Harnessing social media analytics for political ecology: Polish digital discourse on waste incinerators

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Abstract

This study explores how social media analytics (SMA) advances political ecology (PE) through a case study on Polish discourse around waste-to-energy facilities (March 2020–June 2023). Using a social media listening platform (SMLP) for sentiment analysis, geoparsing, keyword frequency analysis, and online reach estimation, SMA provides a big-data-driven framework for examining environmental conflicts and discursive power in the digital sphere. The Polish case shows SMA's ability to tackle PE methodological challenges, including dependence on static datasets, researcher bias, and the complexity of analyzing diverse online data sources. However, its application must be approached critically. The article highlights both its strengths—such as amplifying varied voices across the entire digital domain and enabling real-time analysis of evolving discourse—and its weaknesses, including ethical, environmental, and analytical concerns. Overcoming these obstacles requires a sustainable, collaborative approach that integrates SMA with qualitative methods to provide contextual depth and validate findings. This integration can unlock SMA's game-changing potential for PE.

Keywords: social media, big data, social media analytics, political ecology, environmental conflict, online activism, incinerator, waste, Poland

Résumé

Cette étude explore comment l'analyse des médias sociaux (SMA) fait progresser l'écologie politique (EP) à travers une étude de cas sur le discours polonais autour des installations de valorisation énergétique (mars 2020–juin 2023). En utilisant une plateforme d'écoute des réseaux sociaux (SMLP) pour l'analyse des sentiments, le géoparsing, l'analyse de la fréquence des mots-clés et l'estimation de la portée en ligne, la SMA fournit un cadre basé sur les mégadonnées pour examiner les conflits environnementaux et les dynamiques de pouvoir discursif dans un contexte numérique. Le cas polonais illustre la capacité de la SMA à relever les défis méthodologiques de l'EP, notamment la dépendance aux ensembles de données statiques, le biais du chercheur et la complexité de l'analyse de sources de données en ligne variées. Cependant, son application doit être abordée de manière critique. L'article met en lumière à la fois ses points forts—tels que l'amplification des voix diverses dans l'ensemble du domaine numérique que et l'analyse en temps réel des discours en évolution—et ses faiblesses, notamment les préoccupations éthiques, environnementales et analytiques. Surmonter ces obstacles nécessite une approche durable et collaborative qui intègre la SMA avec des méthodes qualitatives pour fournir une profondeur contextuelle et valider les résultats. Cette intégration peut libérer le potentiel transformateur de la SMA pour l'EP.

Mots-clés: médias sociaux, mégadonnées, analyse des réseaux sociaux, écologie politique, conflit environnemental, activism numérique, incinérateur, déchets, Pologne

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Resumen

Este estudio explora cómo el análisis de redes sociales (SMA) impulsa la ecología política (EP) a través de un estudio de caso sobre el discurso polaco en torno a las plantas de valorización energética (marzo 2020–junio 2023). Utilizando una plataforma de escucha de medios sociales (SMLP) para el análisis de sentimientos, geoparsing, análisis de frecuencia de palabras clave y estimación del alcance en línea, el SMA ofrece un marco impulsado por macrodatos para examinar los conflictos ambientales y el poder discursivo en entorno digital. El caso polaco demuestra la capacidad del SMA para abordar los desafíos metodológicos de la EP, incluida la dependencia de conjuntos de datos estáticos, el sesgo del investigador y la complejidad del análisis de diversas fuentes de datos en línea. No obstante, su aplicación debe abordarse con una perspectiva crítica. El articulo resalta tanto sus fortalezas—como amplificar voces diversas en el conjunto del dominio digital y permitir un análisis en tiempo real de los discursos en evolución—como sus debilidades, incluidas preocupaciones éticas, ambientales y analíticas. Superar estos obstáculos requiere un enfoque sostenible y colaborativo que integre el SMA con métodos cualitativos para proporcionar profundidad contextual y validar los hallazgos. Esta integración puede desbloquear el potencial transformador del SMA para la EP.

Palabras claves: redes sociales, macrodatos, análisis de redes sociales, ecología política, conflicto ambiental, activismo digital, incineradora, residuos, Polonia

1. Introduction

Waste-to-energy (WtE) facilities, promoted as circular economy solutions, often spark conflicts, exacerbate social inequalities, and harm vulnerable communities (Laurian & Funderburg, 2014). In Poland, grassroots resistance to these projects—commonly termed waste incinerators—has grown alongside government expansion efforts driven by environmental and social concerns. Conflicts increasingly unfold on digital platforms, with social media enabling activism and reshaping public discourse. While traditional media, now primarily online, often reflect political or commercial biases that marginalize certain groups, platforms like X provide forums for underrepresented voices and counter-narratives (Checker, 2017; Dey, 2019; Hawkins & Silver, 2017).

Political ecology (PE) has long emphasized the study of conflicts, particularly those arising from asymmetrical power relations (Kalaska, 2021; Le Billon & Duffy, 2018; Martinez-Alier *et al.*, 2016). These struggles inspire diverse forms of activism, with the rise of digital platforms adding new dimensions to how they are understood and engaged. Social media facilitates rapid information dissemination, empowering activists to amplify marginalized voices (Suwana, 2019). These dynamics underscore the concept of discursive power—the ability of various actors to shape public opinion and influence decision-making (Svarstad *et al.*, 2018). Digital spheres, therefore, become arenas of continuous negotiation and contestation over such power.

Social media analytics (SMA), an interdisciplinary field at the intersection of informatics and linguistics, equips researchers with tools to capture and analyze vast digital narratives, such as user-generated content, yet it remains underutilized in political ecology. Concerns about its role in perpetuating power imbalances or exacerbating environmental impacts may contribute to this gap (e.g. Benjamin, 2019; Goldstein & Faxon, 2022). Nonetheless, SMA offers opportunities to analyze online activism and discursive power in environmental conflicts, including those linked to WtE facilities. While recognizing the risks of amplifying inequities or causing harm, this article examines its utility for the field of political ecology.

The article aims to demonstrate how SMA advances PE research by tackling challenges such as reliance on static datasets, researcher bias, and the complexity of analyzing diverse online data sources. Unlike traditional methods, SMA offers a dynamic, big-data-driven approach that mitigates these limitations through the efficient processing of large-scale, heterogeneous online data sources with minimal bias. To explore this potential, this research employs an instrumental case study of WtE-related digital debates in Poland, where environmental conflicts emerge and resonate online.

The contribution to political ecology is through refining methodological approaches to studying digital narratives. It expands the analytical toolkit available to political ecologists, offering insights into how SMA enhances the examination of environmental conflicts and power dynamics in the online sphere.

2. Background and literature review

Social media analytics for political ecology: Bridging methodological gaps

Social media analytics (SMA) is an interdisciplinary research field that combines computational and linguistic methods, leveraging AI-powered technologies like natural language processing (NLP) and machine learning to collect and analyze large digital textual datasets (Stieglitz *et al.*, 2018). SMA effectively handles the unstructured, dynamic, and imprecise nature of online data, which is considered as big data (Andreotta *et al.*, 2019). A core feature of SMA is sentiment analysis, which evaluates the emotional tone of text to explore how emotions influence narratives and shape public discourse (D'Andrea *et al.*, 2015). By identifying themes, emotions, and power dynamics, SMA offers a data-driven lens for various disciplines (Zachlod *et al.*, 2022).

Traditional PE research methods and techniques, which examine environmental conflicts and asymmetrical power relations, have flaws. Qualitative approaches, such as single case studies (Johnson *et al.*, 2018), workshops and document reviews (Morales-Giner *et al.*, 2023), and interviews (Faxon, 2022), offer rich contextual insights but are shaped by researcher involvement (cf. Mahoney, 2010) and may not fully capture the complexity of social dynamics—particularly when focusing on isolated fragments of online realms, such as top-ranked websites in internet browsers (Tran, 2023). Quantitative methods, including statistical comparative analyses, uncover broader patterns but face challenges related to case selection, geographic representativeness, and estimating the total number of conflicts (Hanaček *et al.*, 2022; Scheidel *et al.*, 2018; Tran *et al.*, 2020). These frameworks rely on sampling, which can yield incomplete insights and prioritize emblematic conflicts while overlooking smaller struggles (see Haslam, 2020). SMA introduces a distinct approach by bridging these gaps.

In my view, SMA provides a promising solution to these methodological challenges. Its automated data collection and analysis help mitigate researcher bias, while algorithmic tools identify patterns and trends across vast datasets, providing a more structured perspective on PE-related topics. Moreover, SMA captures the full scope of the digital sphere. Despite its name, it extends beyond social media platforms to analyze diverse online sources, including blogs and news outlets. This broad reach facilitates a comprehensive examination of digitally mediated environmental struggles, incorporating perspectives from both marginalized groups and dominant actors. Unlike static resources, such as the Global Atlas of Environmental Justice (EJAtlas; Temper *et al.*, 2015), which present fixed snapshots of conflicts and are updated only periodically or not at all, SMA supports dynamic, real-time analysis that reflects the evolving nature of struggles and discourses (cf. Zachlod *et al.*, 2022).

By aligning with emerging frameworks like digital political ecologies (DPE) and emotional political ecologies (EmPEs), SMA enhances PE's capacity to examine power dynamics and emotions in online environmental conflicts. Digital political ecologies highlight how digital platforms function as contested arenas for negotiating narratives among activists, corporations, and governments (Nelson *et al.*, 2023; Turnbull *et al.*, 2023), while SMA offers big-data-driven tools to systematically analyze these strategies. Similarly, EmPEs emphasize the mobilizing role of emotions in shaping power dynamics (see Sultana, 2015; González-Hidalgo & Zografos, 2020; Stevens *et al.*, 2020), and SMA's sentiment analysis quantifies emotional tones, revealing their influence on activism and public opinion.

Despite its potential to advance PE research, SMA has notable limitations. It is vulnerable to data manipulation, misinformation, and biases inherent in social media platforms, among other challenges (Calcagni *et al.*, 2019; Teles da Mota & Pickering, 2021). These issues underscore the need for a critical perspective and caution against uncritical reliance on SMA tools. Clearly articulating these limitations is essential to ensuring researchers remain vigilant about potential pitfalls, and approach SMA with informed caution.

With SMA as a research field that has been virtually unused in political ecology, this case study examines its application in analyzing digital discourse on waste incineration projects in Poland, assessing its potential and limitations.

