DEVELOPMENT OF ANTI-FOG AGENT FOR THE REDUCTION OF POTENTIAL OCCUPATIONAL VISUAL HAZARDS AT WORKPLACES

F. Sajjad[*], A. Ali[**] and S.R. Ahmad[*]

[*]College of Earth & Environmental Sciences, University of the Punjab, Quaid-e-Azam Campus, Lahore, Pakistan
[**]Corresponding author: azhar.cees@pu.edu.pk

ABSTRACT: The temperature differences across glass or plastic shield causes fogging which ultimately reduce visibility for workers at workplaces particularly in industry particularly transportation. The research implicated the development of a promising anti-fog agent in order to reduce the risks of accidents due to poor visibility. Anti-fog agent was developed in laboratory through varying formulation of ingredients such as deionized water, Iso propyl alcohol, non-ionic surfactants, sodium lauryl ether sulfate 33%, silicone wacker and alkane sulphonate. After achieving successful results at laboratory and pilot through standard testing, anti-fog agent was provided to drivers of local transport at commercial scale and their responses were obtained through questionnaires. The results revealed significant ($P<0.05$) satisfaction of drivers for wind screens of cars, coasters buses as well as helmet screen of bikers. This study provided a promising solution for one of the most important concerns of fogging in transportation causing accidents. Further, this anti-fog agent can be replicated in other industries facing visual problems as a result of fogging. It is recommended that this anti-fog agent should be supplied at commercial scale after approval from concerning government department to avoid future loss.

Keywords: fogging, vision hazards, transportation industry, stress, anti-fog agent, ecofriendly.

(Received 03.01.2021 Accepted 23.03.2021)

INTRODUCTION

Fogging is the main problem for workers working outdoors (such as construction, mining, and utility workers) as well as indoors in industries like paper and pulp, chemical processing, power generation, and metal refining (Xiang *et al.*, 2014). Workers wearing full body apparatuses such as tactical workers, firefighter, hazmat, cleanroom, and nuclear utility workers are at greater risk causing them to perspire heavily and as a result of this temperature alteration, fogging of apparatus occurs. (Groh, 2011). Potential visual hazards are found in almost every industry due to fogging, therefore, workers avoid wearing safety glasses or goggles (Crebolder, 2004). Approximately 2,000 occupational eye injuries are reported every day requiring medical attention. Yearly, 800,000 eye injuries will occur which may result in $300 million in lost production time, $4 billion economic and production loss, and unimaginable cost of personnel's lost vision. (Harris, 2011).

Fogging is a frequent problem where the climate is humid or warm and where workers move from cool to warm or warm to cool environments frequently. Fog is formed when the temperature of the surface is cooled to below a dew point of atmospheric air, forming fine water droplets that reflect light at different angles to the surface causing hindrance in vision (Yamamoto *et al*., 2013). First responders, forklift drivers, and police constables are few occupations in which they have to go hither and thither going from hot temperature to cold temperature and vice versa (Momin, 2015). Different medias are made from various types of materials, including metal oxides (Takeda *et al*., 1999), glass (Takeda *et al.*, 1999), silicon (Ruzyllo, 2014), and graphene (Li *et al*., 2014), which with time lose hydrophilicity (antifog property) due to airborne pollutant layered on to their surfaces. Another lesser-known cause is the washing of lenses which diminishes its AF properties (Sanchez-Miller, 2017).

According to Occupational Health and Safety Administration (OSHA), standards are available which require owners to provide personal protective equipment (PPE's) for eyes after hazard assessment (OSHA 1910.132(d) (2)). Also, OSHA implies that PPE's should be in "sanitary and reliable condition" (1910.132(a)). Reliable conditions may include the defogging of safety equipment in certain workplaces. Additionally, OSHA regulates training and awareness on provided safety equipment (1910.132(f) (1)), in which fogging hazard should be discussed. (Talbott, 2015).

Severe visual weariness is a very common global injury in industry and in homes (Fea *et al.*, 2008; Lombardi *et al.*, 2005; Smith *et al.*, 2005; Islam *et al.*, 2000), though many social and economic problems can be prevented by proper utilization of defogged protective eyewear. (Mancini *et al.*, 2005). A study done in the year 2000, by the Bureau of Labor Statistics (BLS) projected that out of all the workers working, 60% experienced work-related eye injury. There was an absence of protective eyewear, the wrong type or defogged eyewear was worn at the time of injury (Bureau of Labor Statistics, 2000). According to recent approximations, the National Survey of Health Interviews (NHIS) put forward that 32.1% of workers wear eye protection while performing their activities and 29.3% of US adults engage themselves in activities that could cause an eye injury. (Forrest *et al.,* 2008).

Although with the advancement of new technology in transportation industry, new cars are specialized with anti-foggers and fog detectors (Kang *et al*., 2008) but in case of under developed countries this might be a reason for major accidents or fatalities (Akatsu *et al.,* 2013) According to WHO, 1990 road injuries occur twice as often in underdeveloped and developing countries as they do in developed ones, mainly because of rapid motorization without adequate investment in road safety strategies and urban planning. Fogging of media or windscreens are the issues which are usually overlooked and become the reason of fatal accidents on road (US Department of Transportation, 2009) (Cluett, 2009). Generally, there are three type of conditions when fog appear on windshields of any vehicle, i.e., snow, rain and fog/smoke and most of the lethal road accidents or crashes occur due to this phenomenon because of the visibility obstruction and stress (Hill *et al*., 2007). This issue is usually flouted but it plays an important role in reducing the accident and death rate occurring on roads. (Aty *et al.,* 2011).

