KOLOKIUM PENYELIDIKAN 2021
INSTITUT TADBIRAN AWAM NEGARA
(INTAN)

NATURALLY OCCURRING RADIONUCLIDES FROM COAL FIRED POWER PLANTS IN MALAYSIA

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Presentation Outline

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2) Background of the study
3) Problem Statement
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5) Methodology
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7) Limitation of the study
8) Importance of the study
9) Findings of the study and their implications on government policies
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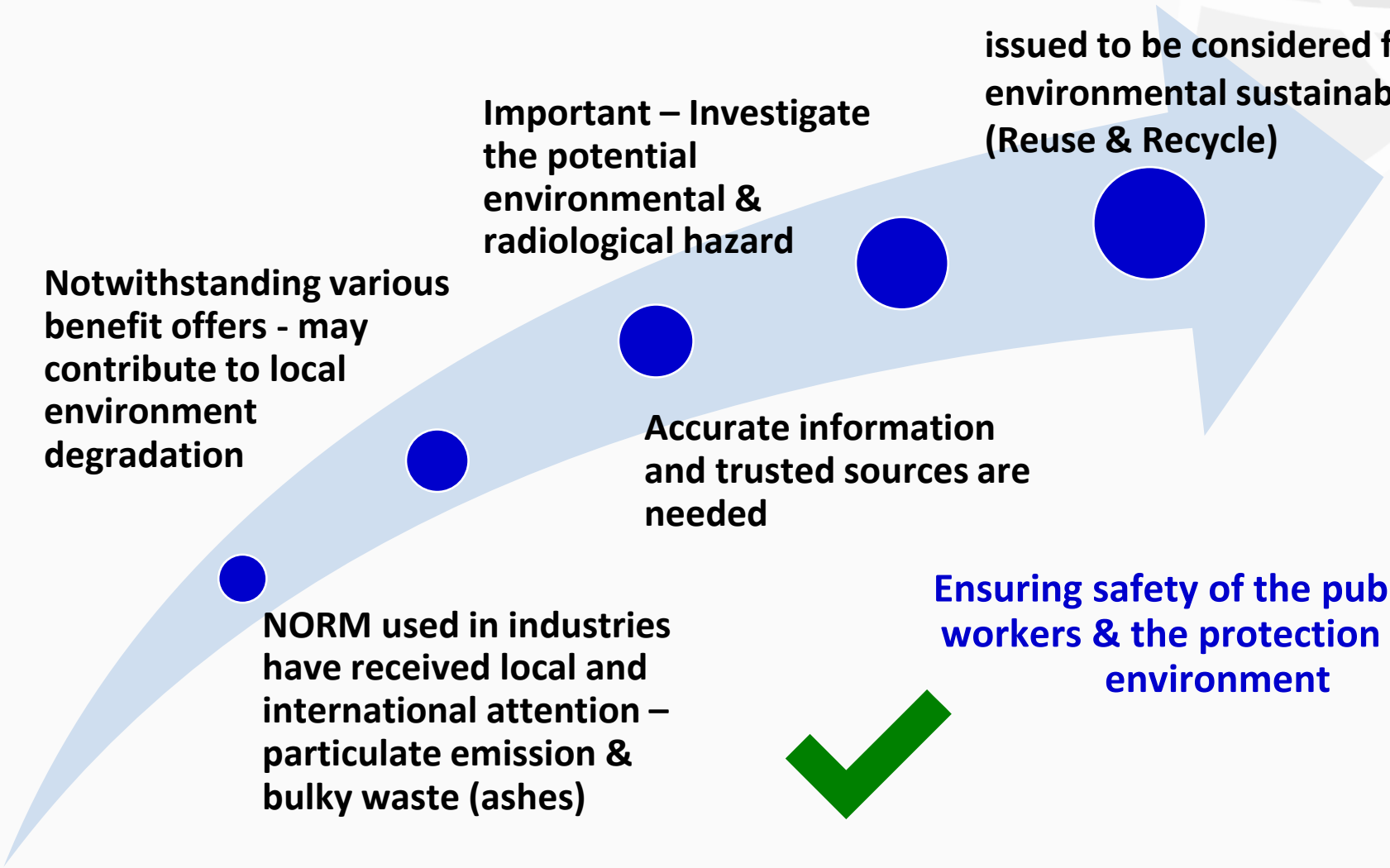
Introduction