Case study justification: Polish online discourse on waste incinerators

Poland's rapid expansion of WtE projects provides a valuable case study for analyzing digital political ecologies through social media analytics. From a single plant in the capital in 2015, the country operated eight facilities across major cities by mid-2023 (Białystok, Bydgoszcz, Konin, Kraków, Poznań, Rzeszów, Szczecin, and Warsaw), collectively processing 2.6 million tons of municipal waste annually, along with co-incineration sites like Zabrze. At the end of 2022, the government approved funding for 39 additional WtE developments, supported by over US$2.5 billion from the EU Modernization Fund (Leśniewski, 2023).

The conservative Law and Justice (PiS) party (2015–2023) pursued WtE plant expansion, driven by three key factors: first, municipal waste held significant energy potential, supporting electricity and heat generation while reducing dependency on environmentally and health-detrimental landfilling. However, in 2022, only 20.2% (2.71 million tons) of collected municipal waste underwent thermal treatment with energy recovery, while 38.1% (5.11 million tons) was still landfilled across 259 sites, highlighting the ongoing reliance on landfilling and the need for alternative waste management strategies. Second, the rapid expansion of mechanical-biological treatment (MBT) facilities—from 73 to 298 units between 2013 and 2015 (Bień, 2017)—led to a significant accumulation of refuse-derived fuels (RDFs), creating a pressing need for disposal solutions. Finally, Poland's 2016 ban on landfilling high-calorific waste further reinforced the necessity of alternative waste treatment methods, particularly WtE incineration (Poniatowska *et al.*, 2022).

Opposition to these developments has steadily grown, led by grassroots movements mobilizing across a dozen localities. Using social media, these anti-incineration groups have revived the vibrant environmental activism of the 2010s (Szulecka & Szulecki, 2017). Social media enables local activists, often mobilizing for the first time, to bypass traditional media and reach wider audiences. Their campaigns advocate not only for halting WtE projects but also for reforms like extended producer responsibility (EPR) laws (STOP wrocławskiej spalarni, 2022d). Reflecting their significance, Polish WtE-related struggles have drawn scholarly attention, with Zu *et al.* (2024) highlighting the impact of a Bielsko-Biała conflict on social stability and sustainability.

Poland was selected as the case study due to its unique position at the intersection of modernization-driven waste policies and rising environmental opposition. Its rapid WtE expansion, supported by EU funding, exemplifies global tensions between economic development and environmental justice. Grassroots resistance, utilizing digital platforms for mobilization, highlights Poland as a compelling context for analyzing occurring online environmental conflicts through SMA.

3. Methodology of the SMA-driven case study

This instrumental case study within a multiple-case framework (Babbie, 2020) examines the potential of social media analytics (SMA) for PE research. Focusing on Polish WtE debates, it demonstrates how SMA uncovers discursive power dynamics in digitally mediated environmental conflicts while addressing gaps such as capturing evolving struggles and reducing researcher bias, as detailed in Section 2. To conduct the study, exploratory research questions were formulated to link the Polish WtE context:

- RQ1: What patterns of online perception emerge around waste incinerators, and how are they geographically distributed?
- RQ2: Which digital actors hold the most influence in shaping waste incinerator narratives, and how does this reflect power dynamics?
- RQ3: What discursive themes shape anti-WtE grassroots groups' responses to these projects?

Data collection and analysis

To explore these questions, one of the leading social media listening platforms (SMLPs), Sentione, was utilized to collect and analyze Polish online content from March 1, 2020 to June 30, 2023. This platform aggregates data from over 5 million digital sources (Sentione, n.d.). These mentions refer to any digital instances where keywords or phrases related to WtE facilities are identified, categorized as follows:

- Articles: News reports or blog entries discussing waste incineration.
- Posts: Social media posts from platforms like Facebook, X, or forums, including public posts by individuals, organizations, or protest groups.
- Comments: User responses under articles, posts, or forums containing relevant terms.
- Reviews: User-generated reviews from platforms that host opinions about WtE projects.

Incinerator-related mentions were identified through Boolean search queries and keyword-based rules, designed to capture both formal terminology (e.g., "waste thermal treatment plant") and informal or colloquial phrases (e.g., "garbage incinerator"). Keywords and their rules were tailored to account for linguistic variations in Polish, including inflections and contextual nuances. This approach ensured thorough identification of relevant mentions while filtering out irrelevant ones, such as metaphorical uses of terms (e.g., 'money furnace'), to maintain the analysis' precision.

Several SMA techniques were applied to analyze the collected data:

1. Sentiment Analysis of Online Mentions: A sentiment analysis tool combining machine learning and lexicon-based methods categorized mentions as positive, neutral, or negative, based on their general emotional tone. The classification was informed by the PANAS scale (Crawford & Henry, 2004), mapping lexical markers of Positive Affect (e.g., "enthusiastic") and Negative Affect (e.g., "distressed"). Neutral mentions exhibited a balance of both. While this method provided insights into public sentiment toward WtE projects, it evaluated the overall tone of mentions rather than attitudes specific to individual facilities, with limitations in capturing nuanced or mixed sentiments.
2. Geoparsing of Online Mentions: Mentions of places associated with WtE facilities, such as cities or districts, were matched to geographic locations using a custom-built gazetteer. The gazetteer consolidated locality names, linguistic variations, and GPS coordinates derived from facility records, grassroots protest Facebook pages, and government co-financing applications. Geotagging was used to extract and standardize place names while geocoding resolved ambiguities by assigning precise coordinates to mentions (Middleton *et al.*, 2018). The spatial distribution of WtE-related discourse, including sentiment patterns, was visualized using a proportional symbol map, highlighting 'discursive' clusters across 74 localities in Poland (Figure 1).
3. Reach Estimation of WtE Content by Accounts: Reach refers to the total potential impressions generated by a specific account's WtE-related content (Solis, 2010). However, it does not represent the true audience size or actual engagement levels. It was assessed using metrics such as likes, shares, comments, and platform-specific dynamics (e.g., domain traffic), reflecting the visibility and influence of accounts within digital discourse. Higher rankings, in my view, indicate greater discursive power—the ability to shape public narratives. SMLP's algorithms analyzed these factors across websites, forums, and social media to identify influential digital actors—such as politicians, journalists, and protest collectives—who shape incinerator-related discussions. While the SMLP did not provide

exact audience figures, influencers were ranked, with metrics like total comments and follower counts serving as proxies for their influence (Table 1).

4. Frequency Analysis of Keywords: This method quantified word usage to identify recurring themes in the online discourse of four influential anti-WtE grassroots groups. It calculated the total frequency of each term across all mentions, including repeated instances within posts and comments. Lemmatization was applied to consolidate grammatical variations into root forms, improving consistency in keyword counts. This analysis used single-word entries, excluding common words like "and" or "the". Bar graphs were generated to visualize term frequency comparisons across collectives (Figure 2).

To enrich the research, SMA techniques were complemented with qualitative methods, which played a dual role in enhancing the study. Unstructured interviews were conducted with three experts: one pro-incineration scientist and two active online opponents of WtE projects. Additionally, a targeted review of key social media accounts was performed, focusing on 26 Facebook pages representing site-specific anti-incineration protest collectives. These qualitative methods not only refined the creation of search queries by incorporating informal and formal terms but also enriched the interpretation of SMA-driven results, providing a means to cross-check findings. This mixed-methods approach enabled a comprehensive analysis by integrating quantitative patterns with qualitative insights, grounding the findings in real-life contexts (Hawkins & Nelson, 2022).

A detailed description of the methodology, focusing on SMA-related data collection and analysis techniques, is included in the Appendix. Additionally, Figure 3 visually summarizes the research workflow.

Reflexivity and ethical considerations

The researcher's positionality as a native Polish speaker with a background in human geography and political ecology has influenced the study. Linguistic proficiency contributed to the accuracy of SMA queries and interpretations. Furthermore, geographical expertise was valuable for the geoparsing of online mentions, ensuring a nuanced understanding of spatial dynamics.

This study adhered to EU GDPR regulations and ethical guidelines, ensuring that only publicly available data was used, and no personally identifiable information (PII) was stored and analyzed. The data collection process was designed with privacy protection as a priority at every stage. Data were initially gathered using a compliant SMLP that excludes personal details protected by social media privacy policies, ensuring no unauthorized access to PII. Additionally, mentions from public accounts were anonymized (e.g., Collective 1, Actor 1) to prevent stigmatization while maintaining analytical rigor. This approach balanced transparency and ethics, respecting the rights of individuals and communities involved.

