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Cultivating Sustainable Communities: An Advanced Prediction Model for Assessing Environmental and Health Impacts in the Vicinity of Landfill Sites via Multiple Linear Regression and Spatial Web

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***Abstract*—The disposal of daily waste in landfills is the prevailing method of waste management today. Landfill sites are significant sources of pollution, affecting land, air, and water. Particularly detrimental are the impacts on individuals residing near these sites, with increased risks of adverse health effects such as low birth weight, birth defects, and certain cancers. This study aimed to develop a predictive model for assessing environmental and health impacts in communities neighboring 80 landfill sites across Ubon Ratchathani province, Thailand. Local government organizations supervise these sites in 21 districts. The study employed data-driven predictive methods to anticipate future scenarios, considering four key factors: Cleanliness Index (CI), Environmental Impact Index (I), Waste Production Rate at Any Time (Pw), and Sub-district Level Community Health Problems (HP). Relationships between these factors were analyzed using multiple linear regression with the "enter" method.**

Additionally, the study aimed to establish a spatial web platform for forecasting impacts and providing recommendations for effective implementation utilizing GIS software. Findings revealed positive associations between CI, Pw, and I with environmental and health impacts, while health problems (HP) at the sub-district level were negatively correlated. Although not statistically significant at the 0.05 significance level, these four variables are considered crucial factors influencing landfill site quality. Assessment of impact levels indicated that 63 sites experienced a high level (78.75%), while the remaining 17 sites (21.25%) had a medium level of impact. GIS-formatted maps were created to develop a geographic web application for predicting environmental and health consequences near landfill sites. This study offers valuable insights into factors influencing landfill site consequences, guiding mitigation efforts and policy decisions.

***Keywords*—prediction model, landfill Sites, environmental, multiple linear regression, spatial web**

I. INTRODUCTION

The global waste production rate is escalating annually. By 2022, solid waste reached around 2.24 billion tons, roughly 0.79 kilograms per person daily. With the population swiftly expanding and urban areas spreading, waste generation is predicted to surge by 37% from 2020 to 3.88 billion tonnes in 2050, with only about 329 million tonnes effectively managed [1]. Landfilling remains the predominant waste disposal method in numerous countries worldwide [2]. Landfills contribute to land, air, and water pollution, especially through heavy metal residues, posing risks to nearby residents [3]. Environmental pollution leads to both short-term and long-term health impacts [4]. In 2021, about 24.98 million tons of solid waste were generated, averaging around 68,434 tons daily, with a generation rate of 1.03 kilograms per person daily. Of this, 15.51 million tons (62%) were sent to landfill sites, while 9.28 million tons (37%) were properly managed, and 6.23 million tons (25%) were disposed of improperly [5]. Despite a rising trend in waste generation from 2011 to 2021, proper waste disposal declined during this period.

Regarding solid waste management in Thailand, 2,137 solid waste landfills were operating in 2021, with 2,050 managed by local governmental bodies. However, only 91 sites adhered to proper disposal practices, while 1,959 reported improper methods. Ubon Ratchathani Province hosts three well-performing waste disposal sites, with the majority managed by 192 local administrative organizations, most of which lack proper management within landfill sites. Additionally, in 2022, 80 solid waste landfill sites across 21 districts still needed to meet technical standards. Challenges in the management of solid waste landfill sites include: 1) Transferring solid waste to landfills; 2) Inefficient daily landfilling; 3) Failed leachate collection system; 4) No control over leachate from contaminated landfills Surface water sources; 5) Water from outside the system entering the landfill area; 6) Issue with monitoring groundwater quality; 7) Poor management of odor and insects; 8) Fires at the landfill sites. Groundwater quality analysis at eight observation sites revealed the presence of BOD, COD, and sulfite gas, impacting nearby residents with wastewater, foul odors, dust, and smoke [5]. This study aims to comprehensively investigate the characteristics of solid waste landfill sites in Ubon Ratchathani Province and formulate a predictive model for assessing environmental and health impacts on nearby communities. Additionally, it aims to develop a Spatial Decision Support System (SDSS) using Geographic Information Systems (GIS) to anticipate environmental and health implications around dump sites, incorporating data on environmental factors and health effects using Multi-Criteria Decision Analysis (MCDA) concepts and processes [6].