Workers are vulnerable to different hazards, in case of lack of compliance with safety eyewear policy, and are susceptible to minor to life-threatening injuries. Apart from safety, workers' productivity is also affected. For instance, when eyewear is fogged, it is removed and cleaned repeatedly which causes an interruption in working and leaving the worker unprotected. (Sanchez-Miller, 2017). A safety trainer Jerry Daniels concludes that fogging is usually an unidentified matter in many workplaces but the good thing is there are solutions that can make a tangible difference in safety (Groh, 2011).

It is reported in literature that safety eye wears are made up of different materials which include acrylic, polycarbonate, other plastics and even annealed glass with anti-reflective, non-scratch and easy to clean coatings. Although 55 % of scientists around the world have shown serious interest in ocular industry (e.g., telescopes, cameras, sensors, and lenses), automobile industry (e.g., windshield glass and rearview glass), solar industry (e.g., photovoltaic modules), the architectural sector (e.g., windows and mirrors), food and beverage industry (e.g., food containing and wrapping), and pharmaceutical (e.g., safety glasses and endoscopes) to avoid fog related accidents (Duran *et al.*, 2018; Groh, 2011). Accidents related to fogging are rarely reported especially in Pakistan. According to national highway, 20% accidents are reported on road due to fogging during rainy and winter season (Maqbool *et al.,* 2019).

Occupational and non-occupational visual hazards can be removed by application of chemically produced anti-fog agents on glass screens of safety equipment and windshields. Anti-fog solutions significantly impact the efficiency of fogging media (Howarter *et al.,* 2008). Reducing fog issues in the industry may considerably enhance worker's performance and efficiency. Workers stop removing their eyewear because of fog-related stress, and safety compliance increases dramatically. The purpose of the study is to develop anti-fogging agent to reduce vision related occupational and non-occupational incidents

MATERIAL AND METHODS

General Information and Data Collection: The current study recruited primarily workers/drivers employed in transportation industry where a large number of accidents occur as a result of fogging in humid/foggy seasons (rainy, winter and snow). Demographic characteristics such as age, gender, marital status, education, type of occupation, no of vehicles and average driving/day in hours of the focused population (drivers) were collected and rate of accidents in commercial and non-commercial sector was calculated (Verriest *et al.,* 1982). The suggested survey was conducted with the full engagement of drivers from both sectors. After a 30-day trial period, 100 drivers were engaged from both sectors which comprised of 20 bus drivers, 15 coaster drivers, 30 car drivers from commercial sector and 20 car drivers and 15 bike riders from non-commercial sector. Desk study, questionnaire surveys, reports, feedbacks from workers or even direct observation were used to identify different hazards.

Hazards about fogging while driving were identified, risk assessment was carried out and a solution to the specific problem was proposed by the formulation of anti-fog agent prepared with commercially available, indigenous and economical chemicals which had cleaning and antifogging properties. Lab scale to commercial scale testing was conducted in order to evaluate the effectiveness of prepared formula. Another set of questions were acquired after providing the agent to drivers for a certain period of time which included data regarding the durability, effectiveness, stress while driving and irritation due to chemicals. Average cost difference per accident was also calculated before and after the usage of solution per season. By keeping this a standard, this might be a solution for other industries where fog is a barrier between the worker and their task.

Data Analysis: The data collected from questionnaires was composed, authorized and evaluated statistically. Quantitative variables were summarized using range, mean, and standard deviation. Categorical variables were tabulated using frequencies and percentages.

Risk Assessment: Risk assessment was carried out in order to calculate the likelihood and severity of hazards under the criteria as shown in Table 1. Inherent risk and residual risk were calculated by using risk matrices table **(**Gul and Guneri, 2016).

In the proposed study, engineering control has been used by applying antifogging agent in order to reduce potential hazards and considering other factors in the selected industry. Administrative controls were also applied in order to reduce the rate of accidents. Residual risk was calculated to ensure safety in the selected occupation. This control might be pragmatic in other industries where fog is the reason for many types of accidents mainly causing eye injuries because of fogging and potential life losses.

Table 1. Potential impacts of different types of hazards.

Hazard	Type of Hazard	Potential Impacts
Low vision/Eyesight	Physical	Vision impairment, Fatigue
Human error/Carelessness	Physical	Loss of life, property
Lack of warning signs/Reflectors	Safety	Severe accident
Lack of adequate instrumentation	Safety	Loss of productivity
Heavy Rainfall	Psychological	Glare issues, anxiety
Road surface obstacles	Ergonomic	Ergonomic stress
Night time driving	Physical, Ergonomic	Loss of life, Severe accident
Speeding	Physical, Chemical	Full body injuries, pedestrian loss
Dirty windscreens	Ergonomic	Eye stress, muscle stress

Experimental Work for The Development of Anti-Fog Agent: Different types of chemicals were selected on the basis of their cleaning and antifogging properties. All the chemicals used were conveniently accessible having environmentally friendly characteristics. By taking into consideration, the cleaning, anti-misting, and anti-fogging properties of these chemicals, an efficient, durable, and cost-effective solution was prepared using trial and error methods. For the development of anti-fog optimized ratios of chemicals were mixed to form a solution. Formulation of anti-fog agent was carried out by the following steps;