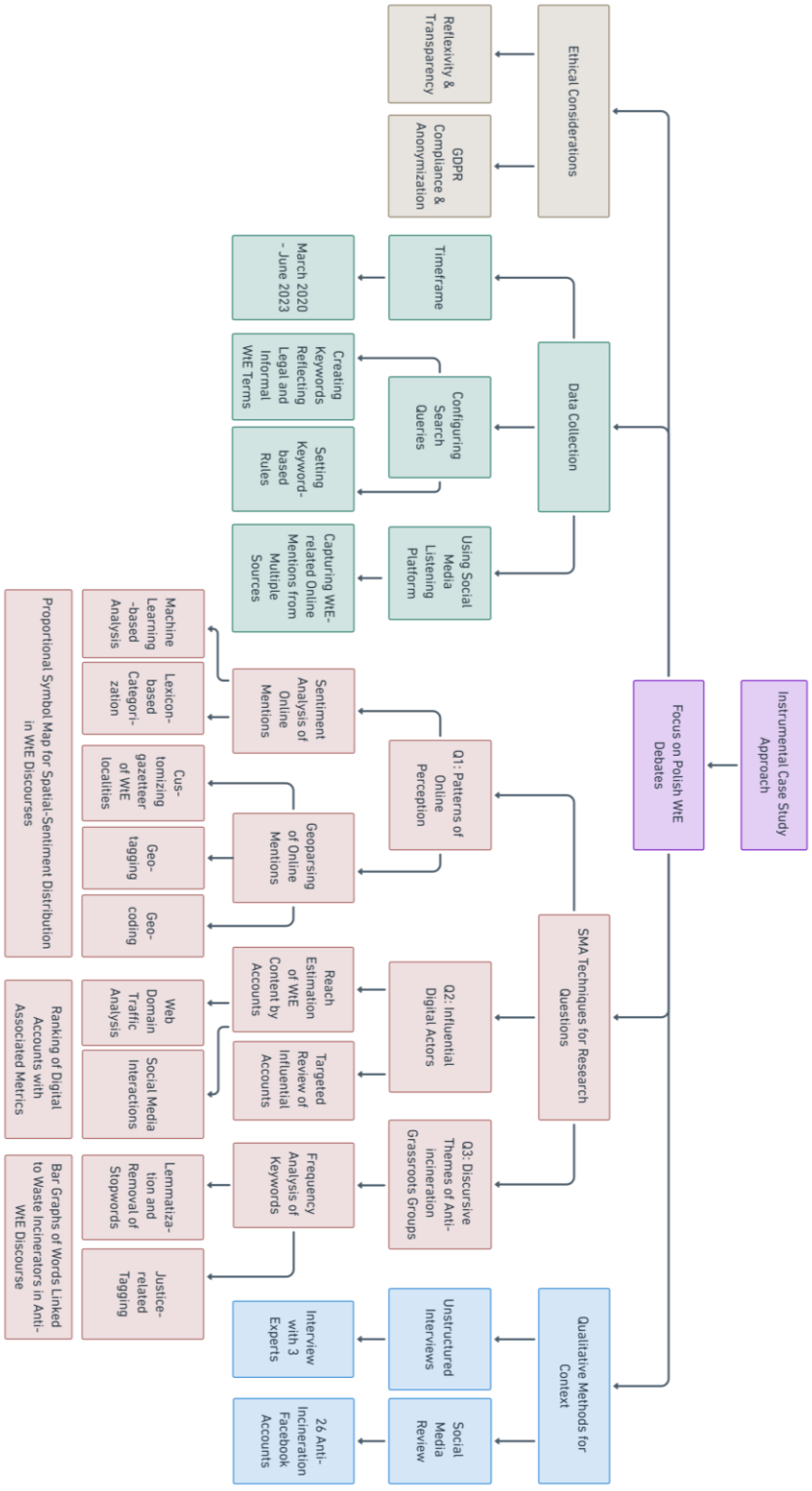

Figure 3. Research procedure of SMA-driven case study.

4. Results of the SMA-driven case study

Sentiments and geographies of discourses

Between March 1, 2020, and June 30, 2023, Polish WtE-related online discussions generated 119,091 mentions. Of these, at least 93,079 originated in Poland, reflecting the fact that over 98% of Polish native speakers reside in the country. Only 393 mentions came from abroad, across 44 countries (mainly the US and the UK). The origin of the remaining 21.2% of mentions remained unknown due to API limitations. Most conversations (62.8%) took place on 1,532 internet portals, with just ten sites contributing 24.5% of the 16,013 articles, including local news platforms and national industry or business portals. Social media platforms also hosted discussions on waste incinerators, primarily on Facebook (29.2% of mentions, including 2,736 posts) and X (6.2%, including 4,059 tweets).

Sentiment analysis, detailed in the Appendix, reveals that most mentions of incinerators are neutral (84,004; 70.5%). These neutral mentions typically consist of factual statements or discussions lacking clear evaluative language. Meanwhile, negative mentions (15,201; 12.9%) appear nearly five times more frequently than positive ones (3,043; 2.6%), indicating a strong imbalance in emotional tone. Negative mentions often convey fear, or anger, while positive ones may indicate support. Despite limitations of sentiment analysis—such as difficulty detecting sarcasm and excluding analysis for news articles (16,483; 13.8%)—the prevalence of negative mentions highlights widespread criticism of WtE projects.

The analysis shows that sentiment evolved significantly over time, with the late 2022 announcement of public funding for 39 new WtE projects—backed by the Polish government and EU support—marking a turning point. This decision sparked widespread distrust toward decision-makers and investors, fueled by concerns over transparency. Grassroots collectives, formed in response to contested developments in dozens of localities, quickly mobilized on social media to amplify these concerns, drawing attention to perceived flaws in the projects. As a result, in the first quarter of 2023, positive mentions accounted for just 13% of all non-neutral digital WtE discussions. These sentiments were derived from all Polish online statements related to waste incinerators across various platforms and contexts. By the second quarter of 2023, this proportion rose to 22%. While negative sentiment still dominated, the increase in positive mentions suggested a shift in public perception, potentially driven by reduced fears that certain WtE proposals would move forward. This change in sentiment coincided with the April 16 referendum in Bielsko-Biała, where 56.9% of eligible residents voted against the construction of the incinerator. Although the turnout did not meet the 30% threshold required to make the referendum legally binding for city authorities, the mayor nonetheless suspended the project. This outcome shows how grassroots online activism and evolving public sentiment influence policy decisions, even without binding legal mechanisms.

Most WtE-related mentions are linked to populous cities like Warsaw and Wrocław, but smaller localities (e.g., Inowrocław, Ostrołęka, Bielawa) also featured prominently (Figure 1). The mentions cluster in areas with high solid municipal waste production, energy-intensive industries (e.g., cement factories, coal-fired plants), or severe air pollution (e.g., Nowy Targ, Nowy Sącz). In contrast, northern Poland, particularly the Baltic coast and Pomerania, sees less debate due to the prevalence of wind energy projects, highlighting a renewable energy shift absent in coal-dependent regions. Overall, discussions are concentrated in central and southern urban areas with high energy demands.

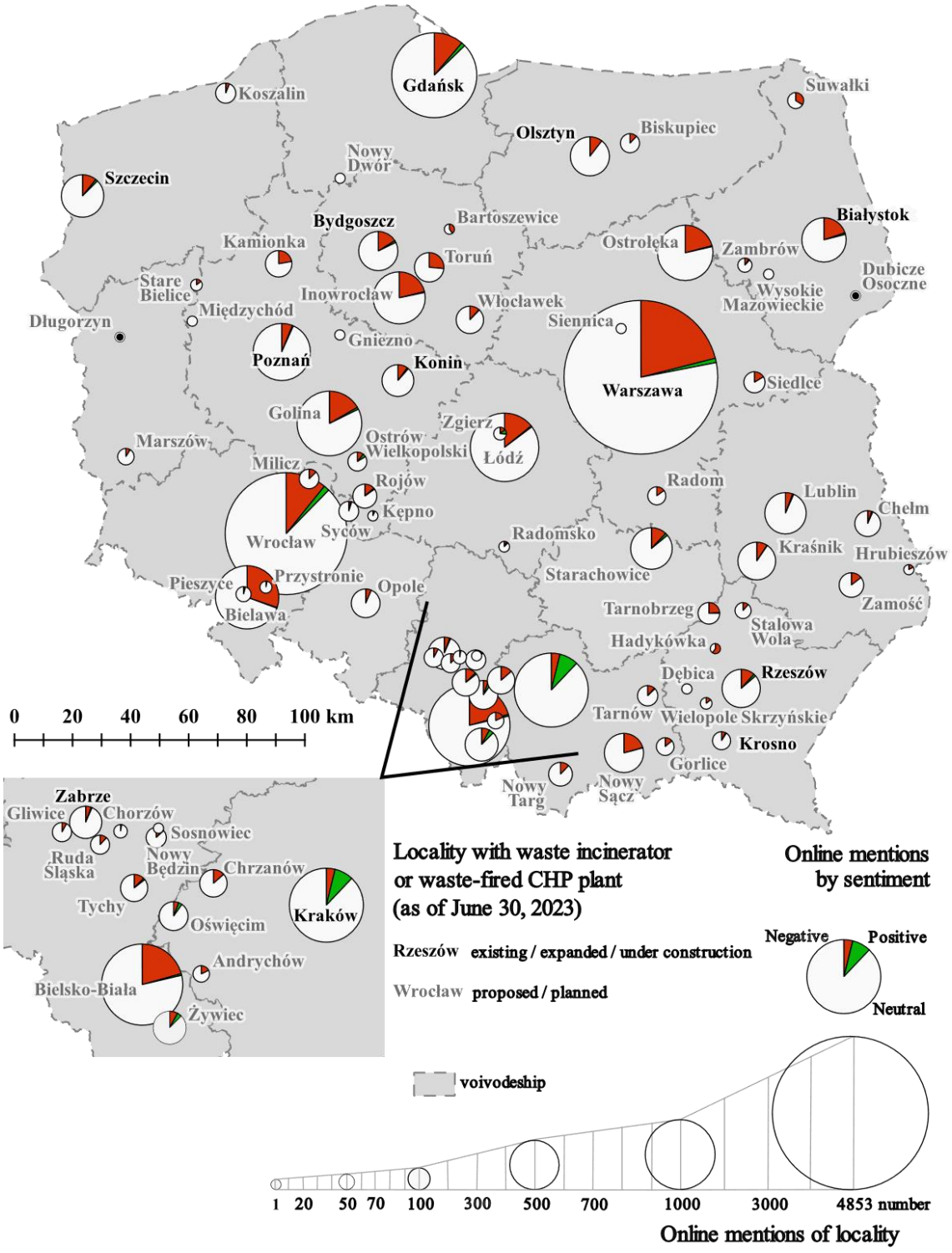

Figure 1: Spatiality of Polish-language waste incinerator discourse (March 1, 2020–June 30, 2023); locality mentions may overlap; sentiment statistics based on Sentione's algorithm; web portal articles excluded.

Localities with operational incinerators generally exhibit low positive sentiment ratios; however, these are notably higher (0.29) than those for facilities that are either undergoing reconstruction or newly constructed (0.05) and those that are planned or proposed (0.06; Figure 1 with locality names in gray). These ratios, reflecting the proportion of positive mentions among all non-neutral mentions, suggest that active facilities gain public support through city-led campaigns framing them as community-focused and environmentally friendly, increasing awareness and acceptance. Kraków stands out with a ratio of 0.68, attributed to initiatives like its "Bee Day"(Kraków, 2020). This annual event at the city's incinerator invites residents to explore the plant, learn how waste is converted into energy, and to enjoy activities like honey tastings from the plant's beehives, or beekeeper demonstrations. While these initiatives aim to build trust, critics argue the *Ekospalarnia* label amounts to greenwashing, obscuring environmental issues tied to incineration. However, despite these efforts, negative sentiment still dominates in most localities, calling into question claims by pro-incineration advocates, including Wielgosiński (2023), that existing plants enjoy broad public acceptance.

Positive sentiment ratios were lowest in Bielawa (0.01), Nowy Sącz (0.02), and Ostrołęka (0.02), where Polish private or partially state-owned companies led incinerator projects. Examples indicate that proposed initiatives are most negatively perceived when located close to densely populated areas, undertaken by companies with negative reputations (Biały, 2022), or associated with specific waste perceived as hazardous: "Even young people … say they will leave after hearing about the hazardous waste incinerator […] People will get sick" (Anonymous, 2023). Many online users advocate for waste management to be handled by local governments rather than outsourced to private businesses.