GIS plays a vital role in evaluating spatial groundwater potential, providing the ability to store, manipulate, and analyze diverse data formats and scales [7]. It enables the visualization of health-related information on maps, empowering health professionals and policymakers to recognize patterns, pinpoint hotspots, and make informed

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decisions [8]. Utilizing GIS-based multi-criteria decision analysis (MCDA) techniques is favored over other methods due to their effectiveness in integrating various spatial metrics, spatial analysis methodologies, and evaluation analyses [9].

Decision support systems (DSS) are increasingly utilized by decision-makers, particularly with the growing prevalence of web-based systems. It recognizes the clear benefits of web-based platforms, such as universal accessibility via the internet and freedom from the need for hard drive storage. This study developed a novel web-based decision support system. Its purpose is to aid decision-makers in selecting the most viable projects [10].

The WB-SDSS was developed using open-source software tools and source code, adhering to open geospatial consortium (OGC) standards to ensure interoperability of worldwide data and web services [11]. The primary objective of this study is to introduce a novel procedure integrated into the WB-SDSS. This procedure combines multiple data sources to create a system and provide information for disease surveillance, prevention, and control, specifically targeting individuals within a 1-km radius of landfill sites (per indicators set by the Department of Disease Control).

II. MATERIALS AND METHODS

A. Study Area

Ubon Ratchathani province, situated in Northeastern Thailand, covers an area of 16,112.61 km^2 and comprises 25 districts and 219 sub-districts.

B. GIS Data Layers of Collection

1) Spatial data: Regional Environmental Office 10 offers a digital map of administrative boundaries at a scale of 1:50,000.

2) Non-spatial data

- The Office of Environment and Pollution Control computes and documents secondary data on the Cleanliness Index (CI), Environmental Impact Index, and annual waste quantity at landfill sites and sub-district levels annually [12].
- Yearly data on health problem (HP) cases for each sub-district are recorded by the Health Data Center (HDC) dashboard.
- Transformation data
- GIS-based Cleanliness Index (CI), Environmental Impact Index, and annual waste quantity (Pw) data, along with health problems (HP) data, are processed by interpolating manipulations from stations and then averaged to provide presentations for each landfill site and sub-district.
- Data normalization: This step is to normalize/standardize data CI, Pw, and HP.

C. Predict the Impact on the Environment and Health in the Community Surrounding the Landfill Site

1) General information regarding waste disposal sites managed by local government agencies [12] includes 1) Distance from archaeological sites and tourist attractions, 2) Distance from main roads, 3) Distance from rivers and water sources, and 4) Distance from groundwater wells.

- Cleanliness Index consists of 1) coefficients based on climate and site characteristics, 2) unusual events that affect the amount of waste, 3) the amount of waste detected in the area, and 4) site characteristics.
- The Environmental Impact Index includes 1) Leachate flow or seepage; 2) Outdoor incineration; 3) Concentration of methane gas; 4) Concentration of hydrogen sulfide gas; 5) Distance from the local community; 6) Presence of flies; 7) Mean wind speed; 8) Annual mean rainfall.
- The waste production rate at any time is the sum of 1) the amount of waste in the current year and 2) the rate of change in waste.

