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A Systematic Review of Open Waste Burning in Southeast Asian Countries for Policy Making

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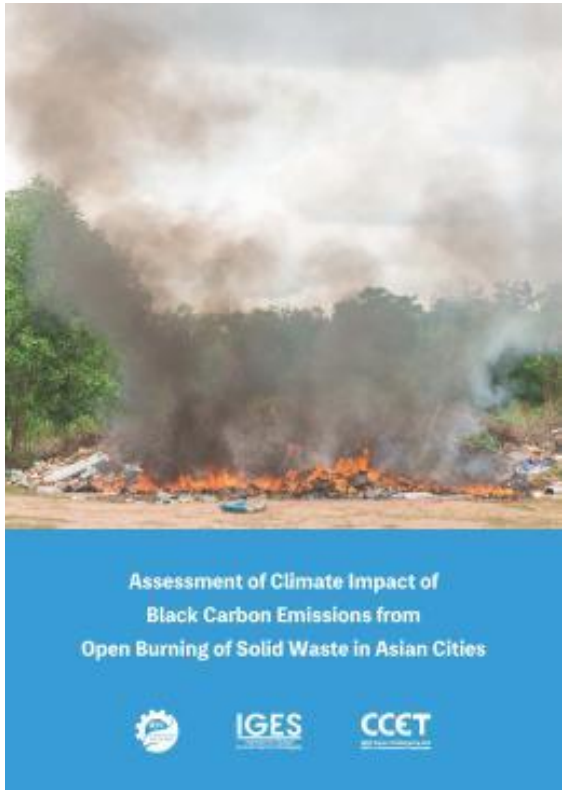
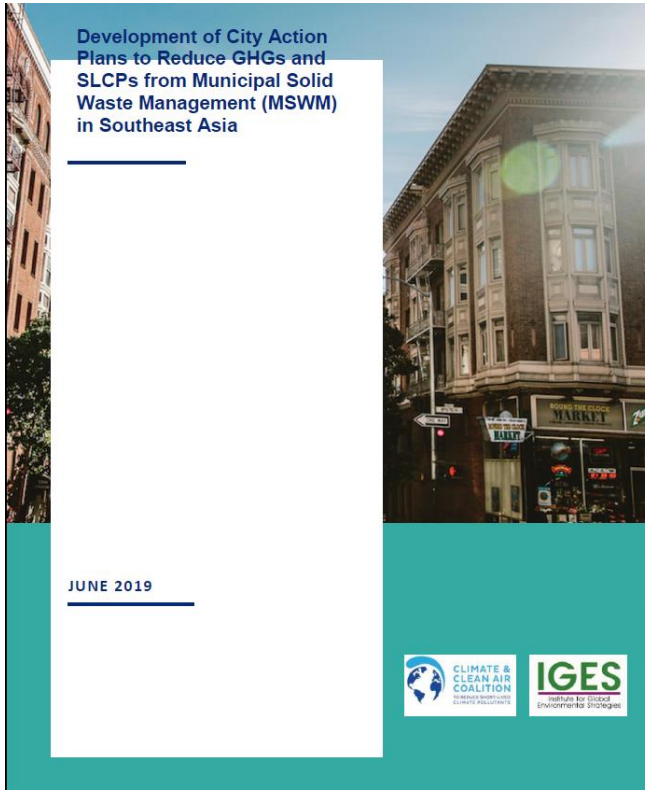
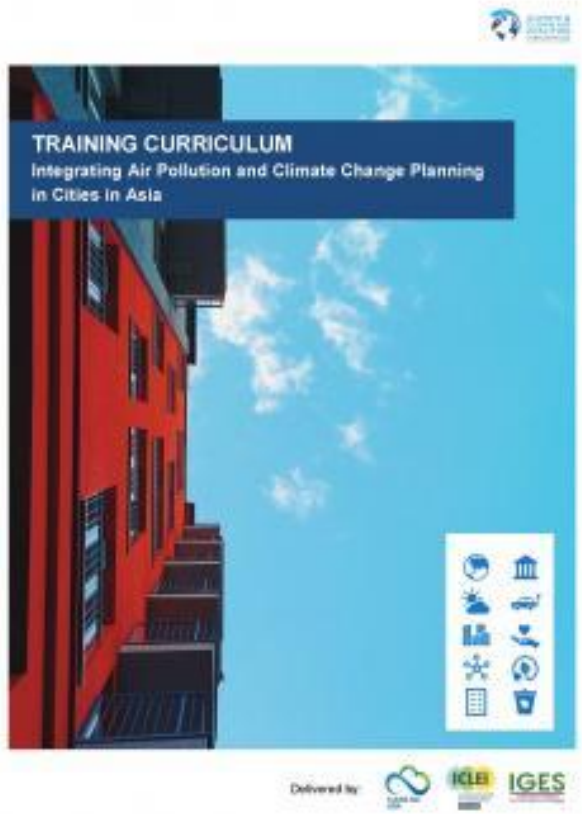
Scientific and Evidence-based Policy Making to Reduce Open Waste Burning in Asia







Objectives and Methodologies

Objectives

1. Determining **the current status of open burning** (municipal waste, agriculture, forest, and others) in SEA countries and its impact on environment and health of human beings
2. Analysing **factors** of OWB practices and **stakeholder's initiatives** to stop burning practices
3. Assessing the appropriate **policy recommendation** for reducing open waste burning in SEA countries