The analysis of WtE-related online mentions reveals predominantly negative public sentiment, especially in areas with planned facilities. This skepticism bolsters anti-incineration campaigns, embedding opposition in public discourse. Sentiment peaks during key moments, such as funding announcements and local referendums, highlighting grassroots activists' role in amplifying resistance. Additionally, urban areas, with their high solid waste production and energy needs, emerge as focal points for public discourse, where protest narratives gain traction, intensifying public distrust toward waste incinerators.

Key netizens with discursive power

A total of 28,211 online profiles contributed to 67,079 incineration-related mentions (accounting for 56.3% overall), although this figure includes duplicate accounts across platforms like X and Facebook. Table 1 ranks user accounts by estimated online reach, calculated by the SMLP, to identify key opinion leaders shaping WtE-related narratives (see Appendix). Online reach represents the total number of times a specific account's content could be displayed to users, including repeated views. Higher reach indicates greater visibility and influence. This "discursive power" reflects the ability of these actors to steer conversations, frame issues, and amplify specific perspectives in digital discourse.

Among the top 25 most influential accounts, the most common type is news media, including 5 national and 3 local outlets (Table 1). News media are expected to play a pivotal role in shaping public opinion by providing balanced and impartial coverage rather than endorsing one side of a contentious issue. However, this is not always the case. For example, the Media Ethics Council, a voluntary advisory body without legal authority, reported that a newspaper failed to label an article as sponsored content despite it being funded by a party advocating its interests in the waste incinerator debate. This omission led to accusations of covert advertising (Rada Etyki Mediów, 2022).

Politicians dominate the ranking, driving WtE discussions through their large follower bases, ranging from the hundreds of thousands to millions. National-level politicians, such as Actor 1, nicknamed the "Twitter king," actively but neutrally engage in such discourses (Kondzińska, 2017). For instance, they frequently share updates on the expansion of WtE facilities in Poland, highlighting operational plants, upcoming projects, and the share of municipal waste processed through thermal treatment with energy recovery, contributing to fact-based content on waste management.

Mayors of large cities also feature among the most influential profiles. Despite posting infrequently, their substantial follower counts help sustain their reach in pro-incineration debates. For example, the head of one city ranks 3rd and 8th, while the leaders of two other cities hold 11th and 22nd positions (Table 1). The

mayor leading Warsaw as a member of the Union of Polish Metropolises and C40 Cities, advocates for WtE practices, stating: "With the Targówek incinerator expansion, we can dispose of 30% of Warsaw's waste and generate 1/4 of municipal energy without harmful fossil fuels. We are addressing the energy crisis and building an eco-friendly waste management system" (Trzaskowski, 2022).

Rank	Dom-ain	Coded authors	Description	State-ments	Reactions / likes	Shares /retweets	Com-ments	Fans/ followers
1	X	Actor 1	politician, former Sejm member	52	303	64	13	183,720
2	X	Media 1	nationwide TV news channel	3	25	3	3	1,929,843
3	FB	Actor 2	mayor of a major Polish city since 2018	8	6,173	343	292	747,533
4	FB	Collective 1	at least a 772-day WtE protest group (as of June 30, 2023)	939	25,914	10,006	2,967	3,148
5	X	Gov 1	official profile of a major Polish city	9	203	34	0	314,537
6	X	Media 2	nationwide daily newspaper	3	21	5	0	881,902
7	FB	Collective 2	at least a 1,217-day WtE protest group (as of June 30, 2023)	637	6,083	2,512	886	983
8	X	Actor 2	mayor of a major Polish city since 2018	2	421	42	0	751,829
9	FB	Actor 3	famous Polish traveler's grandson	106	5,620	358	260	15,824
10	FB	Media 3	news portal of mid-sized Polish city	64	2,048	319	1,036	81,096
11	FB	Actor 4	mayor of mid-sized city since 2018	55	929	823	350	7,810
12	X	Media 4	nationwide TV news channel	1	4	3	0	734,292
13	X	Media 5	news portal of a major Polish city	2	4	0	0	332,025
14	FB	Collective 3	at least a 919-day WtE protest group (as of June 30, 2023)	288	3,790	2,515	441	1,365
15	FB	Media 6	city news portal of mid-sized Polish city	36	1,453	226	877	75,978
16	X	Actor 5	TV / radio presenter	1	33	2	0	601,853
17	web	Actor 6	unknown	238	0	0	0	nd
18	X	Media 7	nationwide daily newspaper	8	4	2	0	85,491
19	X	Media 8	nationwide news portal	3	11	0	0	220,562
20	FB	Collective 4	at least a 458-day WtE protest group (as of June 30, 2023)	179	2,210	2,635	389	1,913
21	FB	NGO 1	national environ-mental NGO	132	2,049	1,490	369	3,373

22	FB	Actor 7	mayor of a major Polish city since 2019	13	1,641	70	77	140,696
23	FB	Actor 8	environmental activist, blogger	45	859	681	82	17,261
24	FB	Gov 2	official profile of a major Polish city	12	1,112	91	37	362,886
25	FB	Media 9	web radio	1	878	56	79	139,089

Table 1: Leaders of Polish-language waste incinerator online discourses (March 1, 2020–June 30, 2023); calculations based on Sentione's reach estimation algorithms

Official city accounts also promote WtE initiatives (5th and 24th place), with municipal companies like the Clean Energy Port in Gdańsk maintaining an online presence. In contrast, pro-incineration influencers are notably absent among waste, energy, or cement industry entrepreneurs. The Polish Waste-to-Energy Plant Operators Association, founded in 2015 and a CEWEP member since 2017, makes only limited public posts, likely focusing their lobbying efforts behind the scenes.

Collectives formed specifically in response to the development of certain incineration facilities, primarily composed of residents living near these project sites, have proven to be significant influencers in the digital sphere. For instance, anti-incineration grassroots groups such as Collective 1 (ranked 4th), Collective 2 (7th), Collective 3 (14th), and Collective 4 (20th) emerged as prominent voices shaping the discourse around WtE projects (Table 1), often mobilizing in direct opposition to nearby proposed or operational plants. These communities mobilizing against incinerators have achieved a strong discursive position despite establishing their online presence only during the review period, unlike long-standing accounts of politicians and mainstream news outlets. The most active collectives regularly posted updates on WtE projects, administrative decisions, and protests, generating substantial engagement through likes, comments, and shares. This high level of interaction broadens their visibility, and bolsters credibility within wider networks. United by shared concerns rather than traditional divisions like class or age, these grassroots groups form a cohesive protest identity.

Beyond SMA-powered results, a targeted review of key social media accounts reveals that grassroots actors can effectively use their online presence to pressure national institutions and gain political leverage over time. For example, Collective 1—comprised primarily of local residents—achieved nationwide impact more than a year after the conflict with the WtE investor began (STOP wrocławskiej spalarni, 2021e). In January 2023, a delegation of protesters, including members from Collective 1, presented allegations of EU law violations by Poland's Ministry of Climate and Environment, the National Fund for Environmental Protection and Water Management, and related corporations during a meeting with representatives of the European Commission's Directorate General for the Environment in Warsaw. Earlier, in November 2022, a Polish Greens MP convened a Parliamentary Team for Environment, Energy, and Climate meeting in response to local city protests. These actions exemplify how grassroots collectives can secure formal recognition and actively engage with governmental bodies, demonstrating the gradual but impactful nature of their activism. While national parliamentarians occasionally lend support, local politicians have played a more consistent and active role in addressing these groups' demands (EJatlas, 2022b).

Grassroots actors, initially marginalized, utilize online tools to challenge institutional hierarchies and shape decision-making processes. As their influence grows, the WtE lobby escalates efforts to discredit them, further highlighting the contentious power dynamics at play. The director of a Polish incinerator engaged in discussions on the protesters' social media profile, accusing Collective 1 leaders of spreading misinformation.

Meanwhile, an incinerator investor-sponsored article described protesters as "thieves of future generations' opportunities" (STOP wrocławskiej spalarni, 2022d; 2022f). Pro-incineration groups also target national environmental NGOs that support grassroots collectives. One such organization, coded NGO 1, is a member of Zero Waste Europe and administers the "SpalarNIE! ZTPO Watch" Facebook group, which has monitored Polish WtE projects since 2018. Ranked 21st among opinion leaders (Table 1), this society's influence has drawn significant attention from the WtE lobby, which sought to criminalize its actions. In September 2022, a company filed a lawsuit against NGO 1, seeking nearly US$65,000 in damages for its opposition to an incinerator project in Oświęcim. The case represents one of Poland's first instances of a Strategic Lawsuit Against Public Participation (SLAPP), a legal tactic often used to intimidate and silence public opposition to controversial developments (STOP wrocławskiej spalarni, 2022e).

The analysis shows that national politicians and mainstream media profiles exert considerable influence in online WtE debates. However, grassroots collectives opposing site-specific projects have effectively challenged this dominance. They have gained national lawmakers' attention and presented cases at the EU level. In response, the pro-incineration lobby has intensified efforts to counter them, employing tactics ranging from social media rebuttals to legal actions to suppress dissent.

Discursive themes of anti-incineration grassroots groups

The four main anti-incineration grassroots groups share common themes, particularly in their frequent use of the term *mieszkańcy* [residents]. This term appears 370 times in 1,793 posts/comments, 275 occurrences in 792, 136 in 374, and 184 in 463, respectively (Figure 2).

Figure 2: Words commonly associated with waste incinerators in the online discourse of anti-WtE grassroots groups (March 1, 2020–June 30, 2023); calculations represent the total occurrences of each term, including repeats within online mentions, and are based solely on Facebook accounts

Groups voice concerns about WtE impact on their communities. They emphasize the preventive stage of mobilization with terms like *budowy* (construction) and *planuje* (plan), while also mentioning *miasto* (city) due to the urban focus of contested projects. Specific locations, such as Wisznia Mała, are often cited as focal points of opposition, underscoring the localized nature of WtE developments (Figure 2, Collective 1). At the same time, protesters also recognize the broader environmental impact, especially air pollution affecting areas within a 20–30 km radius (STOP wrocławskiej spalarni, 2021c). This dual focus on particular sites and wider regions highlights the multifaceted concerns driving their resistance.