2) The level of environmental and health impacts in communities dwelling around landfill sites can be predicted as follows:

- Cleanliness Index (CI) [13] (Eq. (1)).

$$CI = \frac{\lambda C}{nS} \times 1{,}0 \tag{1}$$

where *CI* is the Cleanliness Index (measured in equivalent pieces of waste per square meter), λ is the coefficient influenced by climate and area characteristics affecting garbage dispersal, and n denotes the number of unusual events leading to additional waste, ranging from 1 to 2, where 1 indicates no such events, while 2 signifies an event resulting in increased waste dispersal over time. C is the number of debris pieces detected during inspection, influenced by the type and weight of debris, and S reflects the inspection area (in square meters), determined by the inspection nature, such as a perimeter walk or random subarea check.

- Waste production rates can be determined at any time by Eq. (2) [14].

$$p_w = (p_{wo})e^{r_w t} \tag{2}$$

where P_w is the amount of waste in the forecast year (tons), Pwo is the amount of waste in the current year (tons), t denotes the number of years (years), and r_w is the rate of waste change (tons/year).

- The environmental impact index [15] can estimated by Eq. (3).

The environmental impact index comprises the unprocessed leachate flow or seepage, inadequate for meeting standards, outdoor incineration, methane concentration, hydrogen sulfide gas concentration, proximity to the community, abundance of flies, average wind speed, and annual rainfall averages.

$$I_{\text{ndex Models}} = \sum_{i=1}^{n} w_i s_i \tag{3}$$

where I is the Environmental Impact Index, $W1\ldots$ n are the significance scores for risk factors 1 to n, *and* $S1\ldots n$ denotes the correlation score of factors 1 to n.

- Community health problems at the sub-district level (Health Problems: HP)

The health data status within the sub-district area of the landfill site location is evaluated using occupational disease and environmental impact indicators obtained from the Web Health Data Center (HDC dashboard), Ubon Ratchathani Province [16]. This includes: 1) Heavy metal poisoning-related diseases (CID-10: T56.0-T60.9), 2) Respiratory illnesses (CID-10: J00-J06, J20-J22), 3) Diarrheal conditions

(CID-10: A04.0 – A04.4), and 4) Systemic skin diseases (ICD10: L23.5-L25.9).

$$HP = mean(\sum_{i=0}^{n} W_i) \tag{4}$$

where *HP* stands for community health issues at the sub-district level, $W1\ldots$ n indicates the impact on morbidity rates from 1 to n. It is determined by comparing the median mean morbidity rate (per 100,000 population) of each sub-district with the district's median mean morbidity rate [17] based on data from the previous three years (2019 –2021).

- Below is the equation that predicts the environmental and health effects on communities near landfill sites.

$$y = a_0 + b_1(CI) + b_2(P_w) + b_3(I) + b_4(HP) \tag{5}$$

where *Y* is the environmental and health impacts in the community surrounding the landfill site, *CI* denotes Cleanliness Index (equivalent pieces of waste per square meter), Pw is the amount of garbage in the forecast year (tons), *I* indicates Environmental Impact Index, and *HP* is the community health problems at the sub-district level.

D. Establish Spatial Decision Support System (SDSS) Module

The developer applied the System Development Life Cycle (SDLC) paradigm to establish the spatial web for prediction and harnessed Open-Source GIS Server (UMN MapServer) technology. This spatial web consists of two key elements: the Spatial Decision Support System (SDSS) and spatial web modules illustrated in Fig. 1. The SDSS facilitates input mechanisms for spatial data, allowing for the representation of spatial relations and structures, as well as analytical techniques and output in various spatial formats. Typically, the SDSS includes components such as a Database Management System (DBMS), GIS database, Model-Based Management System (MBMS), Dialog system, User interface, and Model Base for environmental and health impacts.

1) Database Management System (DBMS): A database management system for an SDSS module should incorporate spatial query capabilities, enabling the searching or selection of districts and sub-districts within polygons.

2) GIS Database: The foundation of developing a spatial web is to build a GIS database first.

