

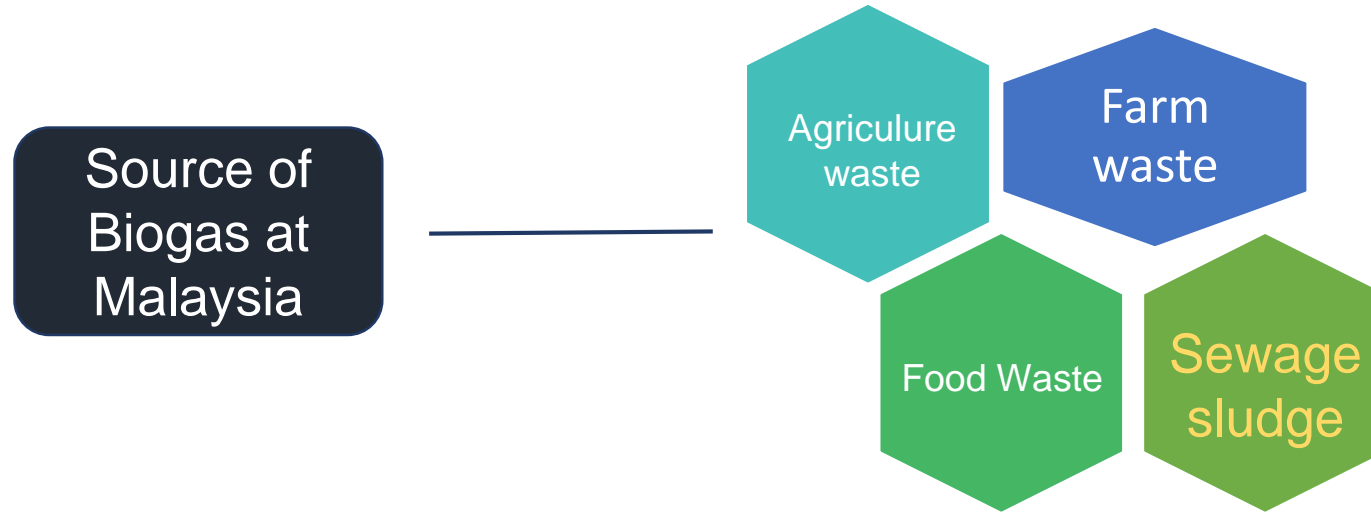
# Hazard Identification and Risk Assessment of Biogas Plant with Proton Exchange Membrane Fuel Cell Technology