Protesters highlight negligence by directly naming pro-incineration politicians and investors in their online protests. Collective 1, for example, frequently mentions the Finnish company Fortum (406 times in 1,793 posts/comments), accusing it of profiting from Russian operations and indirectly supporting the Putin regime (STOP wrocławskiej spalarni, 2022c). Additionally, Collective 4 claims that the city president signed a letter of intent allowing the private chemical company Ciech Soda Polska to build an incinerator without consulting residents, a decision that fueled local outrage. Reflecting this tension, the anti-incineration leader withdrew from his nomination in the Social and Charitable Activity category of the Polska Press Person of the Year 2022 competition, where he was recognized for his opposition to the incinerator. His resignation was a direct protest against the nomination of Ciech Soda Polska's president in the Business category, despite allegations that the company had violated pollution standards and endangered residents' health (NIE dla spalarni w Inowrocławiu, 2022c; 2023).

Each grassroots group actively challenges the myth of emission-free waste incineration. Collective 2 (288 times in 792 posts/comments) and Collective 1 (317 times in 1,793 posts/comments) frequently address emissions. Collective 1 critiques pro-incineration campaigns, emphasizing the significant CO_2 emissions and their contribution to the climate crisis (STOP wrocławskiej spalarni 2022a). Collective 2 also highlights the issue sarcastically: "Dioxin levels are monitored twice a year in Polish incinerators… by a company selected by the incinerator itself. Doesn't that sound objective?" (STOP spalarni śmieci w Bielsko-Białej 2021). Additionally, Collective 4 reports that incinerators can emit up to 45% more pollutants by weight than the waste they incinerate (NIE dla spalarni w Inowrocławiu 2022b).

The narratives of Collective 1 and Collective 2 are strongly tied to EU-related topics, with frequent mentions of *europejskiej*/*europejska* [European] (314 and 148 occurrences, respectively). Collective 1 highlights that EU Directive 2020/852 classifies incinerators as unsustainable, restricting funding (STOP wrocławskiej spalarni, 2022d). Both groups argue that expanding incinerator infrastructure threatens EU recycling targets (60% by 2030, 65% by 2035). Collective 2 also focuses on *ceny* (prices) and *opłatach* (fees) (256 and 212 times in 792 posts/comments), warning that EU Emissions Trading Scheme fees could triple incineration costs by 2028, burdening residents (STOP spalarni śmieci w Bielsko-Białej, 2023).

Collectives often frame incinerators within an environmental context, with the term *środowiska* appearing 338 times in 1,793 posts/comments for Collective 1 and 49 times in 463 posts/comments for Collective 4, respectively. Residents express concerns about such impacts, frequently citing a Wrocław University report detailing risks like groundwater depletion and harm to protected species (STOP wrocławskiej spalarni, 2021b). These worries underscore incinerators' broader environmental dangers.

Collectives raise site-specific concerns about contested projects. For instance, Collective 4 appears to have arisen in direct response to plans for a WtE facility in a spa town, frequently using the term *uzdrowiskowego* (spa) (109 occurrences in 463 posts/comments, Figure 2) to argue that such a facility causes more harm than benefits. It emphasizes the potential economic and social consequences, claiming that guesthouses near brine graduation towers face declining tourism and possible business failures (NIE dla spalarni w Inowrocławiu, 2022a). This collective also highlights health risks, using the term *zdrowia* (health) 61 times. By contrast, Collective 1 does not focus as strongly on this issue, although it remains a central argument, citing research linking incinerators to risks such as prematurity, birth defects, and respiratory diseases (STOP wrocławskiej spalarni, 2021a). However, Vinti *et al.* (2021) note that most studies lack sufficient data to confirm this link, particularly for newer technologies, highlighting the need for cautious interpretation of such claims.

Groups advocate for WtE alternatives by emphasizing the Waste Management Hierarchy, which prioritizes waste prevention, reuse, and recycling. Collective 2 proposes managing 30–40% of total waste by

building a biogas plant to generate heat and electricity. This community emphasizes bio-waste, mentioning it 129 times in 792 posts/comments and frequently cites Ljubljana's zero-waste initiatives as a model, which includes apps for ordering specialized waste collection, separation baskets, reuse centers, or repair cafés (STOP spalarni śmieci w Bielsko-Białej, 2022).

Four protest collectives rarely use terms like "justice" or "injustice," which appear 129 and 13 times, respectively, across 3,422 statements. These terms mainly appear in organizational names, such as the Ministry of Justice, or unrelated contexts, like when Varsovians deemed the water-based waste collection fee (Nov 2020–Dec 2021) unjust. An exception occurred in June 2022 when Collective 1, for the first time since the conflict began, referred to the WtE investor's debate as "just." Moreover, "environmental justice" is never explicitly mentioned, likely reflecting the lack of its framing in Polish WtE resistance.

In summary, the analysis of anti-incineration collectives' narratives highlights how residents mobilize digitally against WtE projects, emphasizing community health, ecological, and economic impacts. They often accuse corporations and politicians of negligence or profiteering while referencing EU policies and financial implications, demonstrating how broader regulations shape local activism.

5. Discussion

By analyzing Polish WtE online narratives from March 1, 2020, to June 30, 2023, this research highlights the utility of social media analytics (SMA) in political ecology as a compelling methodological approach.

Unveiling the empirical findings from an SMA-driven case study

The case study sheds light on the interactions between grassroots activism, public sentiment, and institutional narratives in the digital sphere. These findings align with the research questions outlined in the methodology section: identifying patterns of perception (RQ1), revealing power dynamics among digital actors (RQ2), and uncovering the discursive themes of grassroots resistance (RQ3):

1. Grassroots collective power (RQ2): The study, utilizing online reach estimation of accounts, highlights contrasting discursive power dynamics, showing that grassroots protest collectives—recently formed in response to WtE facility developments and primarily composed of local residents—have emerged as prominent participants in online incinerator-related narratives. Their digital visibility often rivals or surpasses that of established institutional actors, including national politicians, mayors, and news media (see the ranking of discursive leaders, Table 1). While well-resourced proponents, such as the mayor coded as Actor 1 (ranked 3rd with over 747,000 followers), leverage their long-established follower bases to become "incineration influencers," grassroots collectives have built their social media influence from the ground up. For example, Collective 1 (ranked 4th) produced nearly 1,000 high-quality posts, garnering over 25,000 reactions and 10,000 shares, demonstrating their ability to shape discourse effectively. These findings reveal that grassroots groups can gain significant influence in shaping WtE narratives, challenging institutional stakeholders in the digital sphere (RQ2).
2. Public sentiment and key moments (RQ1, RQ2): Public sentiment towards WtE projects is more negative than positive, intensifying after the late 2022 announcement of public funding for 39 new projects. This announcement sparked widespread distrust toward decision-makers and investors, prompting grassroots collectives to amplify these concerns on social media. By early 2023, positive mentions accounted for only 13% of non-neutral comments, reflecting widespread dissatisfaction that likely influenced the decision to hold the April 16 referendum in Bielsko-Biała. In the referendum, residents voted against a proposed incinerator, further demonstrating how shifting public sentiment can shape policy decisions. These trends highlight the temporal dynamics of public perception (RQ1) and illustrate how grassroots actors leverage key moments to challenge institutional power (RQ2).

3. Localized concerns (RQ1, RQ3): Geoparsing and sentiment analysis of online 'mentions' reveal that discussions about WtE projects are concentrated in populous cities with high waste production and areas transitioning from non-renewable energy. Positive perceptions are more prevalent for operational incinerators compared to those under construction or in the planning stages. However, negative views dominate overall, particularly in regions linked to poorly reputed investors or hazardous waste issues, illustrating localized patterns of perception (RQ1). Moreover, frequency analysis of keywords shows that the discursive themes focus on community priorities, environmental risks, and economic impacts, with the term "residents" frequently emphasized to highlight the localized nature of their mobilization (Figure 2). Critiques of incineration's sustainability often reference EU policies, such as Directive 2020/852, and advocate alternatives like biogas plants. Grassroots narratives also name specific corporations and politicians, framing their resistance within broader environmental and social contexts. This opposition, centered on health risks, ecological harm, and investor accountability, aligns with broader PE concerns about the struggles of marginalized communities (RQ3).

These insights highlight SMA's potential to unravel complex digital power dynamics. The next subsection explores its methodological contributions for political ecology.

Shaping the contributions and future research direction of SMA in political ecology

Traditional qualitative and quantitative methods in PE often grapple with challenges such as reliance on static datasets—data fixed at a specific point in time that fail to capture ongoing changes or evolving trends. These approaches are also susceptible to researcher bias, and they struggle to adequately handle diverse online data sources. In contrast, SMA offers a dynamic, big-data-driven solution to these limitations. For instance, by analyzing approximately 120,000 Polish online mentions related to WtE facilities, SMA demonstrates its ability to efficiently process large, heterogeneous data sources from the internet while minimizing subjectivity. Moreover, the Polish case shows that leveraging a leading social media listening platform (SMLP) allows SMA to rapidly and systematically analyze extensive textual datasets, offering time-saving tools that are particularly beneficial for resource-limited researchers.

From my perspective, SMA inspires and opens new avenues into digitally visible environmental conflicts and beyond. The Polish case provides an example of this potential, revealing an intriguing insight: newly formed, locally rooted protest groups—composed largely of residents with limited prior organizational experience—have become key players wielding discursive power in WtE online narratives. This raises a compelling question: Why are grassroots groups emerging as such visible and influential forces in shaping the WtE discourse in the competitive digital sphere?

Addressing this issue requires analyzing variables that explain the prominence of such groups. SMA partially facilitates this by enabling statistical analysis. In such research, the unit of analysis should consist of individual online mentions (e.g., posts). In this context, the dependent variable represents the visibility and resonance of online mentions, operationalized as engagement metrics. This includes data on likes, shares, and comments. Higher engagement indicates greater visibility and influence, providing a measurable way to assess the prominence of grassroots narratives.

The selection of independent variables, such as timestamps, sentiment, and themes/topics, is grounded in logical reasoning and findings gained from the Polish study. Timestamps provide insight into the temporal dynamics of online activity, linking peaks in engagement with external events. Sentiment measures the emotional tone of mentions, shedding light on the audience's reactions. Finally, themes uncover the broader narratives present in the discourse, highlighting how grassroots groups frame their messages.

The Polish case methodology emphasizes SMLPs, applicable to collecting selected variables. Engagement metrics are automatically during data scraping, requiring no adjustments. Timestamps are recorded for each mention, allowing researchers to identify periods of heightened activity and to correlate them with external events. For sentiment analysis, a simplified PANAS scale (neutral, positive, negative; see Appendix)

can be employed. Some SMLPs, like Sentione, provide numerical sentiment values (-10 to +10) for precise emotional tone measurement, though this was not used in the Polish case, it has potential for future studies. Furthermore, advanced computational methods (Wankhade *et al.*, 2022) could capture a broader range of emotions —including joy, anger, and fear—offering deeper insights into emotional dynamics but require expertise and resources beyond SMLPs.