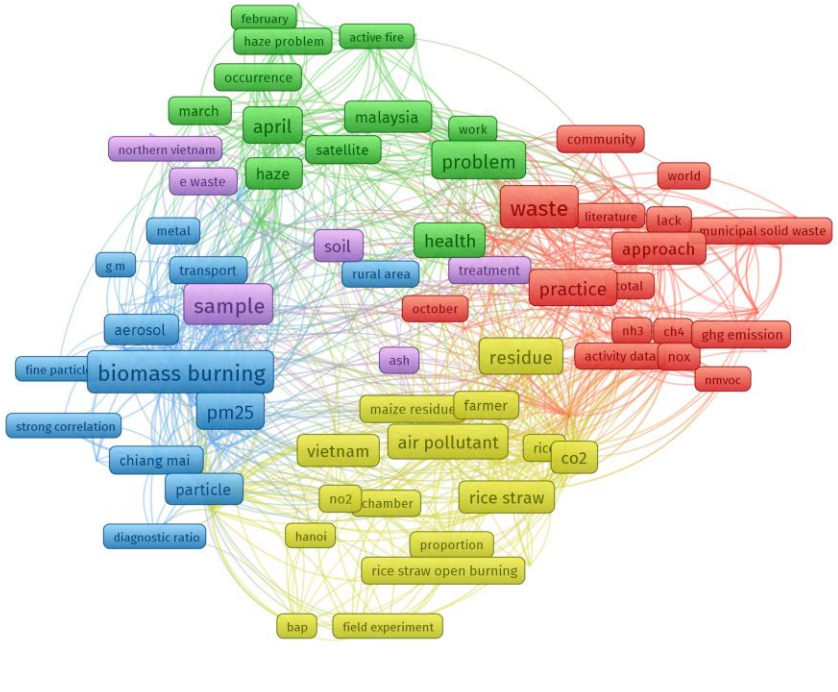
Methodologies

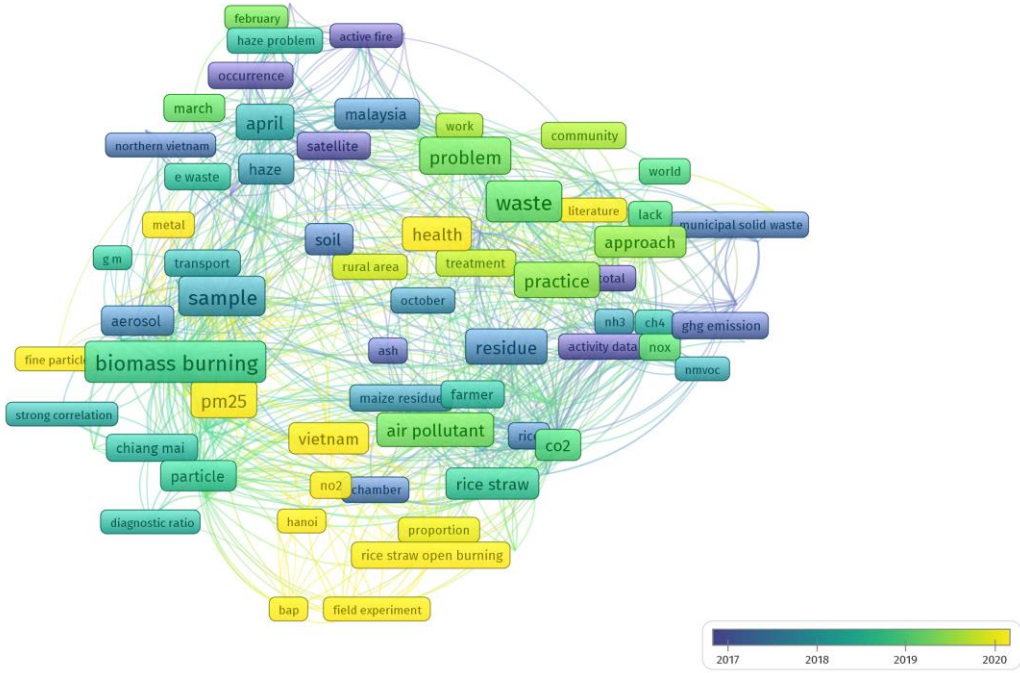
1. Literature review by using PRISMA methodology. Metadata generated from SCOPUS database using keywords of "**Open Burning**".
2. Abstract title, and other metadata were analyzed using VOSviewer software to get the current **research direction** and finding the **gaps**
3. At least **152 documents** were assessed using qualitative analysis to identify the factors, initiatives, and assess policy recommendation at country level

Occurrence Terms in Title and Abstracts

Settings

- Binary counting
- Minimum number of occurrences = 5 (236 meet threshold)





Through the maps we can see 5 clusters can be generated from the terms. Higher occurrences of terms are displayed

1. Red = waste, practice, reduction, approach, inventory (**waste management approach**)
2. Green = problem, health, Malaysia, Northern Thailand, haze (**transboundary haze**)
3. Yellow = biomass burning, pm2.5, ratio, particle. size (**biomass burning**)
4. Blue = residue, air pollutant, CO_2, Vietnam, emission factor (**crop residue burning**)
5. Purple = sample, soil, treatment, e-waste, ash (**e-waste burning**)

