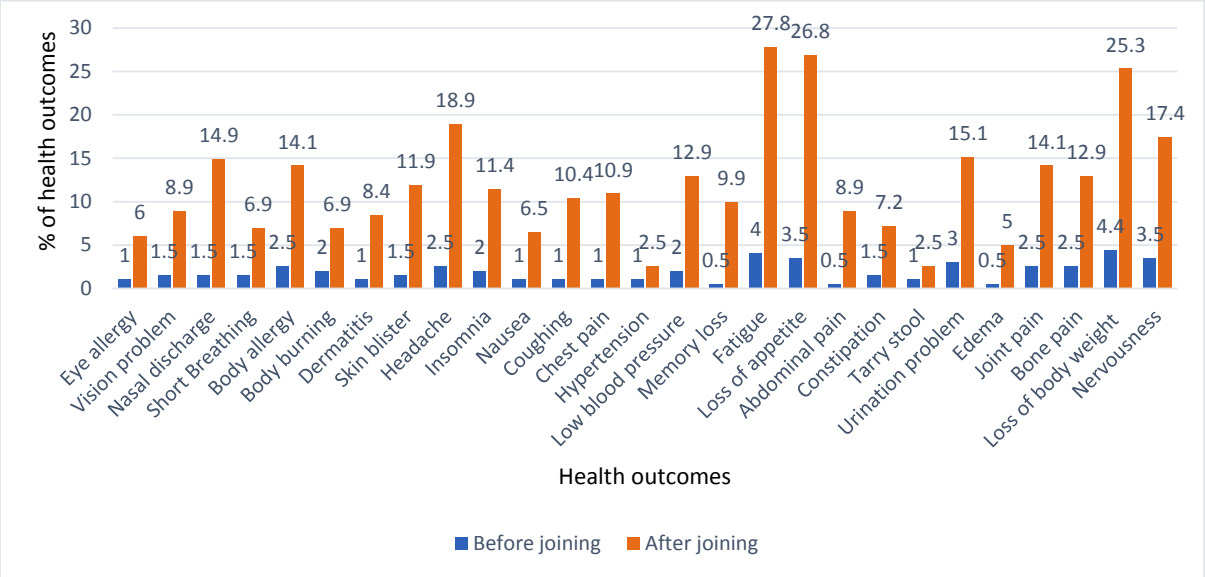

Fig. S1. Percentage of all health outcomes before and after joining in factories

Table S1. Chi-Square (χ^2) test of work duration and common health outcomes after joining in factory

	Chi-Square Tests			
Common health outcomes		**Value**	**df**	***p***
Nasal discharge	Chi-Square (χ^2)	0.37	2	0.83
	Cramer's V	0.03	-	
Headache	Chi-Square (χ^2)	10.52	2	0.005
	Cramer's V	0.16	-	
Fatigue	Chi-Square (χ^2)	6.37	2	0.04
	Cramer's V	0.12	-	
Loss of appetite	Chi-Square (χ^2)	3.17	2	0.20
	Cramer's V	0.08	-	
Urination problem	Chi-Square (χ^2)	30.59	2	<0.0001
	Cramer's V	0.27	-	
Bodyweight loss	Chi-Square (χ^2)	0.80	2	0.66
	Cramer's V	0.04	-	
Nervousness	Chi-Square (χ^2)	10.87	2	0.004
	Cramer's V	0.16	-	

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