Themes or topics can be identified in mentions using various methods, including modern NLP techniques (Abram *et al.*, 2020). However, the Polish case presents a contrast, as it employed a simpler tagging approach. For example, geotagging relied on a "bag of words" containing place names associated with WtE projects (see Appendix). This approach could be expanded by developing keyword sets aligned with PE-grounded categories, such as forms of mobilization—protests, legal actions, and artistic events—drawing on methodologies like those in EJAtlas (Appendix A in Scheidel *et al.*, 2020). Similarly, frameworks like the fourth dimension of environmental justice (Herrero & Vilella, 2018) may provide structure for tagging systems to uncover broader patterns. Moreover, keyword frequency analysis in the Polish case (Appendix) counts term occurrences across all mentions. However, this approach does not strictly align with the conventional definition of tagging, which typically involves assigning predefined labels to specific content. Instead, it processes entire textual mentions, excluding stopwords.

The section above omits the statistical analysis of variables, leaving it for future research. Nevertheless, SMA offers a powerful framework for studying environmental conflicts and other phenomena observable online.

Navigating the challenges for SMA-driven PE research

Applying SMA in PE faces challenges due to the nature of online data sources, particularly centralized and increasingly regulated social media platforms. Additional constraints stem from social media listening platforms (SMLPs) designed for data collection and analysis. These challenges are further amplified by regulations like the EU GDPR, which protect user privacy and apply to the Polish case study.

In addition, SMA incurs environmental costs. These systems consume large amounts of non-renewable energy, require water for server cooling, and contribute to pollution and extractivist practices (see Nost & Colven, 2022; Nost & Goldstein, 2022; Strubell *et al.*, 2020). These impacts are especially significant in PE, which often focuses on sustainability.

Data collection for SMA-driven research is constrained by technical and regulatory factors. In this study, the gathering of online mentions (e.g., posts) was limited to March 2020–June 2023 due to SMLP restrictions on historical exports, hindering long-term trend analysis.

Data accessibility in the Polish study was further restricted by API limitations, which regulate how external tools, such as SMLPs, interact with online sources, including social media platforms (Sentione, n.d.). For instance, in 2023, X disabled the sharing of retweets with the chosen SMLP. Also, access to public Facebook groups, including those managed by grassroots opponents of WtE projects, was unavailable. However, this limitation was minor, as these collectives, while primarily active on Facebook, communicated mainly through fan pages, which were accessible via SMLPs.

Creating search queries for data gathering is challenging. While hashtags typically simplify this process, they are often underused by certain groups, such as Polish grassroots collectives opposing WtE projects. To address this, Boolean keyword-based queries were employed (see Appendix), requiring a nuanced understanding of linguistic practices and the Polish-specific context to capture relevant content. This process can be fairly time-consuming and necessitates the integration of qualitative methods, such as interviews and reviews of online accounts, to enhance query design.

All captured online mentions—regardless of their source—were included in the research without assessing their credibility, leaving mentions potentially generated by trolls or bots unfiltered. This approach follows Mocek (2021), which also did not address online data reliability.

The geographical context of online mentions can significantly shape the dataset. Factors such as the level of internet penetration, state-imposed censorship, and platform accessibility may affect the volume and nature

of online discourse in different regions. Additionally, online mentions do not necessarily reflect the demographic structure of a given area, as digital participation is often skewed by socioeconomic status, generational divides, and varying levels of digital literacy (Bhatt & Pickering, 2021). Consequently, these limitations should be considered when further analyzing the data.

Data analysis in SMA often uses commercial SMLPs, which are user-friendly, cost-effective, and provide access to technical support. However, their proprietary algorithms limit transparency, undermining research robustness (Hayes *et al.*, 2020). For instance, the SMLP used in the Polish study ranks accounts based on the online reach of WtE content, using metrics such as shares, likes, and follower counts—proxies for assessing visibility and influence. However, reach *per se*, meaning the total potential impressions generated by specific content from each account, was not disclosed, complicating the assessment of influence levels. As an alternative, the SMLP's "Influence Score" assigns each profile a single number (from 1 to 10) to represent its influence (Sentione, n.d.). However, because it provides only one value at a time, it does not show how influence changes over time, making it harder to analyze trends or fluctuations.

SMA-powered sentiment analysis of mentions has limitations. While SMLPs assess the overall sentiment of texts, they often overlook nuanced or mixed sentiments within them. In the Polish case, the general tone did not always reflect sentiment towards a specific WtE project but instead referred to other entities, such as individuals mentioned. This analysis also struggles with ambiguity, sarcasm, and profanity, frequently misclassifying such content as neutral. Moreover, some SMLPs are unable to analyze sentiment in web portal articles, further limiting the depth of insights.

Frequency analysis of keywords encounters challenges. Lemmatization, which reduces words to their base form, improved consistency in analyzing single-word occurrences (see Appendix). However, the SMLP used in this research does not support multi-word expression analysis, limiting the identification of meaningful phrases. Additionally, it counts the total occurrences of terms across mentions, including repeated instances within individual posts. While highlighting frequent terms, this approach also amplifies keywords from repetitive content. These limitations necessitated cautious interpretation.

Geoparsing mentions in the Polish study (Appendix) face accuracy challenges. Unclear place references, such as non-unique names that exist in multiple locations, often result in errors. Moreover, linguistic variations, like inflections and abbreviations, complicate analysis, especially in informal social media. While manual corrections improve precision, they are time-consuming. Machine learning enhances disambiguation (Middleton *et al.*, 2018) but increases computational demands, leading to higher environmental costs. This necessitates alternatives to traditional SMLPs like hybrid human-AI approaches.

6. Conclusion

This article highlights the potential of social media analytics (SMA)—an interdisciplinary field focused on collecting and analyzing digital content—for advancing political ecology. Traditional methods are often limited by reliance on static datasets, susceptibility to researcher subjectivity, and challenges in analyzing diverse online data sources. In contrast, SMA offers a dynamic approach that largely mitigates these constraints by processing large-scale, heterogeneous datasets with minimal bias. Moreover, by integrating big-data-driven methods—such as sentiment analysis, geoparsing of online mentions, keyword frequency analysis, and reach estimation—SMA provides a structured framework for studying the digital sphere, paving the way for more pluralistic PE research.

The Polish case study highlights the value of SMA as a research approach, offering a unique capacity to analyze the entire digital sphere rather than focusing solely on selected online sources like X, which often fail to capture the full breadth of virtual interactions. This capability is crucial for understanding complex phenomena such as digitally visible environmental conflicts. By analyzing nearly 120,000 online mentions, SMA ranked accounts based on the reach of incinerator-related content in Poland. The findings reveal the substantial influence of site-specific grassroots collectives opposing proposed WtE facilities, whose voices of dissent gained discursive power through social media. This demonstrates that SMA helps illuminate the critical role of bottom-up resistance within broader Polish WtE narratives by providing quantitative evidence. At the same time, SMA accounts for other digital actors, such as municipal authorities promoting pro-incineration

narratives in Poland, illustrating the dual-sided interplay of power and opposition. These findings open new research avenues, such as examining the mechanisms behind grassroots groups' unexpectedly strong prominence in framing WtE narratives within the highly competitive online space.

One of SMA's key strengths lies in its ability to conduct dynamic, real-time analysis, offering an advantage over static datasets like the EJAtlas. In the Polish case, this potential was only partially realized, as SMA identified sentiment fluctuations during key moments, such as funding announcements for WtE proposals. However, it lacked a comprehensive temporal framework to systematically track incinerator-related online mentions along a timeline. Nevertheless, this capability allows researchers to monitor how narratives develop, gain traction, or fade—not only in response to external events but also due to internal dynamics within digital discourse, such as shifts in grassroots mobilization.

Despite its potential, SMA faces several challenges. In the Polish case, API policies on social media platforms like X restricted access to historical data, limiting the collection of online mentions to those after March 2020. Likewise, the inability to access private or public Facebook groups—key communication channels for some grassroots anti-WtE collectives—hindered insights into community-driven mobilization. Beyond data collection, challenges also arise in data analysis. The reliance on proprietary algorithms in social media listening platforms (SMLPs) raises concerns about transparency. Metrics such as online reach, which depend on undisclosed formulas incorporating likes, shares, and follower counts, complicate the evaluation of actors' relative influence. These examples illustrate some of the key obstacles but are far from exhaustive, underscoring the broader methodological and technical limitations inherent in SMA.

Integrating SMA-powered techniques with qualitative methods can help address some obstacles by validating findings and uncovering nuanced perspectives. However, to fully align SMA with the principles of sustainability and ethics central to PE, its limitations and reliance on technology-centric approaches must also be critically examined. Following Almazán and Prádanos (2024), political ecologists should challenge the techno-optimism embedded in mainstream technologies like commercial SMLPs and advocate for non-commercial alternatives tailored to the needs of PE research. Such tools could incorporate decentralized networks like Mastodon, which prioritize user control and community governance, thereby diversifying the data framework and reducing reliance on centralized platforms like X. Collaboratively developed by academics, practitioners, and communities (as highlighted by Chapman *et al.*, 2024) and guided by ethical principles (Van Wynsberghe, 2021), these tools could enhance transparency, embrace degrowth practices, and embody the "humble techniques" championed by Almazán (2024).

By underscoring methodological implications, identifying challenges, and briefly outlining the potential mitigation strategies while charting new research paths, this article contributes to a more nuanced understanding of how SMA can support political ecology research.

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Appendix: Detailed Methodology

1. Research Questions

To guide the study, three exploratory research questions were formulated:

1. Q1: What patterns of online perception emerge around waste incinerators, and how are they geographically distributed?
2. Q2: Which digital actors hold the most influence in shaping waste incinerator narratives, and how does this reflect power dynamics?
3. Q3: What discursive themes characterize anti-incineration grassroots groups in relation to WtE projects?

The study uses SMA techniques and qualitative methods. In this Appendix, the following description focuses on SMA techniques applied to online mentions about WtE facilities, while qualitative methods, along with challenges and attempts to minimize them, are discussed in more detail in the main text of the article. The description is presented step-by-step and corresponds to Figure 3, which illustrates the research procedure diagrammatically.

2. Data Collection

2.1 Social Media Listening Platform and Timeframe

Social Media Listening Platforms (SMLPs) have become essential tools for capturing and analyzing online content. They support research and decision-making by enabling advanced analysis of vast digital datasets (Hayes *et al.* 2020).