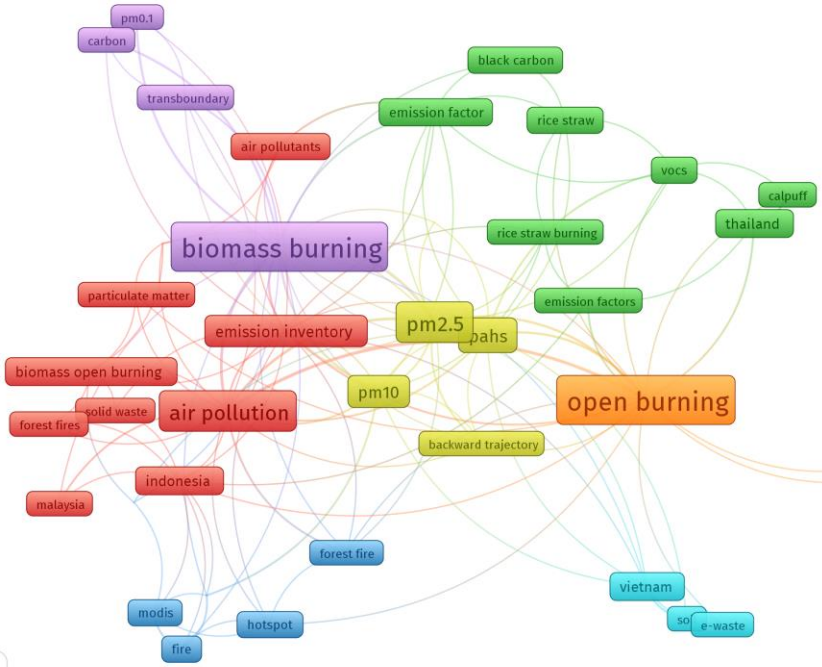
Related to the publication year, there are also some findings:

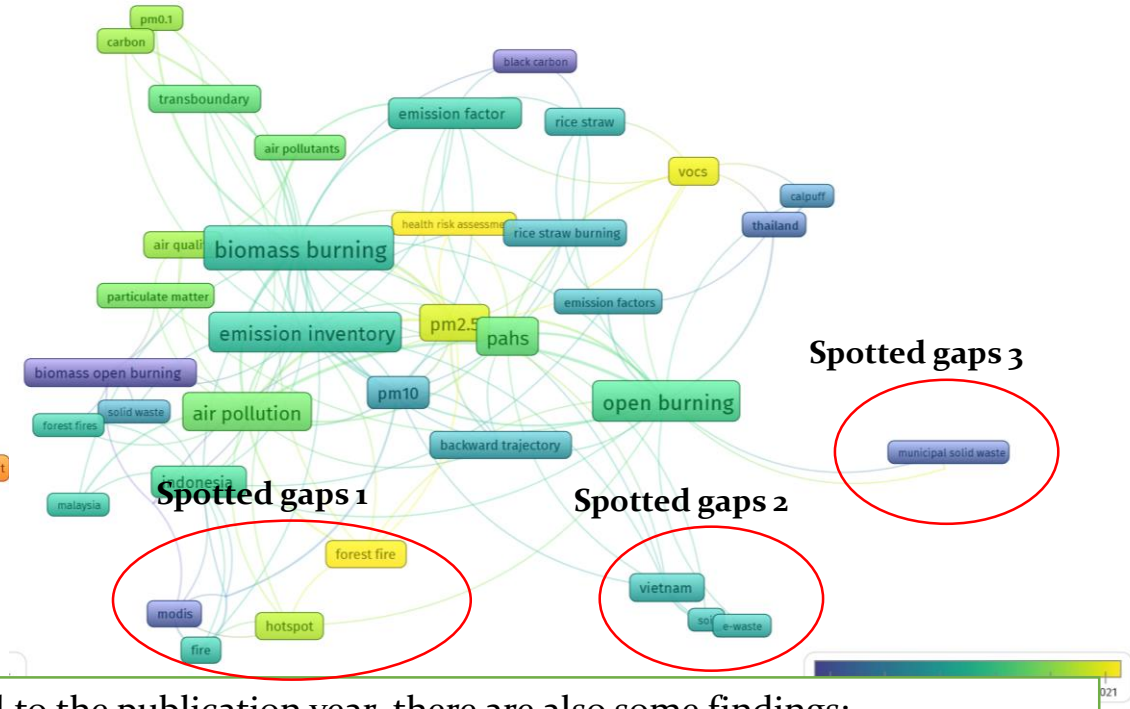
1. The older terms is found in the municipal solid waste, haze and satellite burning. Indicating the concern of researchers on the **transboundary air pollutant** caused by open burning.
2. In the middle publication year (2017-2019), some terms such as biomass burning, community, and approach are found. Indicating the researchers were shifting to **biomass burning activity and its solution**.
3. Current research are found to be focused on **health impact** on crop residue burning especially in Vietnam area.

Occurrence Keywords

Settings

- Full counting
- Minimum number of occurrences = 3 (39 meet term threshold)





Through the maps we can see 7 clusters can be generated from the keywords provided by scientific papers.