Introduction -
Naturally Occurring Radioactive Materials (NORM)

1. NORM is defined as **radionuclides of natural origin** that are **present in natural sources material and undergo several industrial processes** that **may give rise** to these enhance **background radiation exposures** and finally lead to the production of residues or wastes with higher activity concentration than that of the natural resources material (International Atomic Energy Agency, 2013)
2. One source of technologically enhanced NORM is in the CFPP industry (coal) & been neglected as one source of natural radiation.
3. Coal is the dirtiest fuel among the natural hydrocarbons (International Atomic Energy Agency, 2007)
4. However, the naturally occurring radioactive materials containing **no significant amounts** of radionuclides other than radionuclides of natural origin (soil, minerals etc.).

Introduction -

National Legislation: Atomic Energy Licensing Act 1984 (Act 304)

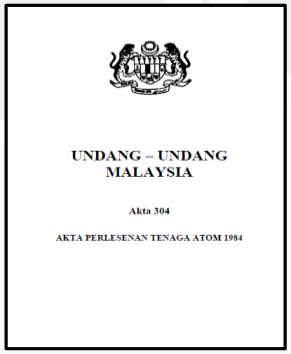
- **issued to be considered for environmental sustainability.**
- **additional external radiation exposures**
- **Coal combustion discharged contain radionuclides**
- **main concern NORM industries[3]**
- **main fuel for power generation**

[3] International Atomic Energy Agency (2006). *Assessing the need for radiation protection measures in work involving minerals and raw materials*. Safety Report Series 49: 11-19.

Radionuclides	Activity Concentration (Bq kg^{-1})[1,2]
Each radionuclides in the uranium and thorium decay chain	1000
K-40	10000

[1] International Atomic Energy Agency (2014]. Radiation Protection and Safety of Radiation Sources: Basic Safety Standard General Safety Guide (GSR) Part 3;

[2] Malaysia Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011.



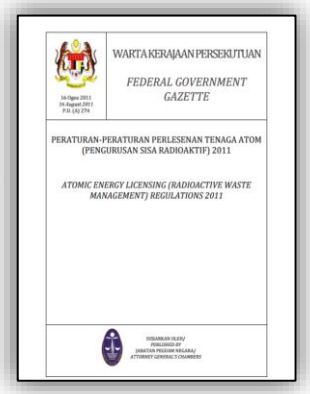
UNDANG – UNDANG MALAYSIA

Akta 304

AKTA PERLESENAN TENAGA ATOM 1984

Radionuclides	Activity Concentration (Bq kg^{-1})[1]
U-238	1000
Th-232	1000
Ra-226	10000
Ra-228	10000