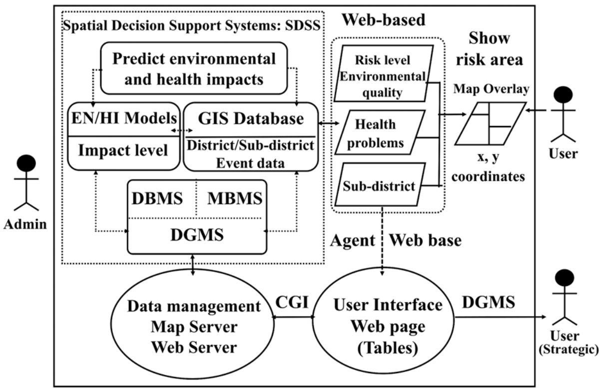


Fig. 1. Conceptual diagram of the spatial web for predicting environmental and health impacts in communities dwelling around landfill sites.

3) Model-Based Management System (MBMS): The system includes all the previously outlined decision models. The MBMS establishes and supervises the model directory and manages input, processing, and output files for model calculations.

4) Dialog Management System (DGMS): Within the Web-based SDSS application, the user uses a web interface crafted with HTML, Javascript, and PHP to designate the location for risk analysis and furnish event details concerning districts and sub-districts. The model operates on the web server utilizing inputs such as the Cleanliness Index (CI), Environmental Impact Index, and Health Problems (HP). Upon user request for a web page, the model outputs can dynamically manifest as a web-based map and graphical representations.

5) User Interfaces: The user interfaces with visual representations empower users to create and submit requests for information and decisions, explore retrieved information and computational results of decision models, adjust inputs for decision procedures, and log in or out of the application systems. Additionally, this component offers the usual functions of DSS and DGMS to engage with users, activating desired application functions, decision procedures, information retrieval, and model/knowledge computational processes.

E. Web-based Module

Combining components, including databases, GIS, the internet, and modeling, this web-based spatial decision support system is engineered to furnish data, information, and tools aiding users in their decision-making processes. Typically, the system components are dictated by the research objectives. Consequently, three modules are posited:

1) A web-based GIS system: The system provides dynamic mapping for graphical display and querying for tabular reports. This module is crafted to facilitate users' dynamic exploration of the map, allowing them to zoom in or out to any level and select different layers of information. Users can also create and print personalized maps. Furthermore, users can access diverse data through queries, aiding their decision-making. These web-based GIS pages utilize three main techniques to generate dynamic web pages: JEP/Servlet, JavaScript, and MapServer.

2) A Spatial Web model: The developed model can simulate results using user input. Users can request risk area landfill site maps from the interface for each sub-district in the Ubon Ratchathani province. Geographic database maps are generated utilizing Internet Map Server technology. Users can interactively examine the locations/areas with varying degrees of risk and determine suitable strategies, as outlined in the subsequent step.

3) Advising preventing/mitigation measures: The system displays categorized outputs to assist users in easily interpreting the results. Based on the output, the system can recommend operators' "Prevention/Mitigation Measures," outlining particular actions to address specific risks in the area.

F. Implementation Systems

A prototype of the described spatial network is utilized as part of the decision-making process. The efficient integration of the Web-based SDSS will facilitate the recording of activities and the administration of databases for all events within the study area.

1) Unit Check concentrates on the most granular unit of software development. It assesses the application's input/output parameters and error-handling mechanism using system design standards to identify potential issues in individual units or modules. 1) Positive testing entails applying test cases to a series of statements in modules to verify that the software functions correctly. It is often referred to as "passing the test." 2) Negative testing is conducted at this stage to demonstrate that the software does not function properly. It is sometimes called a "test to fail." 3) Condition testing is a design approach for test cases that evaluates the logical conditions within a program module.

2) System testing occurs after the entire application development process is finished. User acceptance testing includes functional requirement testing, function testing, usability testing, and security testing.

G. Limitations

This study has several limitations. First, limitations arose in gathering information from relevant agencies. Second, presenting spatial data via the web has its challenges, and data collected through such means requires rigorous accuracy and precision checks. Lastly, this study was concluded based on the existing data available from an environmental health and environmental engineering perspective; interdisciplinary research would be beneficial.