IZAN SHUKRIZAL SHUKOR





# INTRODUCTION

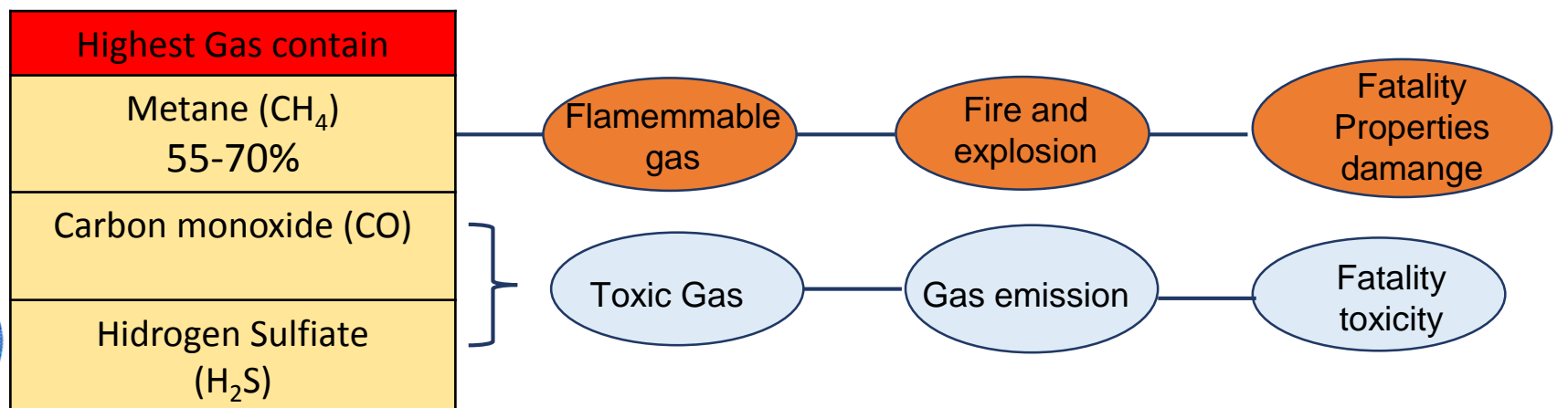
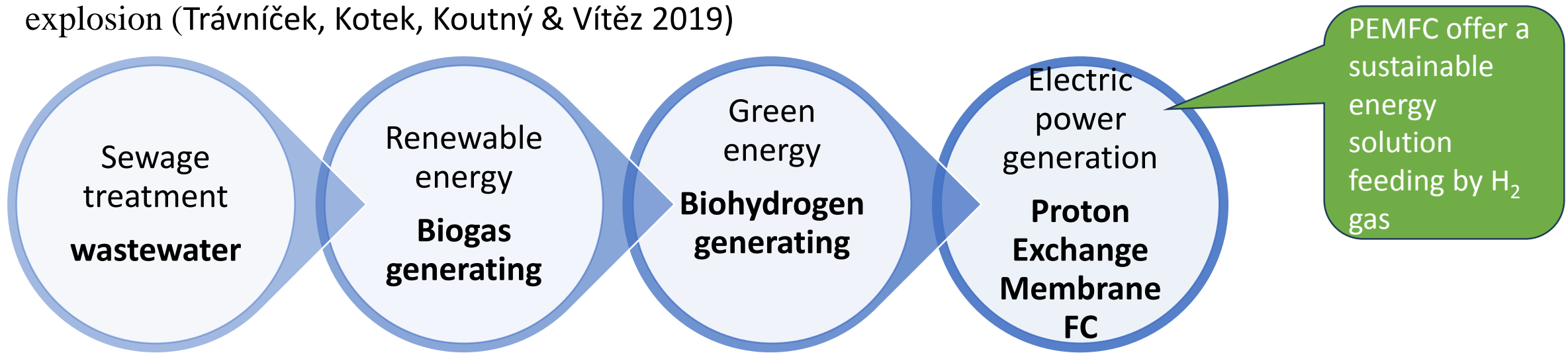


- WHY Sewage treatment plant (STP)
  - i. Sustainable waste and energy supply (Atilgan et al., 2023; Frankowski & Czekala, 2023)
  - ii. Highest methane content, ranging from 60% to 70%, compared to other substrates (Jamaluddin et al., 2021).
  - iii. Contribute 3-4% of global greenhouse gas emissions (Gautam & Agrawal, 2021).



# PROBLEM STATEMENT

- The urgent need for clean and sustainable sources of energy has prompted the development of green technology for sewage and treatment systems worldwide. (Atilgan et al., 2023; Frankowski & Czekala, 2023)
- H<sub>2</sub> technology promising solution to mitigate greenhouse gas emissions (Soam & Börjesson, 2020)
- Improving Hazard identification and risk assessment management at biogas plant can mitigate accident and explosion (Trávníček, Kotek, Koutný & Vítěz 2019)



# GOALS

(1)

**1. Conduct hazard identification and risk assessment at PEMFC Biogas Plant.**

(2)

**Hazard operability study (HAZOP) based high safety index from biogas PEMFC process flow.**

(3)