Step 1: A 100ml diluted solution of isopropyl alcohol was prepared with deionized water and blended for 5 minutes using a magnetic stirrer. Certain parameters such as pH, clarity, wetting, smoothness, cleaning, lining after drying, the residue left on the glass, and anti-fog effect were measured and analyzed. The most optimized ratio was locked and used for the next step of the experiment (Introzzi *et al.,* 2012)

Step 2: During second step, the trail was conducted for different types of non-ionic surfactants. A diluted solution of selected cleaning agent with optimized ratio was taken and with the help of a dropper, a non-ionic surfactant such as Lutensol 30, Lutensol 60, Lutensol 80, and Lutensol 90 was added simultaneously and stirred giving a greasy effect to the solution. Again, the aforementioned parameters were determined and the most suitable proportion was locked and used for the next part of the experiment (Cai *et al.,* 2015).

Step 3: The third step involved the analysis of the effect of an-ionic surfactants using the same abovementioned procedure. By agitating the cleaning agent-water composition with different an-ionic surfactants for at least 10 minutes at room temperature. Chemicals such as SLES (Sodium Lauryl Ether sulfate), Alkane Sulfonate, dioctyl sulfosuccinate, and fatty alcohol sulfate were used in different volumes as anionic surfactants (Asthana *et al.,* 2007).

Step 4: Finally, various types of additives were added to make it appropriate for fogging effects. In the secured emulsion, additives such as polyacrylic acid, polyvinyl pyrrolidone, silicone water base and silicone Wacker were added by succeeding in turns in order to analyze the optimized ratio of chemicals making the solution efficient for antifogging (Wagner, 2001). To enhance the effect of antifogging, other additives were added and, stirred for specific time in previously made solutions such as alkane sulfonate, monoethylene glycol, diethylene glycol, and glycerin. Parameters referred to before were regulated and detected after each step of the experiment in order to get desirable and effectual outcomes.

QUALITY TESTING OF AN ANTI-FOG SOLUTION

Lab Scale Testing: After the preparation, hot fog tests, cold fog tests, and aspiration tests were conducted on the coated glass slide. An uncoated glass slide was used as a standard to examine the anti-fog effect. In hot fog or steam, assessment water was heated at 80°C in a beaker and a glass slide with a coated solution was exposed to water vapor/steam. The visibility through the glass slide was analyzed for the degree of anti-fog. In cold fog test, the smeared glass slide was placed in the refrigerator at 4°C for a certain period of time and then placed on the steam containing the beaker. For standardization, an uncoated slide was also placed in the refrigerator at the same temperature. The third test was a quick analysis done in order to check the anti-fog effectuation of the solution. A breathing/aspiration test was performed on the coated glass slide and observation was done. (Chang *et al.*, 2012; Tang *et al.*, 2014; Nuraje *et al.*, 2011)

Pilot Scale Testing: For pilot-scale study, the vehicle windscreen and personal protective equipment (PPEs) of eye and face protection were selected in order to achieve the reduction of potential visual hazards and avoid probable life losing incidents in different industries. After the completion of pilot-scale analysis, another questionnaire was distributed and collected from transportation industry to discover the effects of solution, vision improvement and stress relief during driving which might result in the reduction of rate of accidents caused by fogging.

RESULTS AND DISCUSSION

Demographic Characteristics of Focused Populations: It was revealed from the statistical analysis that 93.8% drivers responded from the commercial sector (Table-2). Whereas, 26 out of 35 drivers belonged Uber/Careem drivers or domestic drivers. Therefore, out of 100 drivers only 87 drivers (only male) aged between 15 to 50 years participated in the study making the total response rate 87% (Table-2). As company owners were directly contacted that's why the response rate was quite efficient. Most of the drivers working for commercial sectors belonging from backward areas never attended an educational institution, only 34% of them completed their primary education and approximately 13% attended secondary schools. Rather in non-commercial sector 46% of drivers completed their secondary education and 15% are completing higher studies. Most of the men in commercial sector were married, had no other way of income and were sole earner of their families. In case of any kind of injury, the families of the drivers were heavily affected. Heavy traffic vehicle drivers were more stressed spending more than 8 hours at work in a day. Other commercial drivers group worked more than 8 hour which corresponds to 35 % of the total. Most of the domestic drivers worked only 2 to 3 hours a day rather 46% of people working for Uber/Careem had to drive more than 8 hours. In the end, 18%-36% domestic bike riders rode less than 8 hours and approximately 46% riders working for Uber/Careem or other companies rode more than 8 hours in order to make satisfactory income**.** Drivers driving for more than 8 hours a day were facing high stress and fatigue which may increase the risk of accidents eventually.

Table-2. Demographic characteristics of focused population.