III. RESULT AND DISCUSSION

The variables in the prediction equation were pinpointed, comprising the Cleanliness Index (CI), Waste Production Rate (Pw), Environmental Impact Index (I), and Community Health Problems related to landfill waste (HP). It was noted that three of these variables, CI, Pw, and I, displayed positive correlations with environmental and health impacts, while HP showed an inverse relationship. However, none of these four variables demonstrated statistical significance at the 0.05 significance level. An evaluation of solid waste landfill site impact levels revealed that 63 of the sites experienced a high level (78.75%), while the remaining 17 sites (21.25%) had a medium level of impact (Table 1). Nonetheless, these variables are acknowledged as causal factors affecting the quality of solid waste landfill sites. Among them, HP, I, CI, and Pw were the most influential. The Environmental Impact Index (I), covering factors like leachate flow, outdoor waste burning, methane, and hydrogen sulfide gas concentrations, fly abundance, mean wind speed, and annual rainfall, directly impacts the surrounding community's health. Environmental factors can lead to various health issues, such as respiratory illnesses like allergies, flu, and bronchitis. Nuisances like unpleasant odors, flies, and animal carriers can contribute to communicable diseases like diarrhea. The Cleanliness Index (CI) reflects waste scattering; an increase in value can lead to unsightly conditions and the spread of germs. Windy conditions can worsen the situation, potentially causing waste to be blown out of the landfill.

Regarding the Waste Production Rate (Pw) at landfill sites, a significant volume and inefficient waste disposal can negatively impact the Environmental Impact Index and the Cleanliness Index. Over time, heavy metal contamination may arise, affecting groundwater and surface water quality. In this study, a combined score obtained from analyzing all four indicators was applied, assigning graded values to define five distinct levels of environmental and health impacts within communities adjacent to solid waste landfill sites. These levels comprise "very-low impact," "low level of impact," "moderate impact," "high level of impact," and "very high impact," as outlined in Table I.

This comprehensive grading approach unveils a multifaceted spectrum of impacts across various communities. This research aimed to create a straightforward, user-friendly spatial web interface, allowing novice web GIS users to utilize the system with minimal guidance. Fig. 2 depicts the primary interface and describes its key components.

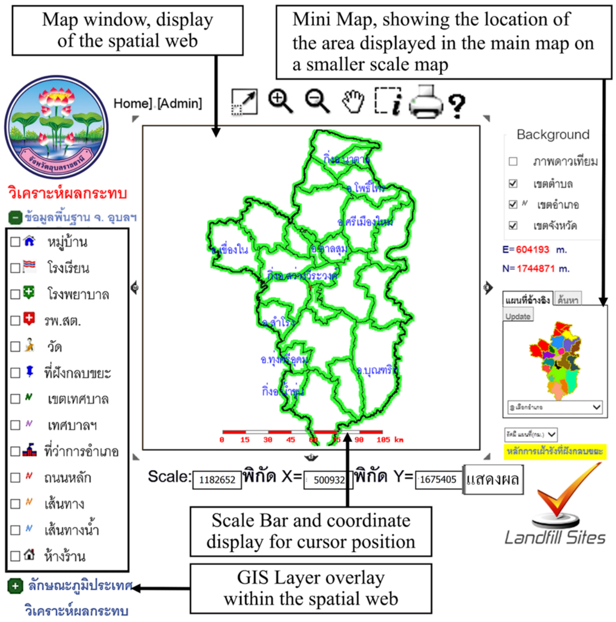
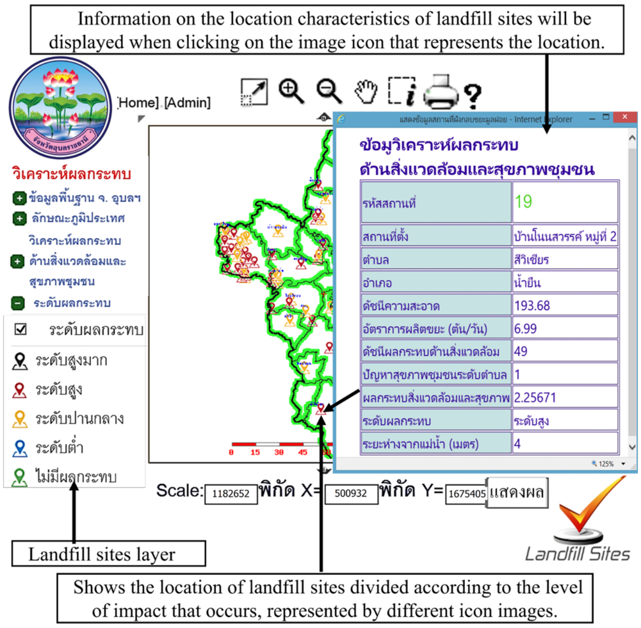