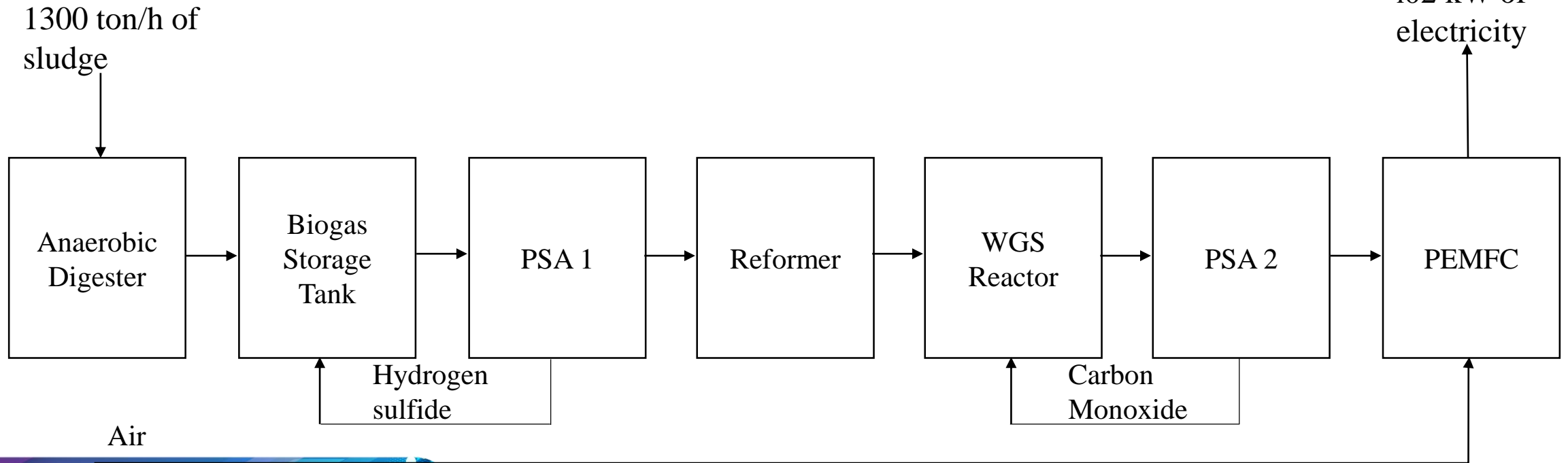
**Stimulate hazard modelling using ALOHA® software**



# Methodology



## SEWAGE TREATMENT PLANT PROCESS FLOW DIAGRAM



# RESULT

## HAZARD IDENTIFICATION : DOW'S FIRE EXPLOSION INDEX (FEI)

### Parameters used in FEI calculation

Material	Material Factor	Operating Temperature	Operating Pressure
Methane, hydrogen sulfide, carbon monoxide, hydrogen	21	Anaerobic Tank: 30°C Storage Tank: 30°C	Anaerobic Tank: 5 bar Storage Tank: 5 bar

FEI Value	Degree Of Hazard
1-60	Light
61-96	moderate
97-127	Pertengahan
128-158	Heavy
>158	severe

Process Units	FEI Values	Degree of Hazard
Biogas Storage Tank	170	Severe
Anaerobic Digester	168	Severe
PEMFC	66.15	Moderate
Furnace	132.3	Heavy
WGS	90.7	Moderate
Reformer	100.8	Intermediate
PSA 2	81.9	Moderate
PSA 1	152.88	Heavy
Condenser	71.4	Moderate

- High Value Index – Extra safety precautions
- High contain Flammable gas and toxic gas



# RESULT

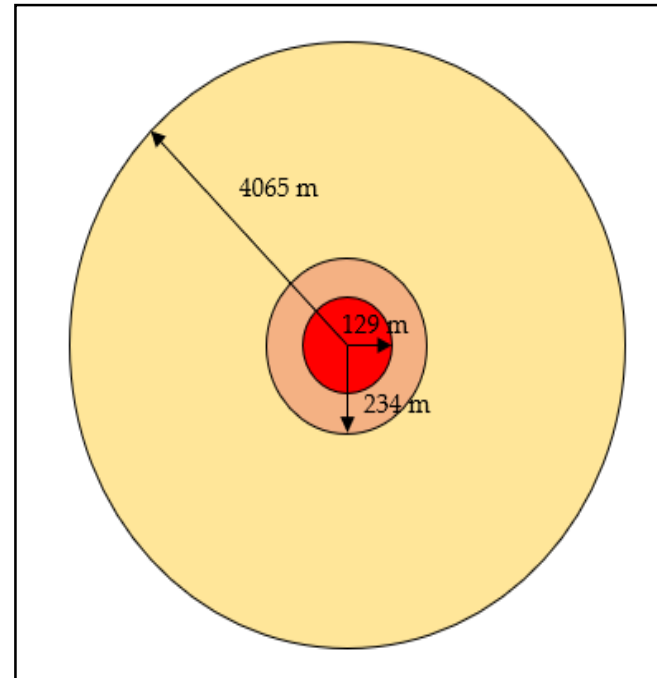
## HAZARD IDENTIFICATION : DOW'S CHEMICAL EXPOSURE INDEX (CEI)

### Parameters used in the CEI calculation

Material	Diameter of pipe leakage (mm)	Operating Temperature	Operating Pressure
Hydrogen sulfide	10	30°C	5 bar

### Hazard distance Calculation for Digester tank and biogas storage tank

$$HD = 6551 \sqrt{\frac{AQ}{ERPG}}$$



ERPG	Hazard Distance (m)	Impact
1	234 - 4065	Smell light rotten egg
2	129 - 234	Severe eye irritation
3	0 - 129	Cough, headache, loss of smell sense and long duration inhalation causes difficulty to breath.