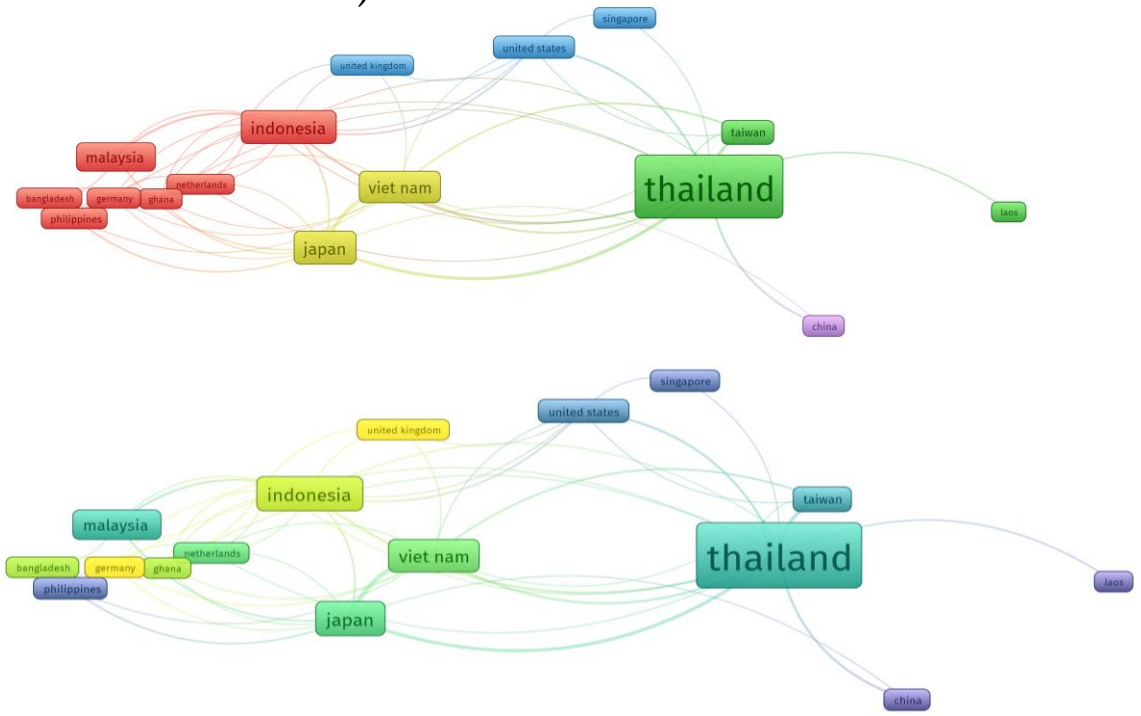
1. Red = Forest fire
2. Green = Rice straw burning
3. Dark Blue= Fire hotspot in ASEAN
4. Yellow= Health risk of open burning
5. Purple = Transboundary pollution of biomass burning
6. Blue = e-waste burning
7. Orange = Municipal solid waste burning

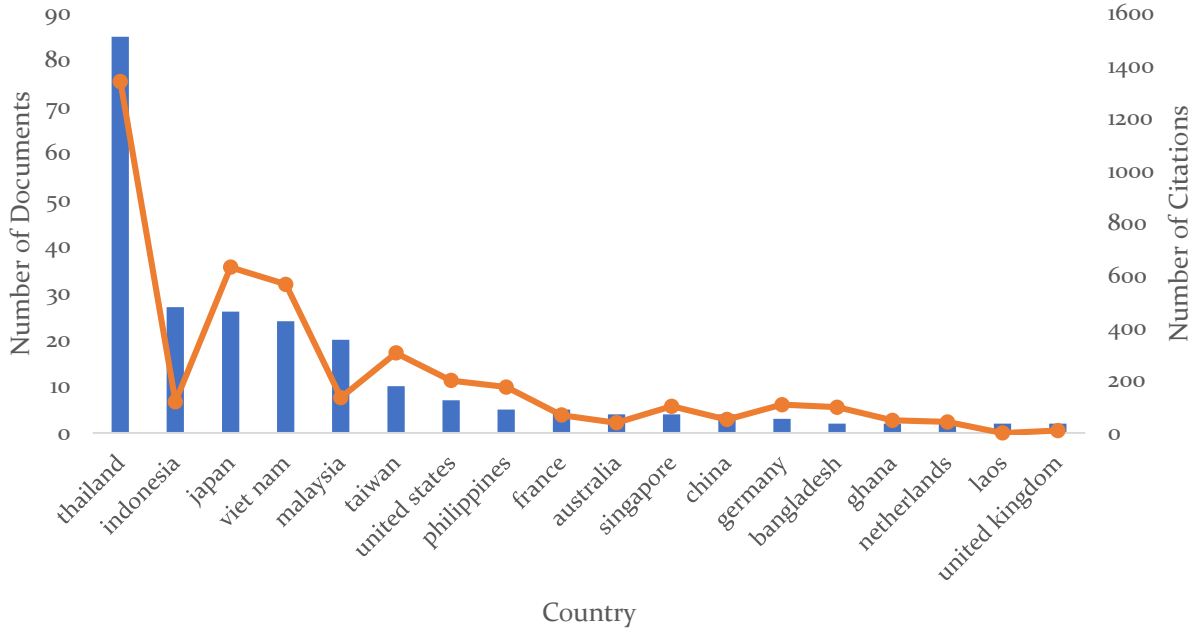
Related to the publication year, there are also some findings:

1. The older terms found such as municipal solid waste, biomass open burning, Thailand, and modis (remote sensing method). Indicating the concern of researchers on the **biomass burning.**
2. In the middle publication year (2017-2019), some terms such as biomass burning, pm10, and e-waste are found. Indicating the researchers were shifting to **crop residue burning.**
3. Current research are found to be focused on **health risk assessment** caused by forest burning.