[1] [Malaysia Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011



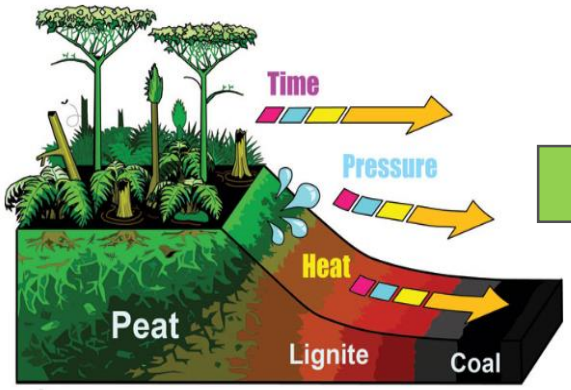
WARTA KERAJAAN PERSEKUTUAN

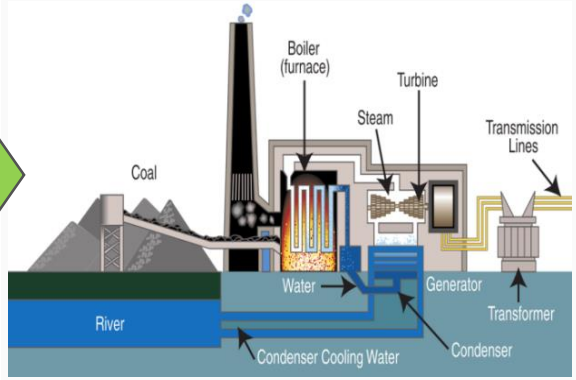
FEDERAL GOVERNMENT GAZETTE

PERATURAN-PERATURAN PERLESENAN TENAGA ATOM (PENGURUSAN SISA RADIOAKTIF) 2011

ATOMIC ENERGY LICENSING (RADIOACTIVE WASTE MANAGEMENT) REGULATIONS 2011

Background of the study





- ✔ Coal, like other minerals contains traces of <u>naturally occurring</u> radioactive elements (NORM) .
- ✔ Coal is widely available fossil fuel resources.

- ✔ During combustion, Coal fired power plant (CFPP) generate combustion residues and released fine particles and gases contains natural radionuclides to the environment.
- ✔ Occupational exposure due to ionizing radiation may (or may not) occur as a result of various activities associated with NORM industries (CFPP).

- ✔ Uncertainty in nuclear power industry and the availability of natural gas and petroleum decreases, it has lead <u>coal remain to be relevant.</u>

Examples of NORM Activities in Malaysia

1 Ferum Oxide (synthetic rutile)

2 Amang (by-product of tin)

3 Tin Slag (metal production)

4 Petroleum sludge (by-product from oil exploration)

5 Petroleum scale (formed on the inner surface of the pipe)

Problem Statement

Perception	Exploitation NORM	Limited Study
Claimed to pose negative impact	Large quantity usage of coal (NORM) & Coal is the dirtiest fuel among the natural hydrocarbons (International Atomic Energy Agency, 2007)	Baseline data - Detail study from the use of feed coal, generation of coal combustion residue (CCR), particulate emission and radiological hazards pose to workers, public and environment.
Less knowledge and awareness on NORM and radiation safety	generate high CCR and emitted fine particulate	• Important of radiation protection to the workers and public • Enhance national legislation framework
Radiological hazards to public, workers and environment	potentially increased in the natural background without proper control	Safety and security aspects & the important of radiation safety

Objectives

1. To investigate the radioactivity content and trace elements concentration in feed coal used as the main fuel in CFPPs

2. To evaluate the partitioning of the naturally occurring radionuclides in feed coal and coal combustion residues (CCR)/ashes

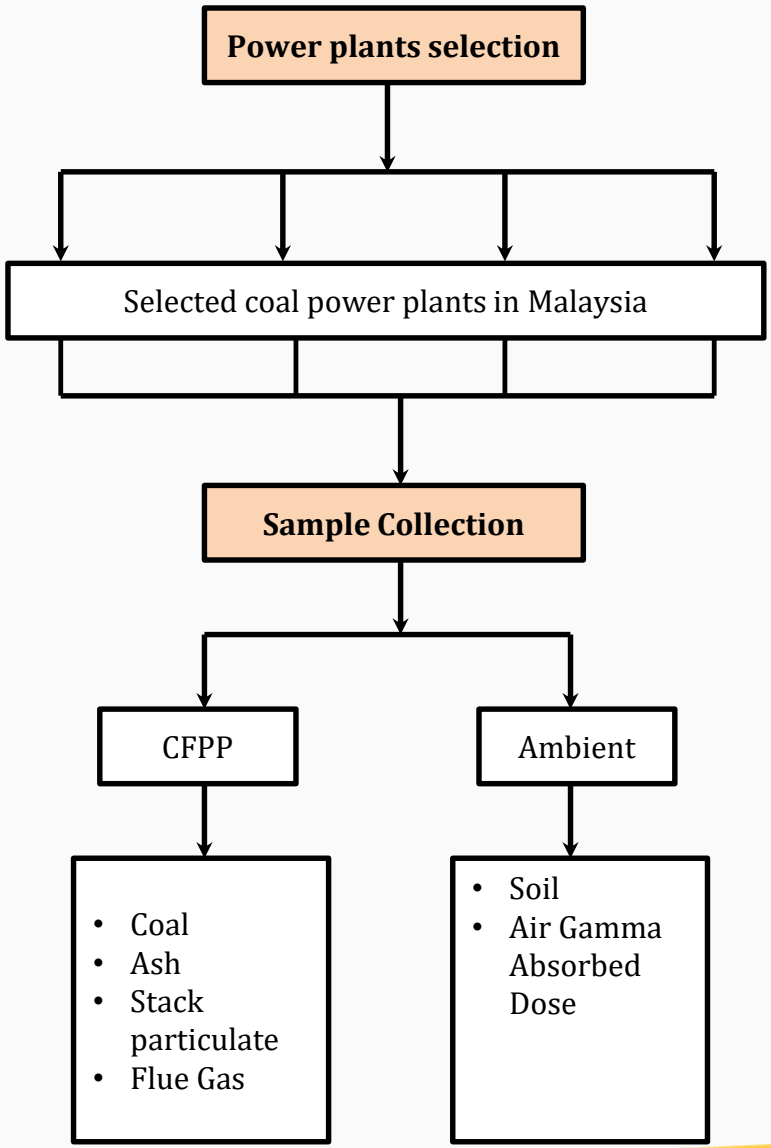
3. To assess the associated potential radiological hazard of coal and coal combustion residues arising from CFPP operation