This study utilized SentiOne, a leading SMLP developed by a Polish company. This platform aggregates publicly available online content globally, sourcing data from over 5 million websites, blogs, forums, review sites, and social media platforms. It complies with EU regulations, ensuring ethical and legal standards. Notable features of the chosen platform include:

- Support for 70+ languages, including highly inflected languages like Polish, which enhances its utility for localized studies (Bányász *et al.* 2022).
- Extensive adoption in Eastern Europe: Although underutilized in political ecology, researchers have employed this platform to topics such as public discourse analysis (Barna & Knap 2021).

Polish-language online mentions were collected for this analysis, reflecting the localized nature of debates about WtE projects and enabling the exploration of geographically specific narratives. Due to the SMLP's export limit of 39 months, data from March 1, 2020, to June 30, 2023, were selected.

Although this study relied exclusively on SentiOne, other well-known SMLPs include Brandwatch, Talkwalker, Meltwater, NetBase Quid, and Sprout Social, which demonstrate the versatility of tools available for analyzing online discourse.

2.2 Definition of Online Mentions

Online mentions were defined as any digital instance where keywords or phrases related to WtE developments appeared. These mentions were categorized into:

1. Articles: News reports or blog entries.
2. Posts: Social media posts from platforms like Facebook, X, or forums.
3. Comments: User responses under articles, posts, or forums.
4. Reviews: User-generated reviews on platforms hosting opinions about WtE projects.

2.3 Search Queries

2.3.1 Boolean Search

Boolean search is a method that uses logical operators (e.g., AND, OR, NOT) to structure queries and filter data precisely. In this study, Boolean queries were applied to identify mentions related to WtE projects, combining keywords, phrases, and special characters.

Logical Operators

1. AND: Ensures all specified terms appear.
    - Example: waste AND incinerator retrieves mentions containing both terms.
2. OR: Includes mentions with at least one term.
    - Example: waste incinerator OR garbage incinerator retrieves mentions containing either or both terms.
3. NOT: Excludes mentions with specified terms.
    - Example: incinerator NOT crematorium filters out crematorium-related results.

Special Characters

1. Wildcard (*): Represents any number of characters, e.g., *instalacj** matches *instalacja* (installation in singular form) and *instalacje* (installations in plural form), capturing word variations.

2. Single-Character Wildcard (?): Represents one character, e.g., *paliw?* matches *paliwo* (fuel in singular form) and *paliwa* (fuels in plural form).
3. Quotation Marks (""): Used for exact phrase matches, ensuring the words appear in the specified order. For example, searching for *spalarnia odpadów* (waste incinerator) will return only results where both words appear together in that sequence.

2.3.2 Search setting

The chosen SMLP identifies mentions by using web crawlers, automated tools that systematically browse the internet to index content. This platform also recognizes the primary language of each mention, which is used for classification. However, this does not guarantee that the entire text of a mention is written in the identified language; parts of the content may include phrases or terms in other languages.

Search queries were configured to:

- Ensure all mentions are in Polish, aligning with the focus on localized discourse.
- Ignore diacritic marks, a crucial setting for Polish due to its frequent use of such marks. This ensures that mentions are included regardless of whether authors use diacritic marks correctly, omit them, or substitute them with other characters.

Each mention was included if the WtE-related terms appeared in:

- Content or Context: The mention's content itself or its parent post (e.g., a comment under an article) contained relevant search terms.
- Publisher Name: The name of the individual or entity who published the mention included the search terms (e.g., a user profile named 'John Doe Waste Incinerator Analyst').
- Profile Name: The profile name associated with the mention contained the search terms (e.g., an X handle like @WasteIncineratorNews).
- Title: The title of the mention contained the search terms (e.g., an article titled 'New Waste Incinerator Regulations Spark Debate').
- Domain Name: The internet domain where the mention was published included the search terms (e.g., a website like 'wasteincineratorsinfo.com').

2.3.3 Keyword-based rules

Keyword-based rules were developed to capture mentions of WtE projects, focusing on terms relevant to the types of facilities defined in The Polish Waste Act, 2012 (2013). The analysis covered two categories:

1. Waste Incinerators: Facilities that thermally process waste, with or without energy recovery, using methods such as gasification, pyrolysis, or anaerobic digestion.
2. Waste Co-incinerators: Facilities that generate energy or products by burning waste alongside fuel, typically in cement kilns or power plants.

These rules were refined through interviews with three experts, including a pro-incineration scientist, and a review of 26 Facebook pages representing site-specific anti-incineration protest collectives in Poland. This process ensured the inclusion of both informal and formal terms. Keywords were selected to reflect both:

- Formal terminology: Found in official statements and scientific publications (e.g., "thermal waste treatment plant").
- Informal language: Commonly used by residents and activists (e.g., "garbage incinerator").

To ensure relevance, all results had to meet at least one of the first three rules, which were structured using keywords, keyword groups, and proximity-based logic to capture mentions specifically related to WtE projects. Additionally, the fourth rule was applied to exclude irrelevant or metaphorical mentions, ensuring that the dataset remained focused on WtE-related content.

First Rule

This rule focused on mentions of WtE facilities identified by abbreviations or specific names, such as *"ZTPOK"* OR *"ZTPO"* OR *"ZUSOK"* OR *"ITPO" OR "ITPOK"* OR *"ITPOE"* OR *"EcoGenerator"*. These terms are commonly used to refer to specific installations or projects.

Second Rule

This rule required mentions to include at least one keyword from two separate groups, where the terms were connected by a maximum distance of one word. The search was confined to a specific area within each mention (e.g., the text of a post or article).

Keyword Groups

1. Facilities and Installations
    - Polish Keywords: *zakład** OR *instalacj** OR *wyposażeni** OR *stacj** OR *blok** OR *obiekt** OR *fabryk** OR *inwestycj** OR *przedsięwzię** OR *placówk**
    - English Translation: plant? OR installation? OR equipment? OR station? OR block? OR unit? OR factor* OR development? OR project? OR facility*
2. Thermal Waste Treatment and Related Processes
    - At least one keyword group from the following subcategories needed to be present:

a. Thermal Waste Treatment

- Polish Keywords: *"termicznego przekształcania śmieci"* OR *"termicznego przetwarzania śmieci"* OR *"termicznej obróbki śmieci"* OR *"termicznego unieszkodliwiania śmieci"* OR *"termicznej utylizacji śmieci"* OR *"unieszkodliwiania stałych śmieci"*
- English Translation: "thermal waste transformation" OR "thermal waste processing" OR "thermal waste treatment" OR "thermal waste disposal" OR "thermal waste neutralization" OR "solid waste disposal"

b. Combustion and Co-combustion

- Polish Keywords: *"spalania odpadów"* OR *"spalania RDF"* OR *"spalania plastik"* OR *"współspalania odpadów"* OR *"współspalania RDF"* OR *"współspalania tworzyw? sztuczn"* OR *"spalania paliw? alternatywn?"*
- English Translation: "waste combustion" OR "RDF combustion" OR "plastic combustion" OR "waste co-combustion" OR "RDF co-combustion" OR "synthetic material combustion" OR "alternative fuel combustion"

c. Gasification and Pyrolysis

- Polish Keywords: *"gazyfikacji odpadów"* OR *"pirolizy odpadów"* OR *"zgazowania plazmowego odpadów"* OR *"gazyfikacji plazmowej odpadów"* OR *"zgazowania odpadów z użyciem plazmy"*
- English Translation: "waste gasification" OR "waste pyrolysis" OR "plasma gasification waste" OR "plasma waste gasification" OR "waste gasification using plasma"

d. Energy and Heat Recovery

- Polish Keywords: *"odzysku energii"* OR *"termicznego przetwarzania z odzyskiem energii"* OR *"odzysku ciepła"* OR *"termicznego przekształcania z odzyskiem ciepła"*
- English Translation: "energy recovery" OR "thermal processing with energy recovery" OR "heat recovery" OR "thermal transformation with heat recovery"
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For example, mentions may include exact phrases such as:

- Polish: "*Zakład termicznego przekształcania śmieci*" OR "*Instalacja termicznej utylizacji odpadów*" OR "*Fabryka zgazowania odpadów*"

- English: "Plant for thermal waste transformation" OR "Installation for thermal waste disposal" OR "Factory for waste gasification"

Third Rule

This rule required mentions to include at least one keyword from two separate groups, where the terms were connected by a maximum distance of seven words. This broader proximity allowed for greater flexibility in identifying mentions.

Keyword Groups

1. Incinerators and Co-incinerators
    - Polish Keywords: *spalarni* OR *kotłowni* OR *cementowni* OR *elektrociepłowni* OR *ciepłowni* OR *współspalarni* OR *"eko?spalarni"* OR *"eko?współspalarni"* OR *"ZOE"*
    - English Translation: incinerator? OR boiler plant? OR cement plant? OR combined heat and power plant? OR heating plant? OR co-incinerator? OR "eco?incinerator?" OR "eco?co-incinerator?" OR "ZOE"
2. Waste and Alternative Fuels
    - Polish Keywords: *"RDF"* OR *"paliw? odpad"* OR *"pre?RDF"* OR *"SRF"* OR *"stał* paliw? wtórn"* OR *"paliw? alternatywn"* OR *"odpad"* OR *"śmieci"* OR *plastik* OR *"tworzyw? sztuczn"*
    - English Translation: "RDF?" OR refuse-derived fuel? OR "pre?RDF?" OR "SRF?" OR solid recovered fuel? OR alternative fuel? OR waste OR garbage OR plastic? OR synthetic material?

For example, mentions may include exact phrases such as:

- Polish: *Spalarnia odpadów* OR *Elektrociepłownia opalana paliwem alternatywnym*
- English: Waste incineration plant OR Combined heat and power plant fueled by alternative fuels

Fourth Rule

This rule excluded mentions containing terms irrelevant or metaphorical phrases to WtE projects by applying the NOT operator. Mentions were filtered out if they included words starting with:

- Irrelevant terms like *krematori** OR *zwłok** OR *ciał** OR *szczątk** (e.g., crematorium, human remains).
- Metaphorical phrases like *spalarnia pieniędzy* (money furnace).

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3. SMA techniques for Research Questions

3.1 Social Media Listening Platform and its AI-driven Tools

The analysis primarily relied on SentiOne, a proprietary SMLP, which was also used during the data collection phase. This intuitive software integrates human expertise with advanced Natural Language Processing (NLP) to provide in-depth insights into online discourse. By processing large volumes of text, the chosen SMLP facilitates tasks, enabling researchers to gain a nuanced understanding of digital narratives (Sik *et al*. 2023).