Number of Country Affiliations

Settings
- Full counting
- Minimum number of documents of a country = 2 (18 meet threshold)



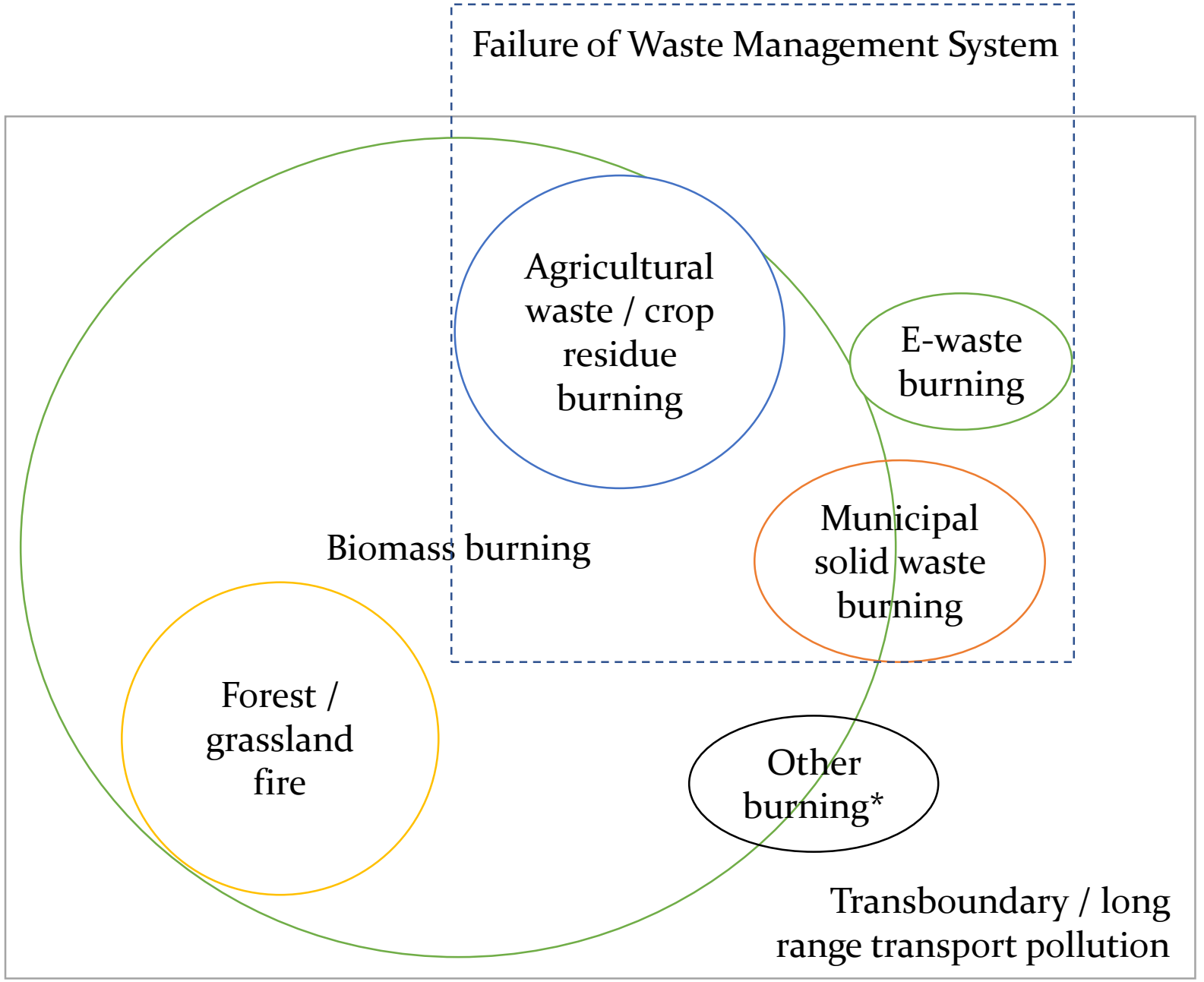


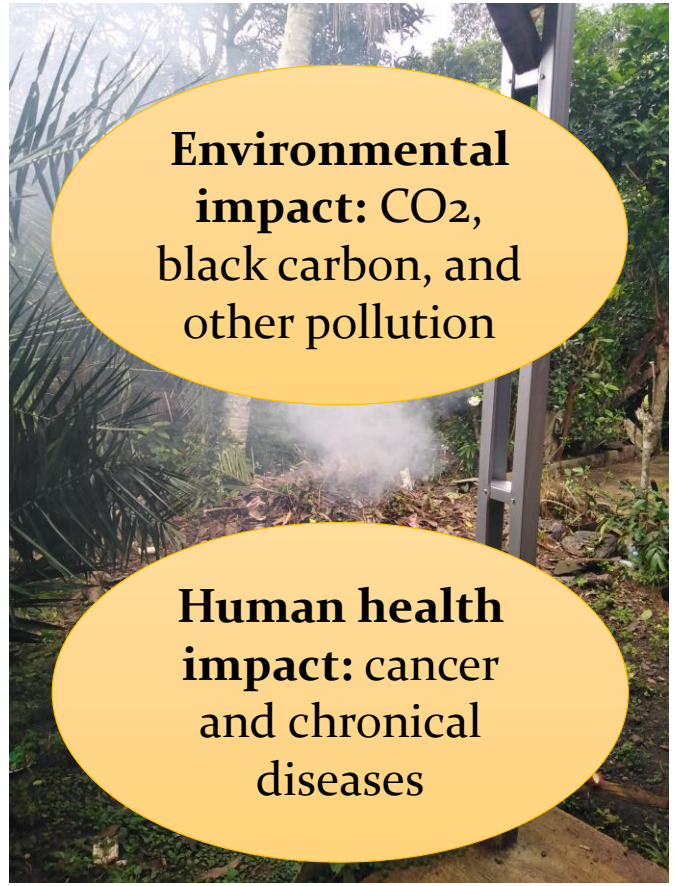
Some **conclusions** from the graph can be drawn

1. Thailand is the leading countries for research in open burning in ASEAN, while Indonesia is the second and Japan is the third.
2. There is an anomaly in the citations of documents from Indonesia and Malaysia, probably the documents are not published in high impact journal or just a conference proceeding or there is another reasons(?)
3. European researchers are found to be interested to studies about open burning in ASEAN.
4. Some clusters are found (showing in different colors) which showing collaboration between the affiliation country.

*Incense burning, Hungry Ghost festival, etc.

Summary





Health Impact

*Sorted from the highest to lowest contributor

Waste burned*	Spesific sources / chemical characteristics	Pathway	Health impact	Study location	References
Biomass (forest and crop residue)	PM10-bound PAHs	Inhalation	Cancer risk from PAHs exposure	Thailand	Wiriya et al., 2013
Crop residue (maize)	PM10-bound PAHs	Inhalation	Cancer risk from PAHs exposure	Thailand	Morknoy et al., 2017
1. Forest fire 2. Crop residue	Black carbon	Inhalation	The same risk with passively smoked cigarette	Thailand	Pani et al., 2019
Forest fire	PM2.5	Inhalation	Cancer risk from PAHs exposure	Thailand	Chantara et al., 2020
Crop residue	PM2.5	Inhalation	Lower respiratory infections, ischemic heart diseases (IHD) = Long-term mortality / non-accidental deaths	Thailand	Chi and Oanh, 2020