Characteristic		**Respondents n (%)**		
		Commercial		**Non-commercial**
Age (Years)	15-25	7(11.4)		9(34.6)
	26-35	23(37.7)		13(50.0)
	36-45	27(44.2)		2(7.6)
	>45	4(6.5)		2(7.6)
Gender	Male/Female	87(100.0)/0		
Marital Status	Single/Married	12(19.6)/49(80.3)		13(50.0)/13(50.0)
Education	None	32(52.4)		2(7.6)
	Primary	21(34.4)		8(30.7)
	Secondary	8(13.1)		12(46.1)
	Higher	0(0.0)		4(15.0)
Type of Occupation	Response Rate	61(93.8)		26(74.2)
Type/Number of Vehicles	Buses	19		-
	Coasters	14		-
	Cars	28		-
	Cars (Uber)	-		15
	Bike (Uber)	-		11
		<4hrs	*4-8hrs*	*>8hrs*
Average driving/day (Hours)	Buses	-		19(100.0)
	Coasters	-		14(100.0)
	Cars	4(14.2)	14(50.0)	10(35.7)
	Cars (Uber)	3(20.0)	5(33.3)	7(46.6)
	Bike (Uber)	2(18.1)	4(36.6)	5(45.4)

Rate of Accidents as A Result of Fogging: Figure 1 shows that approximately 40% bus drivers suffered from fatal accidents because of fogging per season. 25% coasters underwent deadly and life loosing accidents. In the same way 20% of commercial cars faced dangerous affects because of fog issue on windscreens. On the other hand, only up to 2% of non-commercial cars suffered from accident due to foggy media. Rather bike riders suffered from 10% accident ratio because of blurry glass of helmets per season.

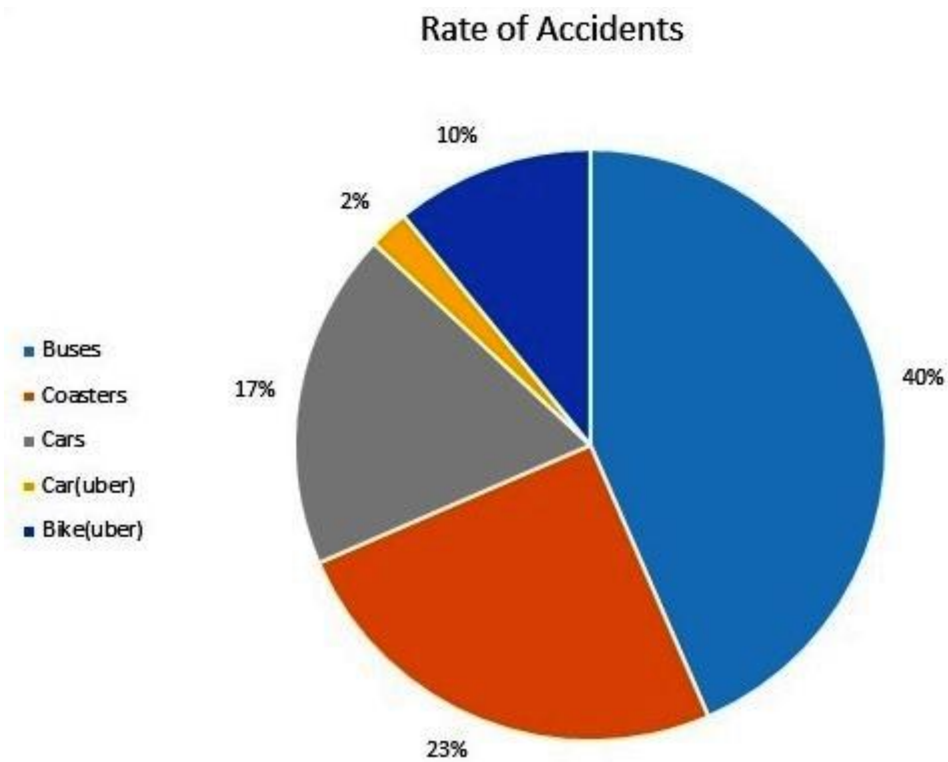

Figure-1: Rate of accidents per season.

It was inferred from the analysis that as a result of such lethal accidents, there is a great loss of life and property and sometimes may become the reason of socioeconomic crises for the company owners. Direct losses can somehow be measured using different methods but the costs related to losing the driver to injury or death is impossible to measure and also the incalculable cost afflicted of the families of workers or passengers (Douglas, 2003). All kinds of costs are usually paid off by the owners of the companies in case of commercial sector i.e., in this case travelling agencies. While non-commercial individuals have to make up on their own for their losses.

Risk Assessment: Hazard identification in transportation industry with commercial and non-commercial vehicle was done qualitatively and objectively using different techniques from literature (Table-1) (Glossop *et al.,* 2005). Research studies, incident data, interview, physical observations were used to note down major hazards during driving in foggy conditions.

After the thorough identification of hazards, qualitative risk analysis was done in order to determine the severity of hazards and the likelihood of hazard to create certain impact (Table 3). Risk assessment matrices and heat maps were used to highlight these hazards and to prioritize them into High, Medium and Low. These tools are quite useful for assigning risks into matrix or map so that highest level risks are determined and analyzed without difficulty. Inherent risk and residual risk were also calculated (Table 4). The risk after identifying the hazards was reduced by applying various control measures (Manuele, 2005). Blurriness of windscreens might be a reason of psychological stress, physical injury or even in worst case, death. Inherent risk *i.e.*, 12 or 20 (high) of blurred windscreens was reduced to 6 (low) by proper training and awareness, frequent breaks during driving and using anti fog agent for cleaning and defogging (Alvaro *et al.,* 2018). Then inherent risk for rash during and dirty wind screens was calculated to be 15 and 12 respectively which could be reduced by using warning signs, road breakers and windscreen cleaners (Verma *et al.,* 2018). After applying the mitigatory measures residual risk became quite acceptable (low or 0). During heavy rainfall fog appear on wind screens causing high level of risk (15) to drivers which may be diminished by training the driver to drive in rainy conditions and keeping the windscreens defogged (Konstantopoulos *et al.*, 2010; Mutlu *et al.*, 2016).