Fig. 2. Main window of the spatial web (http://localhost:85/waste/main/index.php).

Table 1. Level of impact on the environment and health in the community

Description	Level of impact	Logistic Y Range
Most impacts are long-term nuisances within a radius of no more than 10 meters from the landfill site. They do not affect the environment or overall public health.	Very low	0.00–0.40
There is no impact on the nearby environment or public health from various animal carriers surrounding the landfill site. There was just a nuisance during the landfill activities.	Low level	0.40–0.60
There is no impact on nearby water sources. Nuisances and various animal carriers may be encountered near the landfill site.	Medium level	0.60–0.85
Nuisances may disturb nearby communities, impacting the environment and public health in the vicinity.	High level	0.85–0.95
It severely impacts the environment and public health or affects the residents' quality of life.	Very high	0.95–1.00

The spatial web empowers users to incorporate different layers into the system for visualization, such as streets, villages, rivers, and water sources. Furthermore, users can evaluate environmental and health impacts near landfill sites using multiple linear regression layers derived from the development equation. These calculated values are then transformed into points indicating various environmental and health impacts (Very low level, Low level, Moderate level, High level, and Very high level) at the landfill site location, as illustrated in Fig. 3.



Information on the location characteristics of landfill sites will be displayed when clicking on the image icon that represents the location.

Landfill sites layer

Shows the location of landfill sites divided according to the level of impact that occurs, represented by different icon images.

แสดงข้อมูลสถานที่ฝังกลบขยะมูลฝอย - Internet Explorer

ข้อมูวิเคราะห์ผลกระทบ
ด้านสิ่งแวดล้อมและสุขภาพชุมชน

รหัสสถานที่	19
สถานที่ตั้ง	บ้านโนนสวรรค์ หมู่ที่ 2
ตำบล	สีวิเชียร
อำเภอ	น้ำยืน
ดัชนีความสะอาด	193.68
อัตราการผลิตขยะ (ตัน/วัน)	6.99
ดัชนีผลกระทบด้านสิ่งแวดล้อม	49
ปัญหาสุขภาพชุมชนระดับตำบล	1
ผลกระทบสิ่งแวดล้อมและสุขภาพ	2.25671
ระดับผลกระทบ	ระดับสูง
ระยะห่างจากแม่น้ำ (เมตร)	4

Scale: 1182652 พิกัด X= 500932 พิกัด Y= 1675405 แสดงผล

Fig. 3. Spatial web assessing environmental and health impacts in the vicinities of landfill sites. (http://localhost:85/waste/main/index.php).