Biomass (forest, crop residue, and grassland)	PM2.5	Inhalation	**Stroke burden,** ischemic heart disease (IHD), lung cancer (LC), and chronic obstructive pulmonary disease (COPD) = premature death	Thailand	Punsompong et al., 2021
1. Forest fire 2. Crop residue	n.d.	Inhalation	Respiratory disease, such as COPD and lung cancer	Thailand	Kaewrat et al., 2022
1. Forest fire 2. Crop residue	PM-bound PAHs during haze events	Inhalation	Respiratory health risks	Thailand	Insian et al., 2022

Health Impact (Cont.)

*Sorted from the highest to lowest contributor

Waste burned*	Spesific sources / chemical characteristics	Pathway	Health impact	Study location	References
Crop (rice straw) residue	PM2.5-bound PAHs	Inhalation	Cancer risk from PAHs exposure	Vietnam	Pham et al., 2019
Open biomass burning (forest and crop residue)	PM2.5	Inhalation	Respiratory morbidity, ischemic heart disease (IHD), lung cancer (LC), chronic obstructive pulmonary disease (COPD), cardiovascular disease	Laos, Myanmar, Cambodia, Thailand, Vietnam	Thao et al., 2022
1. Municipal waste 2. Biomass (as fuel)	PM2.5-bound PCDD/Fs (dioxin)	Ingestion, diet	Cancer risk from dioxin exposure	Thailand, Vietnam, Taiwan	Chi et al., 2022
1. E-waste 2. Municipal waste	Flame retardant additives (for plastic or electronic additives)	Ingestion, inhalation, dermal	Autism, affect brain development, promote the growth of cancer cells, protein denaturation, membrane cells malfunction	n.d.	Chean-Yiing et al., 2022
E-waste (cables and wires for metal recovery)	Dioxin (PAHs), flame retardant, and metals	Inhalation, ingestion, diet	Non-cancer risk (bioaccumulation) caused by metals contamination. Other adverse effect related to the emitted pollutant.	Vietnam	Hoang et al., 2022