Table 3. Guidelines for risk assessment (Cooper *et al.*, 2005; Wegman, 2007).

Guidelines for Risk/Impact Assessment					
Measurement of Likelihood			**Measurement of Severity**		
Level	Descriptor	Description	Level		Description
5	Almost Certain	Will certainly occur in most of the circumstances	5	Very High	Multiple Fatalities
4	Likely	Will probably occur in most of the circumstances	4	High	Single Fatality
3	Possible	May occur at some time	3	Moderate	Major Health Effect/Injury
2	Unlikely	May occur in some exceptional circumstances	2	Low	Minor Health Effect/Injury
1	Highly Unlikely	Have never heard of such happening	1	Very Low	Slight Health Effect/Injury

Risk/Impact Level

Likelihood

1	2	3	4	5
2	4	6	8	10
3	6	9	12	15
4	8	12	16	20
5	10	15	20	25

Severity

Risk/Impact Level

Table 4. Results of risk assessment and control measures in transport industry.

Sr. No.	Process /Activity	Identified Hazard	Impacts	Impact Rating: Likelihood (L)	Impact Rating: Severity (S)	Impact Rating: Risk/Impact Value (LxS)	Control Measures	Residual risk
1	Driving in rain/fog	Blur windscreen in snow/fog	Mental Stress and eye stress	3	4	12	training and awareness, cleaning of windscreen, frequent breaks during driving	R: 2x3=6
2		Blur windscreen in snow/fog	Physical injuries and fatality	4	5	20	training and awareness, antifog agent for windscreen	R: 3x2=6
3		Use of mobile during driving in fog	Physical injury	3	3	9	Warning signs, awareness, reflectors on roads	R: 2x3=6
4		Rash driving/overspreading	Physical injury, damages to vehicle	3	5	15	warning signs, road breakers	R: 2x4=8
5		Dirty windscreen during driving	Ergonomic stress, anxiety, glare issues	3	4	12	Windscreen cleaner agent	R: 2x3=6
6		Human error during driving	Physical injury	2	3	6	Training and awareness	
7		Heavy rainfall	Physical injury, damages to vehicle, chain accidents	3	5	15	safety signs for rain, awareness about driving in rain.	R: 2x4=8

Optimization of Anti-Fog Solution: A series of experiments were performed to prepare solution to get its maximum efficiency. Most effective ratio was observed in solution B with the values of deionized water 90ml, IPA 15ml, SLES 33% 0.75ml, silicone wacker L05 0.2ml, alkane sulphonate 0.5ml. Various parameters for all samples were tested to optimize the best solution including pH values of 7.1, clarity, wetting, smoothness, lining, residue on glass and anti-fog effect (Table 5).

Table 5. Formulation of anti-fog agent.

Optimization of enhanced anti-fog action				
Trial	A	B	C	D
Materials	Quantity(100mL)			
Deionized water	95	90	85	80
IPA	15	15	15	15
SLES 33%	0.75	0.75	0.75	0.75
Silicone Wacker L05	0.2	0.2	0.2	0.2
Alkane sulphonate	0.25	0.5	0.75	1
Parameters				
pH	7.1	7.1	7.1	7.1
Product clarity	✓	✓✓	□	□
Wetting on glass	□	□	✓	✓
Smoothness	✓	✓	✓	✓
Lining after drying	✓	□	✓	□
Residue on glass	✓	□	□	□
Anti-fog effect	D	D✓	ND	ND

Laboratory and Pilot Scale Testing: During lab scale testing, an uncoated glass slide was used as a standard and fog dissipation time was calculated. Video tape recordings determined that after only maximum of one to two seconds fog was dissipated off the coated glass slide. The results were even better in the case of aspiration testing. Then pilot scale testing was done on PPEs and windscreens of different cars during rain/fog. The glass began to defog after a few seconds and remains defogged for the next round. During Covid-19, people wearing a combination of glasses and surgical masks, when provided with such agent were free from foggy glasses because of the effectiveness of agent.

Application of Tested Solution to Transport Industry: The results revealed during survey that 90% of drivers from commercial sector were unaware of any such product rather 70% from non-commercial sector knew but never used the product because of high prices (Fig 2). Most of them used air conditioning to remove fog from windscreen. Before and after the application of anti-fog, it was determined that there was a 50% to 75% decrease in the cost of accidents in commercial sector due to fogging. Previously, when bus accidents occurred there would be a loss of around 20 lacs/season or more altogether including the cost of vehicle damage, cost of driver's injury, cost or passenger's injury and uncountable cost of indirect effects. By using the agents, owners can not only prevent lethal accidents but also the cost might reduce to 8 lacs per season. There was a 60% reduction in the cost of bus and coaster accidents (as shown in Fig 2). In the same way 75% reduction in case of commercial cars, 90% in case of non-commercial cars (Uber). And there was 100% reduction in case of motor bike accidents.