### H<sub>2</sub>S ERPG values for the CEI calculation

Component	Molecular weight	ERPG-1 (ppm)	ERPG-2 (ppm)	ERPG-3 (ppm)	AQ (kg/s)
Hydrogen sulfide	34.1	0.1	30	100	0.05931



## RISK LEVEL IDENTIFIED FOR ANAEROBIC DIGESTER AND STORAGE TANK FROM RMA ANALYSIS

RISK	UNIT OPERATION	PROBABILITY RATING	SEVERITY RATING	RISK VALUE	RISK LEVEL
Poisoning due to high toxicity	Anaerobic digester	4	5	20	HIGH RISK
	Storage tank	4	5	20	HIGH RISK
Explosion caused by high-pressure unit	Anaerobic digester	3	5	15	HIGH RISK
	Storage tank	4	5	20	HIGH RISK
Fire due to the presence of flammable gases	Anaerobic digester	4	4	16	HIGH RISK
	Storage tank	4	4	16	HIGH RISK
Difficulty in breathing	Anaerobic digester	2	4	8	MODERATE RISK
	Storage tank	2	4	8	MODERATE RISK





# RESULT

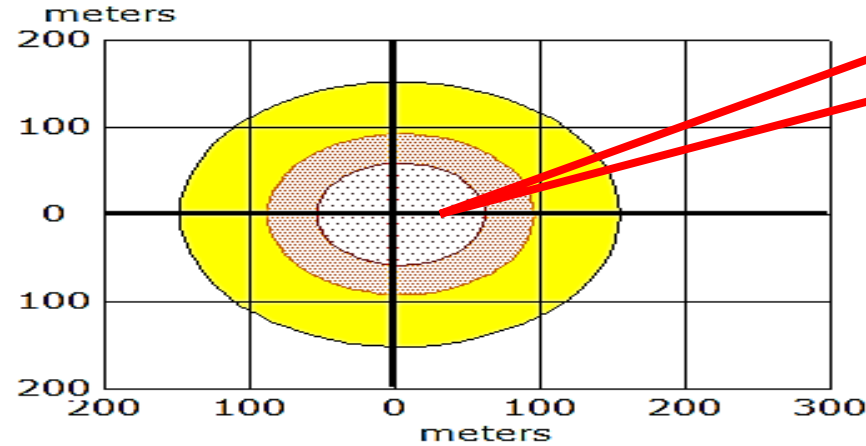
Parameters	Guide Word	Deviation	Causes	Consequences
<b>Flow</b>	Low	Content Leak	Leakage in the digestion tank	Sludge decreases over time; Delay in biogas production; Release of H <sub>2</sub> S to environment
	High	Content Overpressure	Control valve failure	Sludge reaches maximum level, leading to overflow; Increased tank pressure
<b>Temperature</b>		Sludge Overflow	Flow exceeds limit	Overflow from tank
		Fire Risk	Gas prone to ignition	Fire hazard explosion
	High	High Environmental Temperature	External high temperature	Increased internal pressure
		Explosion Risk	High internal pressure	Digestion tank explosion
<b>Pressure</b>	High	High pressure in tank digestion	Valve control failure	Tank likely to explode, biogas cannot be operated.