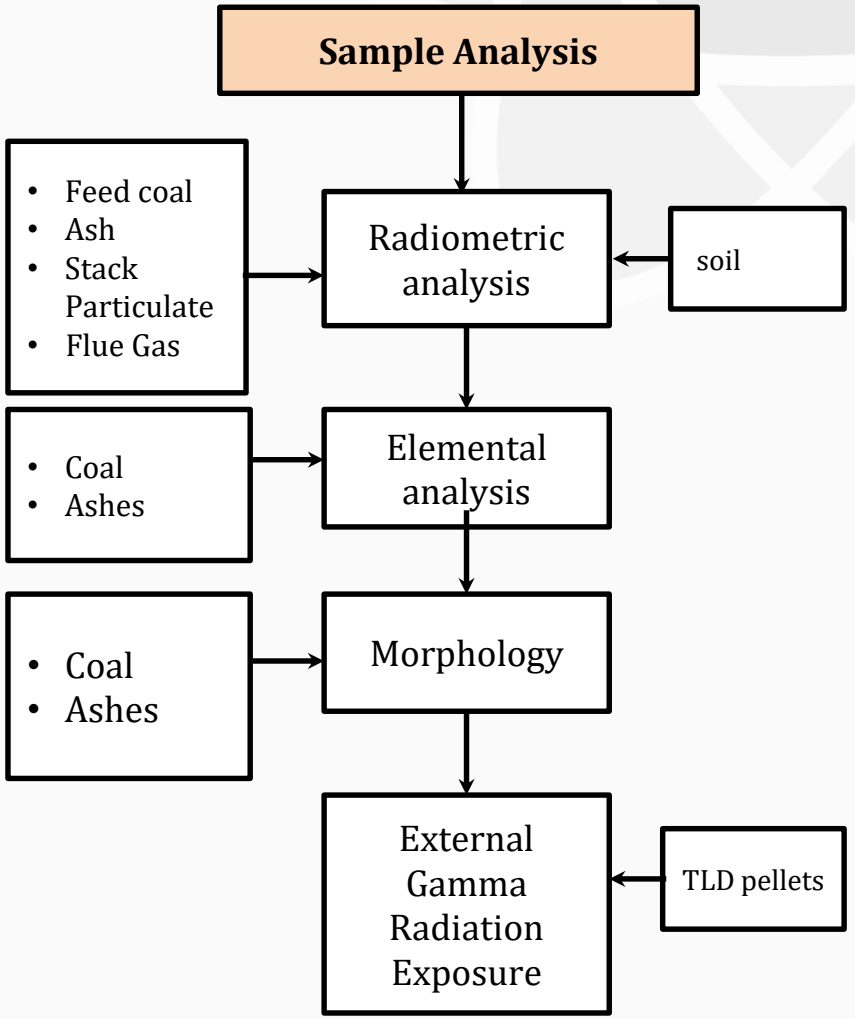
4. To estimate the potential radiological contamination of stack particulate emission to the environment from CFPP by air dispersion modelling.