Spotted gaps

Environmental Impact

Study location	Fuel Type	Emission Factor (dry biomass)		Total Annual Emission Estimation (Mt)		References
		CO_2 (g kg^{-1})	BC (g kg^{-1})	CO_2 (Mt)	BC (kt)	
Thailand	Sugarcane biomass (pre- and post-harvesting)	1,515	-	Pre-harvest 9.80 Post-harvest 12.7	-	Sompoon et al., 2014
Indonesia	Rice straw	-	0.939 ± 0.417	-	-	Hafidawati et al., 2017
Thailand	Rice straw	1,177 ± 140	0.53	5.34	2 1 ± 1	Junpen et al., 2018
Vietnam	Rice straw	1,177	0.51	3.82	1.6	Le et al., 2020
Thailand	Rice straw	1,247 ± 190	-	8.23	-	Hong Phuong et al., 2022
Indonesia	Savanna / shrub land	1,613	0.48	*Total emission* = 57.28	*Total emission* = 0.24	Permadi et al., 2013 (2007 data)
	Peat land / mangrove forest	1,703	0.57			
	MSW	1,453	0.65			
	Tropical forest	1,580	0.66			
Thailand	Cropland	1,585	0.75	*Total emission* = Myanmar 64 ± 12 Cambodia 45 ± 8 Laos 13 ± 2 Thailand 27 ± 9 Vietnam 30 ± 12	*Total emission* = Myanmar 20 ± 12 Cambodia 13 ± 7 Laos 4 ± 3 Thailand 10 ± 5 Vietnam 13 ± 6	Junpen et al., 2020 (2015 data)
	Forestland	1,643	0.52			
	Shrubland / savanna	1,686	0.37			

Environmental Impact (Cont.)

Study location	Fuel Type	Emission Factor (dry biomass)		Total Annual Emission Estimation (Mt)		References
		CO_2 (g kg^{-1})	BC (g kg^{-1})	CO_2 (Mt)	BC (kt)	
ASEAN	Crop residue (RS = rice straw, M = maize, S = sugarcane, OCR = other crop residue)	RS 1,177 M 1,350 S 1,130 OCR 1,130	RS 3.1 M 2.2 S 3.3 OCR 0.7	172	74	Oanh et al., 2018
	Forest	-	-	655	220	
Vientianne, Laos	MSW	1,453 (wet basis)	-	0.027	-	Babel and Vilaysouk, 2016
Luangprabang, Laos	MSW	1,453 (wet basis)	5.5	0.005	0.007	Vilaysouk and Babel, 2017
Depok City, Indonesia	MSW	801.2	-	0.26	-	Kristanto and Koven, 2019
Thailand	MSW	n/a (IPCC calculation)		0.499	-	Pansuk et al., 2018
Philippines	MSW	n/a (IPCC calculation)	0.65	944.69 (uncollected waste)	1.63	Premakumara et al., 2018

Emission from MSW in ASEAN countries is not fully understand
The number of **waste burned has not estimated yet**

Emission from MSW burning has the same potential of **BC** emitted from **rice straw residue burning in Vietnam**

Regional Outlook

In avg, **57%** of waste **are not collected** in ASEAN countries which subjected to improper waste disposal

Country	Population[a]	GDP[a] (billion USD)	GDP per Capita[a] (USD)	CO_2 Emissions[a] (t per capita)	Total GHG Emissions[a] (kt CO_2-eq)	Avg Waste Generation (kg/cap/day)	Waste Collection Efficiency (%)
Singapore	5,453,566	360.90	66,176.4	8.3	67,230	1.10[b]; 0.94[c]	100[g]
Brunei Darussalam	441,532	13.21	29,927	16.1	9,300	0.66[b]; 1.40[c]	50-70[h]
Malaysia	32,776,195	354,88	10,827.3	7.9	313,020	0.81[b]; 0.90[c]	66-90[h]
Thailand	69,950,844	438.62	6,270.4	3.8	422,090	0.64[b,c]	59[n]
Indonesia	276,361,788	1,070.00	3,855.8	2.3	1,002,370	0.76[b]; 0.49[c]	65[i]
Vietnam	98,168,829	331.13	3,373.1	3.5	450,150	0.61[b]; 0.41[c]	60[e]
Philippines	111,046,910	378.96	3,412.6	1.3	234,280	0.52[b]; 0.40[f]	65[f]
Papua New Guinea*	9,119,005	24,21	2,655.2	0.9	22,410	0.41[d]	n/a
Laos	7,379,358	19.05	2,582.2	2.6	29,280	0.55[b]; 0.64[c]	40-50[j]
East Timor*	1,343,875	2.19	1,626.4	0.5	5,910	0.45[e]	55[k]
Cambodia	16,946,446	23.72	1,399.8	1.0	40,060	0.52[b]	72[l]
Myanmar	54,806,014	70.81	1,292.1	0.7	133,250	0.45[b]; 0.44[m]	53-84[m]

[a]data.worldbank.org accessed Nov 26, 2022; GDP is calculated using constant USD from 2015; [b]Nguyen Ngoc et al. (2009); [c]Kawai and Tasaki (2016); [d]Karak et al. (2012); [e]Woodruff (2014); [f]Premakumara et al. (2018); [g]Jerin et al. (2022); [h]Faulstich et al. (2011); [i]https://sipsn.menlhk.go.id/sipsn/ accessed Nov 27, 2022; [j]Global Green Growth Institute (2022); [k]Ximenes and Maryono (2021); [l]Pheakdey et al. (2022); [m]The World Bank Infographic (2019); [m]Pansuk et al. (2018); *Observer countries