Stimulate hazard modelling using ALOHA<sup>®</sup> software

PARAMETER	INFORMATION
LOCATION	KUALA LUMPUR, MALAYSIA
WIND DIRECTION	SOUTH
WIND SPEED	3.62 m/s
AIR TEMPERATURE	34°C
CLOUD COVER	5 TENTHS
STABILITY CLASS	D
RELATIVE HUMIDITY	50%

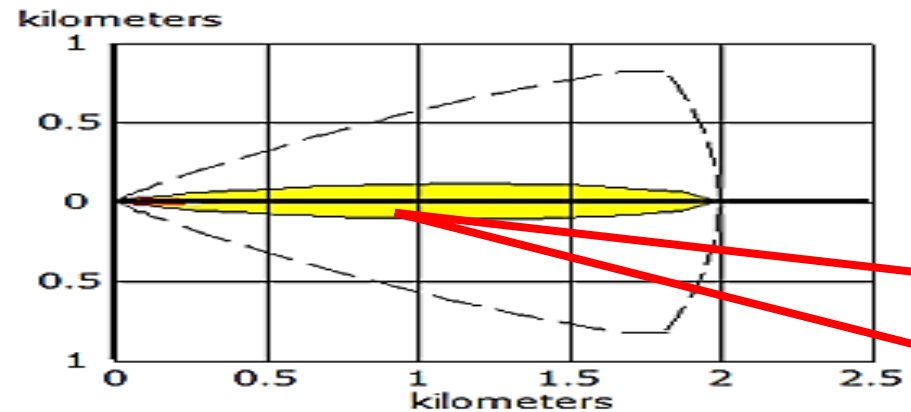
# RESULT



0-50m – high risk(death)  
 50-100m – 2<sup>nd</sup> degree burn  
 100-150m heat impact pain

- greater than 10.0 kW/(sq m) (potentially lethal within 60 sec)
- greater than 5.0 kW/(sq m) (2nd degree burns within 60 sec)
- greater than 2.0 kW/(sq m) (pain within 60 sec)

Thermal radiation threat zone of methane gas.



0-200m – more than 30ppm  
 Cough, headache, loss of smell sense and long duration inhalation causes difficulty to breath.

- greater than 100 ppm (ERPG-3)
- greater than 30 ppm (ERPG-2)
- greater than 0.1 ppm (ERPG-1)
- wind direction confidence lines

Toxic threat zone of hydrogen sulfide gas.

# CONCLUSION

1. The study employed various methods such as Fire Explosion Index (FEI), Chemical Exposure Index (CEI), Risk Matrix Analysis (RMA), hazard modeling via ALOHA<sup>®</sup> software, to comprehensively analyze and evaluate the risks associated with the operation of biogas-fed PEMFC plants.
2. The FEI analysis revealed that the anaerobic digester (FEI =168), and bio-gas storage tank (FEI =170), exhibited severe hazards, thereby signifying the highest risks within the plant. CEI analysis revealed the spread of the highest hydrogen sulphide (H<sub>2</sub>S) concentration up to 129 meters from the anaerobic digester and storage tank location.
3. HAZZOP study determine parameter flow, temperature and pressure can occur the fire and dispersion of chemical.
4. Generating electricity by biohydrogen and PEMFC not resulting the high-risk activities.





**COSH**

2024

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**THANK YOU**



# SPEAKER GUIDELINE

## NOTICE TO THE PRESENTER OF THE COSH & SciCOSH

With all due respect, we are pleased to inform you some important points that need to be given attention by the presenters as follows:

### i) ATTIRE

- Presenters are required to dress neatly and wear **coats/blazers** during the presentation.

### ii) SLIDE PRESENTATION

- Presenters need to ensure that the **presentation slides use a minimum of 20 font sizes** to ensure that the information in the presentation slides can be seen.
- The PowerPoint used is a **version of 2010 and above**.
- Presenters are **requested to submit final presentation slides** to the NIOSH Liaison Officers
- A presentation (especially conclusion part) should be associated with COSH/ SciCOSH theme
- Should avoid all sensitive issues (e.g. race, religion, politic etc.)
- Should avoid to promote own business excessively

### iii) DURING PRESENTATION

- You are given **50 minutes** to present for **workshop session** (It is highly advisable not to exceed 15-- 20 slides)
- You are given **20 minutes** to present for **paper session** (It is highly advisable not to exceed 10-15 slides)
- The **question and answer session** will continue for **10 minutes** after the end of the presentation session.

### iv) ATTENDANCE IN THE PRESENTATION HALL

- Presenters are asked to be **ready 30 minutes early** in the presentation hall.

The cooperation and willingness of Prof/Dr/Sir/Madam to comply with this matter are greatly appreciated.

Thank You.