Scopes

CFPP(s)	Sample (s)	Parameter
Selected coal fired power plants in Peninsular Malaysia	1. Coal and coal ashes 2. FGD (inlet and outlet) 3. Stack particulate emission (PE) 4. Soil (S) 5. Thermo Luminescent Dosimetry (TLD) pellets	1) Naturally occurring radionuclides (radionuclides of concern i.e. U and Th Series) 2) Elemental (trace elements of concern) 3) Morphology 4) Radiological Hazards • Radium equilibrium (Ra_{eq}) • External hazard index (H_{ex}) • Air absorbed dose rate (D) • Annual Effective Dose (AED) 5) External Radiation Exposure 6) Air dispersion modelling (calculation & AERMOD)

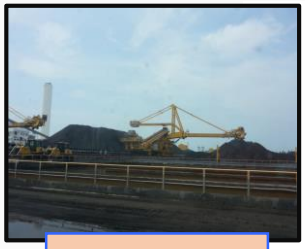
Methodology





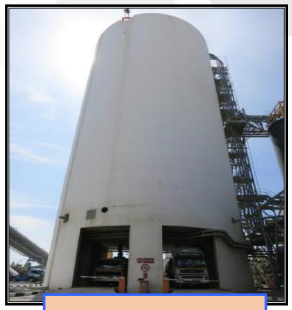
Methodology – Data collection

Selected Coal-fired power plants

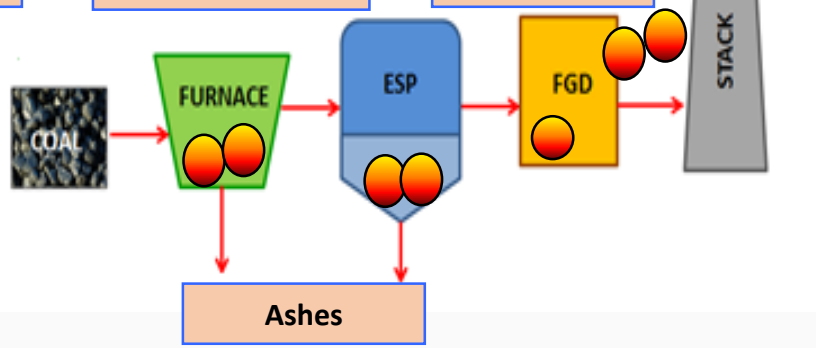


Coal yard

Coal pulverizer



Ash silo



Coal-fired power plant

thimble

Thimble canister

Sampling train

Methodology – experimental

Method	Laboratory (Agency)	Samples	Parameter(s)
Neutron Activation Analysis	Malaysia Nuclear Agency	• Feed Coal (FC) • Ashes (A) • Particulate emission (PE) • Soil (S) • Flue gas desulphurization (FGD) inlet & outlet	Radionuclides Trace elements
Gamma Spectrometry	Malaysia Nuclear Agency	FC, A, FA, S, FGD inlet & outlet	Radionuclides
Wavelength dispersive X-ray fluorescence (WDXRF)	Department of Geoscience and Mineral	FC, A	Trace elements
Field Emission Scanning Electron Microscope (FESEM)	SIRIM (AMREC)	FC, A	Morphology
TLD Reader – Harshaw Model 4500	Malaysia Nuclear Agency	Thermoluminescent (TLD) pellet	Air gamma absorbed dose

Results and Discussions

(1) Concentration in the feed coal, ash and particulate emission

Samples		Radionuclides (Bq kg^{-1})		Regulatory compliance
		U-238	Th-323	
Feed coal	CFPP	9.0 ± 0.0	10.3 ± 0.6	coal concentrations were within the control limit
	Regulatory Limit	1000	1000	
Ash	CFPP	77.7 ± 3.2		ash and particulate emission concentrations were found much higher that the coal but still within the control limit.
Particulate emission	CFPP	54.7 ± 21.8	78.2 ± 37.7	
	Regulatory Limit	1000	1000	

Results and Discussions (cont.)