OWB Profiles

Around **40%** of waste is burned worldwide (Wiedinmyer et al., 2014)

Location	Average waste generation (Mt/year)	Total waste burning (kt/year)	Fraction of open burning (%)	Composition (%)							References
				Food waste	Garden waste	Plastic	Paper	Metal and Glass	Textile and Rubber	Others/ Inert	
Vientiane City, Laos	0.23	35.18	15	34.0	30.0	12.0	7.0	8.0	8.0	1.0	Babel and Vilaysouk, 2016
Luangprabang City, Laos	0.03	2.64	9	39.0	31.0	8.0	6.0	2.0	5.0	9.0	Vilaysouk and Babel, 2017
Depok City, Indonesia	0.41	25.55	6.3	73.0	3.7	3.6	7.1	2.6	3.6	6.4	Kristanto and Koven, 2019
Semarang City, Indonesia	0.61	58.80	9.7	53.9 *0.2*	- *73.4*	21.5 *17.5*	10.9 *4.3*	8.7 *0.3*	- *3.3*	5.0 *1.0*	Hadiwidodo et al., 2022 Ramadan et al., 2022*
Thailand	26.20	3,430	13	- *10.3*	48.0 *17.4*	15.0 *36.3*	15.0 *0.9*	10.0 *4.7*	- *18.1*	14.0 *12.2*	Pansuk et al., 2018*
Philippines	14.86	2,602	17.5	52		28.0			20.0 (include special waste like e-waste, healthcare, and bulky waste)		Premakumara et al., 2018

*The italic number represents the composition of burned waste pile (below) which is different with the municipal waste composition (above)

Please noted that **plastic burning** especially **PET and Polystyrene** emit the higher black carbon than other type of waste (Reyna-bensusan et al., 2019). See the **emission factors** based on lab-scale measurement (g kg^{-1})

Paper and Cardboard	Garden waste	Textiles	LDPE	HDPE	PET	Polystyrene	Mixed waste*
0.02	0.5	9	0.1	0.2	46	53	4.7

*Mexico case study

E-waste Burning

Concerned on emerging pollutants from flame retardants burning, dioxin-related compound

Metals and organic compound pollution to the environment

Producers, importers and sale agents; Formal waste treatment

E-waste generation*
3.7 kg/capita/year

Traditional recycling of e-waste by informal sector

Metal recovery and burning fewer valuable materials

*Vietnam case study
Noted that municipal waste generation is **0.41 kg/capita/day** (Kawai and Tasaki, 2016)

Open burning, manual dismantling, plastic recycling

Recovery process: (1) primary dismantling, (2) crushing and enrichment, (3) smelting and precious metal recovery

#Photos credit to Hoang et al. (2022)

Key factors of OWB Practices

Technical factors

- Lack of proper domestic waste disposal (Kong et al., 2020)
- Lack of regulatory / law enforcement (Kong et al., 2020)
- Inadequate waste transportation infrastructure (Ramadan et al., 2022b)
- Bigger space for waste dumping in the backyard (Ramadan et al., 2022b)
- Distance between landfill to the service area (Ramadan et al., 2022b)

Non-technical factors

- Lack of environmental health awareness, attitude, and practices (Kong et al., 2020)
- The need of heat from burning activities (Ramadan et al., 2022a)
- Lack of motivation to sort waste (Ramadan et al., 2022b)
- Exceeding volume of waste due to some specific event (Ramadan et al., 2022b)
- Local people's rejection of the establishment of waste collection facility (Ramadan et al., 2022b)
- Impatience habits in waiting collection services (Ramadan et al., 2022b)

Initiatives

Decentralized waste management system, case of Phillippines (Premakumara et al. 2018)	• Localized approach for implementing MSWM policy is useful to reduce open burning. Law/policy enforcement and commitment from the national to local level could reduce the burning activity.
Community empowerment (Brotosusilo and Naldi, 2021 and Budihardjo et al. 2022)	• In many places in Indonesia and Thailand, waste management which is empowering local actors to manage their own waste was introduced and strengthened in the national policy. This initiatives are useful to boost recycling thus reducing waste burning practices
Zero burning policy in Upper Northern Thailand (Yabueng et al. 2020)	• To reduce the biomass burning event in Thailand, the government enforced the policy during February to April (dry season) since 2016. The biomass burning hotspot reduced in the implementation of the policy, while this situation could also be done for open burning of waste.

Summary and Policy Recommendations

Summary

- Many researchers are focusing on biomass and crop residue burning. While the information of other burning practices such as MSW and e-waste burning are lacking.
- MSW burning is potentially emitted significant number of pollutant with the similar or even higher impact than biomass burning.
- More work in the MSW and e-waste burning field are needed to fill the scientific gaps and baseline study for appropriate policy recommendation.

Recommendation

- Improvement of collection and transportation service
- Regular inspection reinforcement
- Establishment of policies both local and national to reduce burning practice
- Establishment of community waste management unit to do recycling activities
- Establishment of community education and awareness campaign
- Promoting recycling activities of informal actors at household levels
- Improving working condition of informal recycling actors

ご清聴ありがとうございました。

Thank you very much for your attention.

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