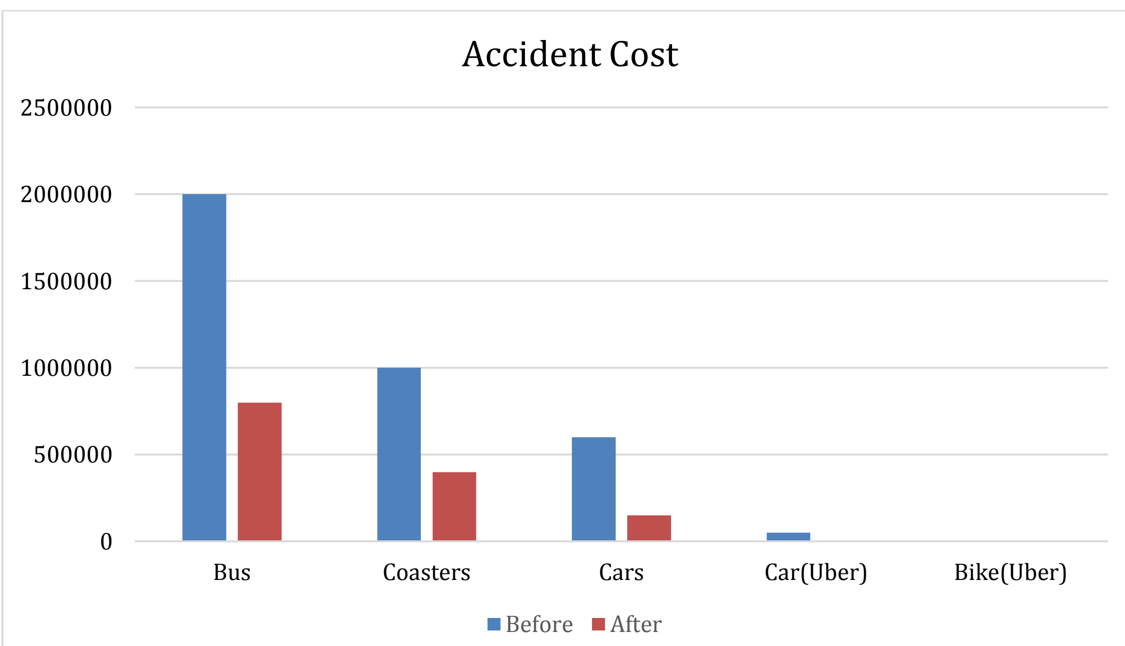

Figure 2. Cost of accidents in transportation industry per season.

The results have shown that around 83% of bus drivers especially 79% coasters drivers experienced the ease of driving after applying the anti-fog solution at night time. Whereas, 73% car drivers from commercial sector and 54% drivers from non-commercial sector were satisfied with the tested product. Similarly, the application on helmet for bike rider (79%) were found good while riding in foggy and rainy season. The ergonomic stress level diminished to quite an effective level, around 80% bus drivers, 74% coaster drivers and 70% car drivers from commercial sector have shown stress free driving apart from overloaded time schedule of all drivers (Fig 3). As there is a greater risk for bike riders, 75% of them were free of fog related ergonomic/eye stress.

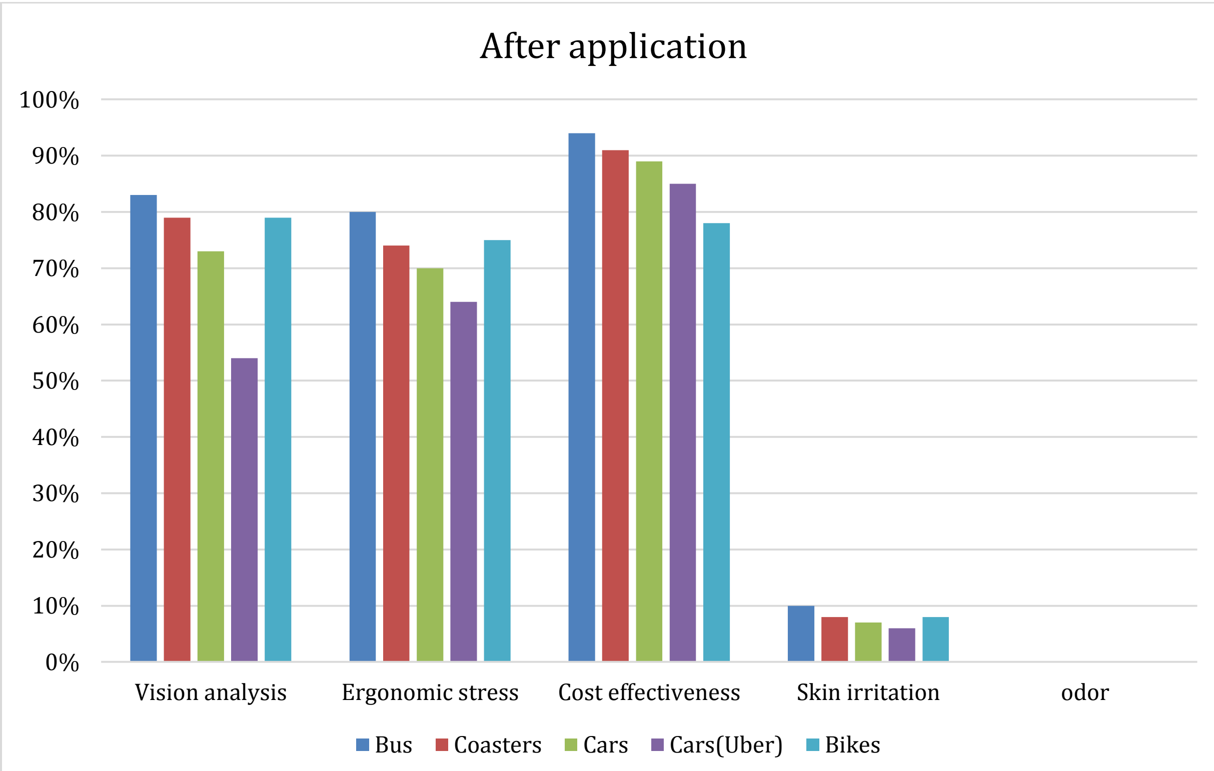

Figure 3. Factors Assessed after the application of antifogging agent.