(2) Radiological Hazards

Radium Equilibrium (Ra_{eq}), External Hazard Index (H_{ex}), Air Absorbed Dose Rate (D) and Annual Effective Dose Rate (AED)

Samples	CFPP(s)			
	Ra_{eq} (Bq kg-1)	H_{ex}	D (n Gy h^{-1})	AED (mSv y^{-1})
Feed Coal	29	0.08	13.1	0.02
Ash	225	0.61	103.2	0.13
Limit	370	1.0	55 -131 (Malaysia)	1.0
Regulatory compliance	ash results were found much higher that the feed coal but still within the control limit			

Results and Discussions (cont.)

(3) Potential radiological contamination of stack particulate emission to the environment: natural radionuclides particulate concentration (intake in the air)

Table 1: The comparison made between the predicted Cmax with the several regional ambient air quality standards.

Particle	Predicted C_{max} ($\mu g\ m^{-3}$)	Total particulate standards, $\mu g\ m^{-3}$ (24-hours average time)						Hazard Quotient (HQ)
		Malaysia	Singapore	Thailand	Indonesia	Philippines	USA (EPA)	
Particulate (total)	52*	150	150	120	150	150	150	0.3

Note: HQ = predicted/standard.
*short term averaging time.

Table 2: The natural radionuclides for particulate released from CFPP.

Calculated C_{max} ($\mu g\ m^{-3}$)	Calculated X_{max} (m)	Natural radionuclides particulate concentration ($Bq\ m^{-3}$)		DAC of radionuclides in air ($Bq\ m^{-3}$)			
				Worker		Public	
		^{238}U	^{232}Th	^{238}U	^{232}Th	^{238}U	^{232}Th
52	1600	2.9×10^{-6}	4.1×10^{-6}	5.0	0.3	0.045	0.003

Note: DAC =Derive Activity Concentration

Results and Discussions (cont.)

(3) Potential radiological contamination of stack particulate emission to the environment: natural radionuclides particulate concentration (intake in the air)…cont.