The research revealed that all four variables incorporated into the prediction equation are causal factors that influence the quality of solid waste landfill sites. The greatest impact variables are HP, I, CI, and PW. The environmental impact index (I) includes: 1) leachate flow or seepage, 2) outdoor waste burning, 3) methane gas concentration, 4) hydrogen sulfide gas concentration, 5) fly abundance, 6) mean wind speed, and 7) mean annual water volume from rain. Enhancements in these factors could adversely affect the surrounding community's health, leading to respiratory diseases such as allergies, flu, bronchitis, etc., or result from nuisances like odors, flies, and carrier animals, potentially leading to infectious diseases such as diarrhea. The cleanliness index (CI) relates to the dispersal of garbage, which could lead to unsightly conditions or breeding grounds for germs, particularly during the windy season when garbage might be blown out of the landfill. Concerning the rate of waste production at landfill sites (PW), a substantial quantity coupled with inefficient waste disposal can alter the environmental impact index and cleanliness index, eventually leading to contamination of groundwater and surface water with heavy metals over time. Each index factor is directly linked to health problems, influenced by how quickly or slowly the disease develops, and tied to the principles of outbreak dynamics, which are dependent on the waste management practices at the landfill site [18] and health data indicating that diseases with the lowest morbidity rate over three years are those associated with heavy metals. This study analyzed the total scores from five criteria levels, demonstrating impacts at every level. Future improvements in prediction equations may include collecting more continuous and long-term health data. Additionally, the study identified significant factors that exacerbate the severity of environmental impacts at unsanitary landfill sites, including 1) distance from villages, 2) distance from surface water sources, 3) distance from the main river, 4) distance from the main road network, 5) slope, 6) land use and soil type, 7) distance from flood risk areas, 8) size of the area [19]. These spacing or distance variables suggest that closer proximity to communities may intensify health problems.

The evaluation results of the spatial web's forecasting performance were generally positive, indicating its suitability for the intended purpose. The design adheres to effective website design principles, considering user convenience and benefiting from the Minnesota map server program connected to the MySQL database. The implementation employs PHP, Java Applet, and MapScript to define database connection conditions without licensing. This solution is cost-effective, as it is freeware and compatible with the free Linux operating system. Furthermore, the Minnesota map server offers versatility in application development, spanning from basic systems to diverse applications. However, limitations were encountered during system development, notably requiring programming personnel with extensive knowledge and experience due to the utilization of freeware [20].

Table 2. The results of predicting the impact level of solid waste landfill site

Landfill Site	CI	Pw	I	HP	Y	Logistic Y	p-value	Level of impact
Ban Khueang Klang	182.46	3.42	43.00	1.25	2.14	0.89	0.037	High level
Ban Sompoi	186.24	0.42	28.00	1.00	2.11	0.89		High level
Ban Nong Khun	128.95	0.42	28.00	1.00	1.88	0.86		High level
Ban Don Chiang Tho	150.00	9.47	46.00	1.50	1.94	0.87		High level
Ban Phai	101.19	1.54	38.00	1.75	1.55	0.82		Medium level
Ban Na Kham Yai 2	104.17	3.25	44.00	1.25	1.84	0.86		High level
Ban Pa Kha	180.00	0.15	44.00	1.25	2.14	0.89		High level
Ban Na Kham Yai 1	185.71	0.15	33.00	1.25	2.05	0.88		High level
Ban Daeng Mor 1	129.17	1.54	47.00	1.25	1.96	0.87		High level
Ban Daeng Mor 2	166.67	1.83	62.00	1.25	2.26	0.90		High level
Ban Din Dam	135.93	6.60	47.00	0.75	2.21	0.90		High level
Ban Nong Saeng	104.35	3.35	46.00	1.00	1.96	0.87		High level
Ban Srisuk 2	80.00	0.64	42.00	1.75	1.50	0.81		Medium level
Ban Kok	178.57	2.11	46.00	1.50	2.05	0.88		High level
Ban Klang Yai 3	153.38	0.29	47.00	1.75	1.85	0.86		High level
Ban Klang Yai 9	160.00	0.22	26.00	1.75	1.66	0.84		Medium level
Ban Chan Khueang	151.58	0.76	42.00	1.50	1.89	0.86		High level
Ban Yang Khi Nok	100.66	1.40	26.00	1.75	1.43	0.80		Medium level
Ban Phon Sai	197.89	2.16	44.00	1.50	2.10	0.89		High level
Ban Sang Tho	121.05	6.85	28.00	1.50	1.64	0.83		Medium level
Ban Kut Krasian	151.58	6.27	46.00	1.50	1.94	0.87		High level