As mentioned above, the solution was made with commercially available, inexpensive and eco-friendly chemicals it was quite cost effective for both commercial and non-commercial sectors. The larger the vehicle the solution would be more cost effective as it would be much less than the cost of accidents or injury to the workers. The internationally imported antifogging products in the market are quite expensive. Proportional to that, the proposed product was prepared at a price as low as 80Rs to be used locally. As the chemicals were ecofriendly, so skin irritation and other allergies only occurred if driver had any special allergy/condition. The product was scented with desired aromas; therefore, odor did not affect any driver/rider.

Conclusions: Hazards related to fogging are found in many industries that are causing severe accidents and injuries. The rate of accidents because of fogging is considerably high in transport industry. In Pakistan, the health status, life and property are negatively affected by the ignorance towards such substantial affairs. An anti-fog agent was prepared in optimum concentrations of indigenous and economical chemicals and to solve visual hazards due to fogging in any occupation. The results of its application revealed that the number of accidents that could occur in transportation industry due to fogging on windscreens/media in commercial and non-commercial sector. It was inferred that on commercial scale, rate of accidents as a result of fogging was reduced to 50-75% which in turned reduced the cost inflicted on owners as a result of severe accidents. It is concluded that locally prepared anti-fog agent is effective to reduce visibility hazards in transportation industry. It is recommended to develop statistical data of number of road accidents, therefore, application of anti-fog agent can be prepared and tested on larger scale.

Acknowledgment: We are thankful to the contribution of Shafi Reso Chemicals for the development of anti-fog agent. Special thanks to Mr. Muhammad Naveed Ashraf for kind guidance to carry out this research.

REFERENCES

Abdel-Aty, M., M., A.A. Ekram, H. Huang and K. Choi (2011). A study on crashes related to visibility obstruction due to fog and smoke. Accid Anal Prev. 43(5): 1730-1737.

Akatsu, K. and N. Matsui (2013). June. New trend of motor technology for automobiles-Introduction and overview. In 2013 IEEE ECCE Asia Downunder. pp. 130-135. IEEE

Alvaro, P.K., N.M. Burnett, G.A. Kennedy, W.Y.X. Min, M. McMahon, M. Barnes, ... and M.E. Howard (2018). Driver education: enhancing knowledge of sleep, fatigue and risky behaviour to improve decision making in young drivers. Accid Anal Prev. 112: 77-83.

Cai, M., Q. Li, and X. Chen (2015). Synthesis, surface activity, and antifogging property of triethanolamine monolaurate ester. Chin. J. Chem. Phys. 28(2): 223-229.

Chong, S.J., C. Smith, A. Bialostocki and C.N. McEwan (2007). Do Modern Spectacles Endanger Surgeons: The Waikato Eye Protection Study. Ann. Surg. 245(3): 495.

Cluett, C., D. Gopalakrishna and L. Osborne (2009). Road weather management program performance metrics: implementation and assessment (No. FHWA-JPO-09-061). United States. Dept. of Transportation. Research and Innovative Technology Administration.

Cooper, D.F., S. Grey, G. Raymond and P. Walker (2005). Project risk management guidelines: Managing risk in large projects and complex procurements. John wiley & sons, Inc.

Crebolder, J.M. and R.B. Sloan (2004). Determining the effects of eyewear fogging on visual task performance. Appl Ergon 35(4): 371-381.

Douglas, M. (2003). Risk acceptability according to the social sciences (Vol. 11). Psychology Press.

Durán, I.R. and Laroche (2018). Current trends, challenges, and perspectives of anti-fogging technology: surface and material design, fabrication strategies, and beyond. Prog. Mater. Sci. 99: 106-186

Fea, A., A. Bosone, T. Rolle and F.M. Grignolo (2008). Eye injuries in an Italian urban population: report of 10620 cases admitted to an eye emergency department in Torino. Graefes Arch. Clin. Exp. Ophthalmol. 246(2): 175-179.

Forst, L., I.M. Noth, S. Lacey, S. Bauer, S. Skinner, R. Petrea and J. Zanoni (2006). Barriers and benefits of protective eyewear use by Latino farm workers. J Agromedicine 11(2): 11-17.

Forst, L., S. Lacey, H.Y. Chen, R. Jimenez, S. Bauer, S. Skinner and L. Conroy (2004). Effectiveness of community health workers for promoting use of safety eyewear by Latino farm workers. Am. J. Ind. Med. 46(6): 607-613.

Glossop, M., A. Loannides and J. Gould (2000). Review of hazard identification techniques. Health & Safety Laboratory

Groh, J. (2011). Coming Out of the Fog. Occup Health Saf. (Waco, Tex.) 80(9): 58-59.

Gul, M. and A.F. Guneri (2016). A fuzzy multi criteria risk assessment based on decision matrix technique: A case study for aluminum industry. J Loss Prev Process Ind 40: 89-100.