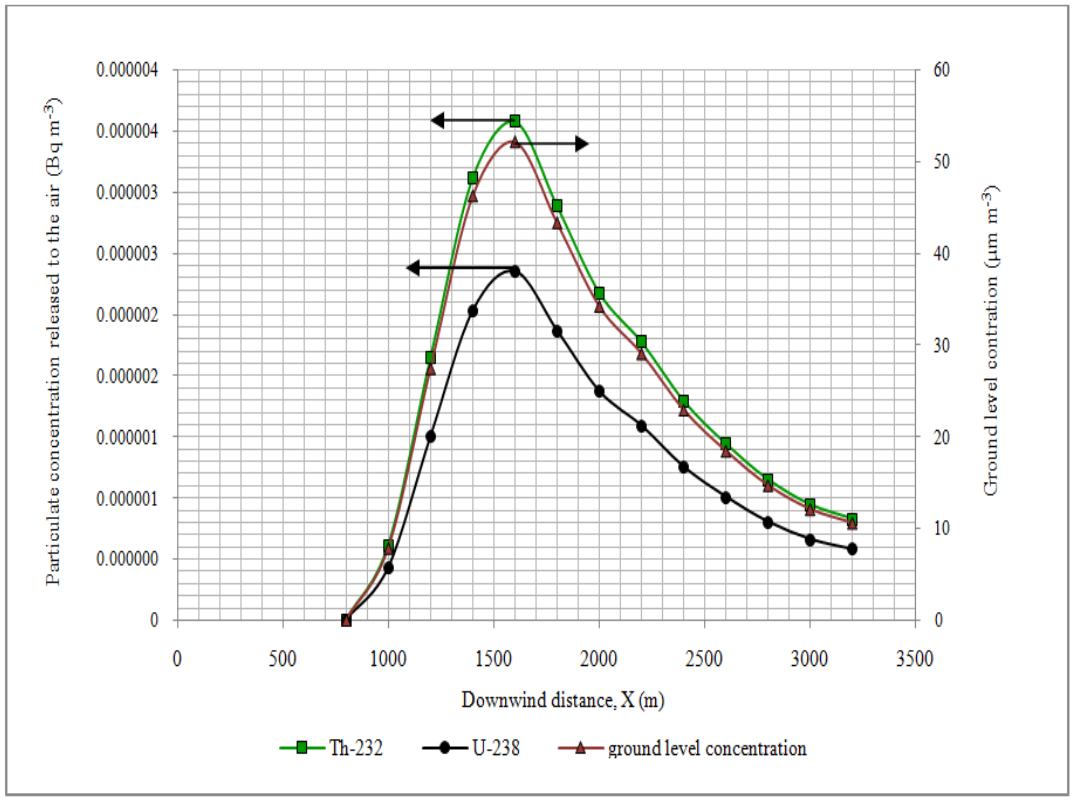


Figure 1: Concentration of natural radionuclides particulate as a function of downwind distance from CFPP.

Parameter	Value
Stability	A
Wind speed, μ (m s^{-1})	1.2
Emission rate, Q (g s^{-1})	129
Physical stack height, h (m)	155
Plum rise, Δh (m)	1078
Effective stack height, H (m)	1233

NO.	Parameters	Data
1	Estimated max. Particulate emission concentration (Cmax)	52 µg m^{-3}
2	Max. downwind distance (Xmax)	1600 m
3	^{238}U concentration (intake)	2.9 x 10^{-6} Bq m^{-3}
4	^{232}Th concentration (intake)	4.1 x 10^{-6} Bq m^{-3}

Limitation of the study

1) Not all CFPPs in Malaysia were involved in the study (Sabah and Sarawak not included due to cost and time constrain);
2) Comprehensive study is needed in a longer time period for complete process cycle/batch with the same parameters (i.e. use of coal from the same source, maintain same plant operation conditions etc); and
3) Limited research equipment and resulting in high cost for sample analysis (i.e. recommended: Neutron Activation Analysis, Gamma Spectrometry);

Findings

1) Coal contain naturally occurring radionuclides & results showed that the activity concentration in ashes were much higher (more than five orders of magnitudes) compared to the feed coal. However, the radioactivity level recorded are in compliance with national legislation and international standard.
2) Successfully obtained CFPPs information and able to assist power plant management to select and purchase proper coal (low ash content).
3) The radiological hazard study obtained from this study were found to be acceptable and safe use for construction materials.
4) The radiological hazards and external radiation exposure from all CFPPs is remote.
5) The predicted ground level particulate concentration was significantly lower than the national limits and does not impose any significant effect to the human population at large.
6) The results presented, the radiological risk from inhalation due stack particulate concentration released from the stack is insignificant.