NLP, a branch of artificial intelligence (AI), enables machines to process and interpret human language. It analyzes syntax, semantics, and context to identify linguistic patterns, detect sentiment, and extract key entities like organizations. In this study, platform's NLP ensured accurate interpretation of Polish-language mentions, accounting for the complexity of inflected words and grammatical structures.

The platform's NLP capabilities are further enhanced by machine learning (ML), allowing it to refine its analytical precision over time. ML trains algorithms on large datasets to identify patterns, classify information, and minimize errors.

This combination of NLP and ML was instrumental in processing and analyzing the diverse datasets associated with WtE discussions. By leveraging these AI-driven tools, the chosen SMLP effectively supported geographically specific narratives, identified key actors, and examined the discursive themes of grassroots resistance with precision. These capabilities were central to addressing the study's research questions, ensuring accurate and relevant interpretations of the complex dynamics within online discussions.

3.2 Analytical methods for RQ1

3.2.1 Sentiment Analysis of Online Mentions

To address RQ1: Patterns of Online Perception, I utilized a sentiment analysis tool that combines machine learning techniques and lexicon-based classification to evaluate the emotional tone of textual mentions. The analysis was grounded in the 20-unit Positive and Negative Affect Schedule (PANAS) scale, developed by Crawford and Henry (2004), to categorize mentions as positive, neutral, or negative based on their affective tone.

The PANAS scale, originally designed as a self-report tool, measures two key dimensions of affect: Positive Affect (PA) and Negative Affect (NA). Each dimension consists of 10 descriptors (e.g., "enthusiastic" for PA and "upset" for NA). While traditionally used with a 5-point Likert scale, this framework was adapted for text-based analysis. The sentiment analysis tool mapped words and phrases from online mentions to these descriptors, identifying lexical markers indicative of positive or negative emotional states.

In this context, the sentiment analysis tool processed textual mentions to determine their alignment with PANAS-related emotional tones. Mentions dominated by terms such as "enthusiastic," "proud," or "alert" were classified as positive, reflecting PA. Conversely, mentions containing terms like "distressed," "angry," or "nervous" were classified as negative, reflecting NA. Neutral mentions exhibited minimal or balanced use of PA and NA-related terms. This allowed for a nuanced categorization of the sentiment conveyed in online mentions.

3.2.2 Geoparsing of Online Mentions

Geoparsing extracts, disambiguates, and assigns geographic coordinates to location names mentioned in text. By bridging natural language processing (NLP) and geographic information systems (GIS), it interprets place references, offering nuanced spatial insights into geographic patterns (Middleton *et al.* 2018). Unlike geolocation, which focuses on tracking devices or users, geoparsing transforms unstructured textual data into actionable geospatial information. This method is widely used in public discourse analysis to understand how locations are discussed and framed.

In this study, to further address RQ1: Patterns of Online Perception, geoparsing began with the identification of possible places associated with WtE facilities—whether existing, under construction, or proposed—sourced from:

- Facility records of WtE projects as of June 30, 2023.
- Grassroots social media pages maintained by anti-incineration protest groups.
- Government co-financing applications submitted to the National Fund for Environmental Protection and Water Management in 2022.

From these sources, nearly 100 localities or districts were identified. A custom gazetteer was created to enhance the geoparsing process. This database consolidated place names, linguistic variants, and geographic coordinates, serving as a reference for the two core stages of geoparsing: geotagging and geocoding.

1. Geotagging: Conducted on the selected SMLP, this process identified and marked place names mentioned in online content related to WtE projects (e.g., mentions of "waste incinerator" alongside locality names). Standardization accounted for linguistic variations, ensuring consistency. Place names were grouped to reduce redundancy by aggregating mentions referring to the same geographic area (e.g., a district within a specific city).
2. Geocoding: Using Google Earth Pro (open license), geographic coordinates were assigned to these grouped mentions, resolving ambiguities such as duplicate names. Manual corrections addressed remaining inconsistencies, enhancing data reliability. This process resulted in precise GPS coordinates for 74 localities.

The spatial distribution of Polish-language discourse on waste incinerators was visualized using a proportional symbol map in QGIS, an open-source GIS platform. Figure 1 displays the volume of online mentions for each locality, represented by proportional circles, while pie charts within the circles depict the sentiment distribution (positive, neutral, or negative) for each locality. Data points include cities and districts associated with waste incinerators or waste-fired CHP plants, categorized by their operational status (existing, under construction, or planned). The visualization highlights areas of concentrated discourse, where public sentiment and concerns are most prominent. This approach offers a clear and detailed representation of spatial and emotional patterns in public discussions on WtE facilities.

3.3 Analytical methods for RQ2

3.3.1 Reach Estimation of Content by Accounts

Online reach is the total number of potential impressions a piece of content could generate (Solis 2010). While reach is an important metric for understanding content visibility and popularity, it should not be mistaken for true audience size or engagement levels. Since the same user may encounter the content multiple times, reach alone does not provide an accurate measure of how many unique individuals have genuinely interacted with the message. To gain deeper insights, researchers often analyze reach alongside engagement metrics—such as likes, comments, shares, and click-through rates—to determine how effectively the content resonates with its audience. Additionally, factors like platform algorithms and user behavior can influence reach, making it essential to assess this metric in context rather than in isolation.

In this study, online reach refers to the total potential impressions generated by WtE content published by accounts. It is key to identifying and assessing the influence of digital actors—those shaping the incineration debates. High-reach contributors often shape public narratives, inform policy discussions, and influence societal attitudes toward waste incinerators.

To address RQ2: Influential Digital Actors, SMLP's reach estimation algorithms were used to analyze visibility and interaction metrics across various online sources. While the platform protects the exact code of its methods to maintain proprietary security and competitive advantage, it is known that these systems adapt their approach based on the specific medium of the content, ensuring accurate and comprehensive evaluations:

- Web Pages: Reach is estimated by integrating external domain traffic data with metrics such as unique visits, content type (e.g., article, comment), and update frequency. These factors determine the likelihood of audience exposure to web-based content.
- Internet Forums: A neural network model calculates reach based on thread activity and structure, including participation levels and engagement patterns within discussions.
- Social Media: Engagement metrics such as likes, shares, and follower counts are used to approximate the reach and influence of posts, reflecting their potential to spread and impact public discourse (Sentione n.d.).

By employing this multi-faceted algorithm, the chosen SMLP identified key contributors to WtE debates, as shown in Table 1, which lists the most influential authors, including accounts of politicians, journalists, media outlets, protest collectives, and organizations, along with their corresponding reach metrics. These authors were determined to play a pivotal role in shaping public opinion through their contributions. Importantly, the platform does not reveal the exact number of individuals who are estimated to have seen the content. Instead, it provides aggregated metrics, such as the number of shares, likes, and follower counts, which serve as proxies to estimate visibility and influence.

3.3.2 Targeted review of influential accounts

In addition to quantifying influence, a targeted review of WtE-related mentions from these key authors was conducted. This qualitative analysis aimed to uncover the underlying power dynamics within the debate, examining how these actors framed the discourse and their impact on public narratives. This dual analysis—quantitative reach estimation and qualitative content review—provides insights into power dynamics and information flows in WtE debates.

3.4. Analytical methods for RQ3

3.4.1 Frequency Analysis of Keywords

Frequency analysis of keywords is a research method used to quantify the occurrence of specific terms within a dataset, providing a systematic approach to identifying recurring themes in textual data such as social media posts and comments. While frequency analysis is instrumental in highlighting patterns in discourse, it serves as a foundational tool rather than a definitive method for identifying discursive themes. The identification of themes requires contextual interpretation of the topics and patterns uncovered by frequency counts. This combined approach enables researchers to evaluate discursive trends from large datasets, especially when manual analysis is impractical.

In this study, a frequency analysis of keywords was conducted to address RQ3: Discursive Themes of Anti-Incineration Grassroots Groups, to explore recurring themes in the online discourse of site-specific protest collectives. Themes in the text represent broad, conceptual ideas that frame the entire narrative of these groups. These are the overarching concerns, values, strategies or motivations that drive their online activism. The dataset consisted of posts and comments from the Facebook pages of four influential anti-WtE grassroots groups, identified using reach estimation algorithms from an earlier stage of the research.

To ensure the accuracy of the analysis, lemmatization was applied to consolidate grammatical variations of words into their root forms. This linguistic technique reduces inflected or derived word forms to a shared base, ensuring consistency in keyword frequency counts. For example, the Polish noun *spalarnia* (incinerator) was analyzed along with its inflected forms, such as *spalarni* (genitive and dative singular) and *spalarniach* (locative plural). This approach minimized distortions by grouping related forms under a single term.

Lemmatization in this analysis was further influenced by the capabilities of the chosen platform, which enables the generation of only 1-grams rather than 2-grams or higher-order n-grams. An n-gram is a sequence of *n* words appearing together in a text:

- A 1-gram (unigram) consists of single words, such as *spalarnia*.
- A 2-gram (bigram) consists of two consecutive words, such as *spalarnia odpadów* (*waste incinerator*).
- Higher-order n-grams include longer phrases, such as *spalarnia odpadów komunalnych* (*municipal waste incinerator*).

The study placed particular emphasis on terms with discursive significance, such as keywords related to "(in)justice," which facilitated an exploration of justice-related narratives in the resistance discourse, a key focus in political ecology. Tags were used on the chosen platform to label specific mentions, highlighting the relevance of justice as a key concept in political ecology and its role in framing resistance efforts.

To visualize the results, bar graphs were employed instead of traditional keyword clouds (Figure 2). While keyword clouds offer an aesthetically appealing summary by adjusting font size to reflect word prominence, bar graphs provided a more precise depiction of keyword occurrences, enabling quantitative comparisons across the four anti-WtE grassroots groups.

To enhance clarity, stopwords—common words that do not add meaningful information to the analysis, such as and, is, or the in English—were excluded from the graphs. In the context of Polish, this included terms like *i* (and). Additionally, generic terms with limited cognitive value in this study, such as installations or waste, were also excluded. Removing these words reduced noise in the dataset, ensuring the focus remained on more significant terms and improving the quality of subsequent linguistic analysis.

The visualizations, generated in Microsoft Excel using data extracted from SMLP, allowed for nuanced comparisons of discursive themes between the groups, providing greater insight into the differences in their narratives and focus areas.