Harris, P.M. (2011). Workplace Injuries Involving the Eyes, 2008. Mouth, 3: 7-1.

Hill, J.D. and L.N. Boyle (2007). Driver stress as influenced by driving maneuvers and roadway conditions. Transportation Research Part F: Transp Res Part F Traffic Psychol Behav 10(3): 177–186.

Howarter J.A., and J.P. Youngblood (2008). Self-Cleaning and Next Generation Anti-Fog Surfaces and Coatings. Macromol Rapid Commun. 29(6): 455-466.

Introzzi, L., J.M. Fuentes-Alventosa, C.A. Cozzolino, S. Trabattoni, S. Tavazzi, C.L. Bianchi, ... and S. Farris (2012). “Wetting enhancer” pullulan coating for antifog packaging applications. ACS Appl. Mater. Interfaces 4(7): 3692-3700.

Islam, S.S., E.J. Doyle, A. Velilla, C.J.Martin and A.M. Ducatman (2000). Epidemiology of Compensable Work-Related Ocular Injuries and Illnesses: Incidence and Risk Factors. Occup Environ Med. 42(6): 575-581.

Kang, D.C., D.K. Park and S.B.Cho (2008). A New Fog Detection Technology by Using a Current (pA ~nA) Path on the Interior Windshield of a Vehicle and Application. SAE Technical Paper Series.

Konstantopoulos, P., P. Chapman and D. Crundall (2010). Driver's visual attention as a function of driving experience and visibility. Using a driving simulator to explore drivers’ eye movements in day, night and rain driving. Accid Anal Prev 42(3): 827-834.

Li, Z., Y. Wang, A. Kozbial, G. Shenoy, F. Zhou, R. McGinley and H. Liu (2013). Effect of airborne contaminants on the wettability of supported graphene and graphite. Nat. Mater. 12(10): 925-931.

Lombardi, D.A., R. Pannala, G.S. Sorock, H. Wellman, T.K. Courtney, S. Verma and G.S. Smith (2005). Welding related occupational eye injuries: a narrative analysis. Inj. Prev. 11(3): 174-179.

Mancini, G., A. Baldasseroni, G. Laffi, S. Curti, S. Mattioli, F.S. Violante (2005). Prevention of work related eye injuries: long term assessment of the effectiveness of a multicomponent intervention among metal workers. Occup. Environ. Med. 62: 830–835.

Manuele F.A. (2005). Risk assessment & hierarchies of control. Prof. Saf. 50(5): 33-39.

Maqbool, Y., A. Sethi AND J. Singh (2019). Road safety and Road Accidents: An Insight. International Journal of Information and Computing Science 6: 93-105

Mutlu, M., G. Sevilgen and M. Kilic (2016). Evaluation of windshield defogging process in an automobile. Int J Veh Des , 71(1-4), 103-121.

National Research Council (1984). OZONE. Emergency and Continuous Exposure Limits for Selected Airborne Contaminants: Volume 1.

Négrel A.D. and B. Thylefors (1998). The global impact of eye injuries. Ophthalmic Epidemiol 5(3): 143-169.

Ruzyllo, J. (2013). Assessment of the progress in gas-phase processing of silicon surfaces. ECS J. Solid State Sci. Technol. 3(1): N3060.

Sanchez-Miller, W. (2017). Tips for combating Fog on Safety Lenses to improve safety, productivity.

Smith, G.S., A.E. Lincoln, T.Y. Wong, N.S. Bell, P.F. Vinger, P.J. Amoroso and D.A. Lombardi (2005). Does occupation explain gender and other differences in work-related eye injury hospitalization rates? Occup Environ Med. 47(6): 640.

Sumner, R., C.J. Baguley and J. Burton (1977). Driving in fog on the M4. Transport and Road Research Laboratory.

Takeda, S., K. Yamamoto, Y. Hayasaka and K. Matsumoto (1999). Surface OH group governing wettability of commercial glasses. J Non Cryst Solids 249(1): 41-46.

Takeda, S., M. Fukawa, Y. Hayashi and K. Matsumoto (1999). Surface OH group governing adsorption properties of metal oxide films. Thin Solid Films. 339(1-2): 220-224.

Talbott, R. (2015). Clear the Fog to Decrease Eye Injuries. Occup Health Saf (Waco, Tex.), 84(8): 16-20.

Varma, V. S. K. P., S. Adarsh, K.I. Ramachandran and B.B. Nair (2018). Real time detection of speed hump/bump and distance estimation with deep learning using GPU and ZED stereo camera. Procedia Comput Sci. 143: 988-997.

Verriest, G., J. Van Laethem and A. Uvijls (1982). A new assessment of the normal ranges of the Farnsworth-Munsell 100-hue test scores. Am. J. Ophthalmol. 93(5): 635-642

Wagner, P. (2001). Anti-fog additives give clear advantage. PLASTICS ADDITIVES AND COMPOUNDING 3(11): 18-21.

Wegman F. (2017). The future of road safety: A worldwide perspective. IATSS Res. 40(2): 66-71.

Xiang, J., P. Bi, D. Pisaniello, D and A. Hansen (2014). The impact of heatwaves on workers′ health and safety in Adelaide, South Australia. Environ. Res. 133: 90–95.

Yamamoto, T., S. Yoshida, H. Ikari, K. Ikemori, K Ohtaka and H. Ukuda (2003). U.S. Patent No. 6,506,446. Washington, DC: U.S. Patent and Trademark Office.