Importance of the study

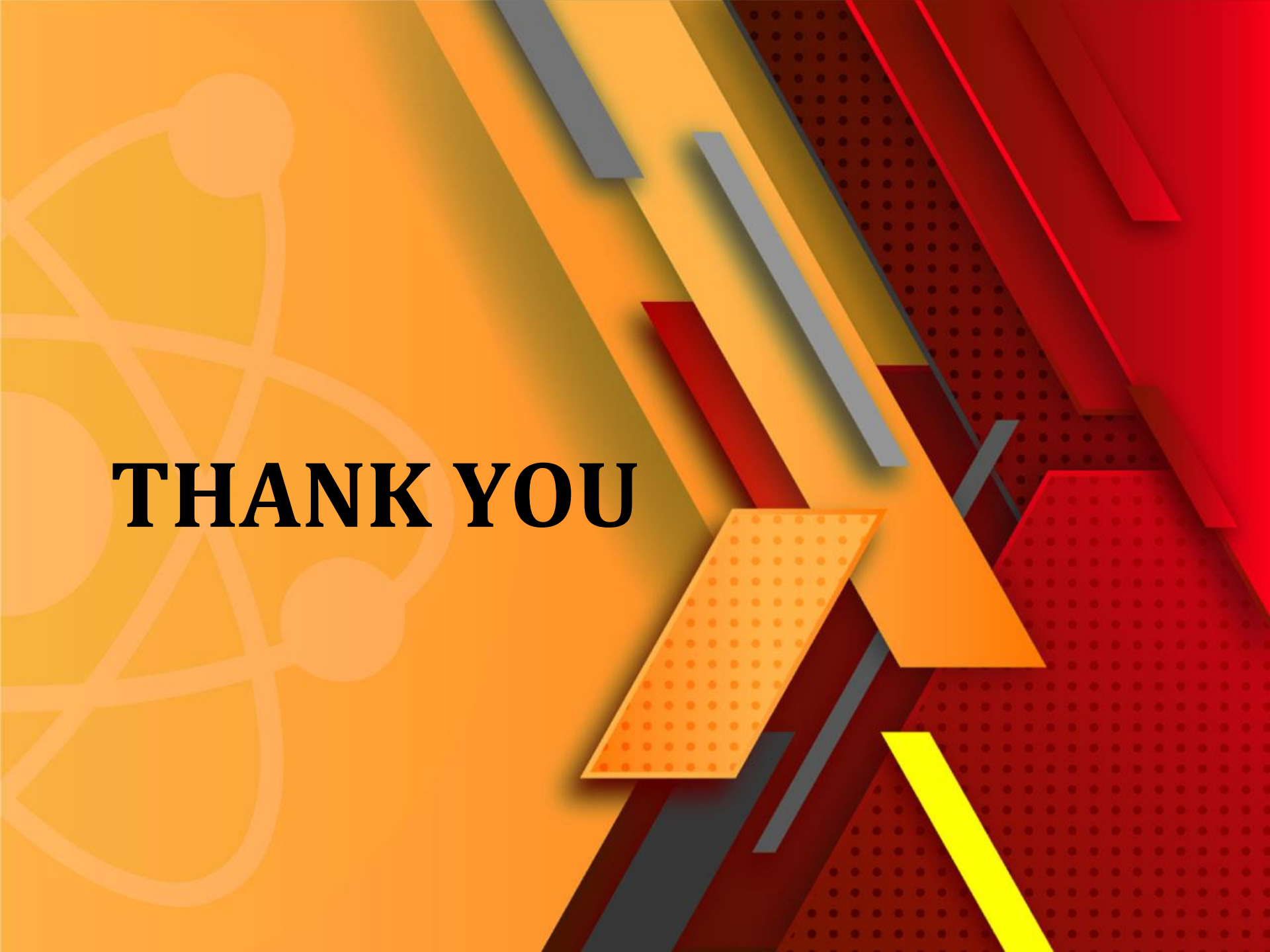
1) Knowledge in term of naturally occurring radionuclides in coal and residues as well as their potential enrichment;
2) Identify effectiveness in system operation and pollution control and guidance in raw material selection; and
3) Potential radiological hazards from CFPP operation and radiological contamination due to particulate emission at vicinity of the plant;

1) Justified findings (a) scientific data, (b) increase public confidence and acceptance, and (c) reduce wrong perception in NORM;
2) Safety and environmental issues in term of process, system operation, radiation safety and environmental sustainability;
3) Enhance and strengthening the current national legislation as well as development of national policy on radioactive waste management;

Towards ensuring safety of the public, workers and the protection of the environment

Conclusion and implications on government policies

1) Baseline data on radioactivity in coal (NORM) and ashes (technologically enhanced NORM) as well as particulate emission had been successfully obtained for Peninsular Malaysia;
2) The is a need to review existing national legislation, the Atomic Energy Licensing Act 1984 (Act 304) – Rang Undang-undang berkaitan Tenaga Atom (RUUTA)
3) There is a need to develop national radioactive waste management policies and strategies (including NORM and NORM activities); and
4) There is a need to strengthen regulatory control especially in the area of NORM and NORM related activities – RUUTA, regulatory research, international commitment (Treaty, Convention, etc.).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