Ban Saeng Noi	125.00	0.58	44.00	1.25	1.92	0.87	High level
Ban Srisuk 1	120.73	0.86	44.00	1.75	1.69	0.84	Medium level
Ban Chan Tanon	113.16	1.28	50.00	1.75	1.72	0.84	Medium level
Ban Tha Sanam Chai	166.57	1.93	32.00	1.75	1.75	0.85	High level
Ban Nong Bo	153.51	1.28	52.00	1.75	1.89	0.86	High level
Ban Dong Bang	158.33	1.28	48.00	1.75	1.88	0.86	High level
Ban Phon Ngam	117.86	1.75	50.00	1.75	1.74	0.85	High level
Ban Hua Kham	186.47	2.56	39.00	0.75	2.33	0.91	High level
Ban Pa Ao	166.04	5.94	55.00	1.75	1.98	0.87	High level
Ban Thung Na Mueang	86.84	0.64	50.00	1.25	1.82	0.86	High level
Ban Khan Tha Kwian	171.43	1.09	55.00	1.25	2.21	0.90	High level
Ban Non Sawan	117.86	0.97	50.00	1.25	1.94	0.87	High level
Ban Nong Phue	144.74	4.48	50.00	1.25	2.06	0.88	High level
Ban Sasom	131.10	0.44	34.00	1.25	1.84	0.86	High level
Ban Na Pho Tai	128.57	0.60	50.00	1.25	1.99	0.87	High level
Ban Nong Luang	146.34	2.16	48.00	1.00	2.15	0.89	High level
Ban Toei	121.05	9.90	46.00	1.00	2.04	088	High level
Ban Na Waeng Mai	110.53	2.48	46.00	1.25	1.88	0.86	High level
Ban Phanom Dee	113.16	9.41	42.00	1.25	1.85	0.86	High level
Ban Jiad	121.05	3.85	42.00	1.50	1.78	0.85	High level
Ban Rueang Udom	128.05	5.62	42.00	1.75	1.70	0.84	Medium level
Ban Hua Na	176.84	1.03	42.00	1.00	2.21	0.90	High level
Ban Rat Phatthana	121.05	8.22	32.00	1.75	1.57	0.82	Medium level
Ban Tha Pho Si	103.76	1.22	55.00	1.25	1.94	0.87	High level
Ban Pa Muang	94.74	7.84	50.00	1.00	1.96	0.87	High level
Ban Bua Ngam	73.68	7.62	52.00	0.75	2.01	0.88	High level
Ban Na Nun Nuea	134.21	3.71	50.00	1.50	1.91	0.87	High level
Ban Khon Sai	107.89	2.91	50.00	1.50	1.80	0.85	High level
Ban Nam Thiang	115.79	4.21	52.00	1.25	1.96	0.87	High level
Ban Lai Thung	172.63	0.99	50.00	1.25	2.17	0.89	High level
Ban Don Yai	68.42	0.56	34.00	1.75	1.38	0.79	Medium level
Ban Lai Soong	189.47	1.33	34.00	1.25	2.07	0.88	High level
Ban Ka Chap	86.84	2.92	50.00	1.25	1.83	0.86	High level
Ban Na Pho 2	97.37	1.07	44.00	1.25	1.81	0.85	High level
Ban Rai Klang	78.95	1.11	33.00	0.75	1.84	0.86	High level
Ban Nong Samran	77.07	3.86	33.00	1.75	1.40	0.80	Medium level
Ban Non Bok	125.00	1.47	44.00	1.75	1.70	0.84	Medium level
Ban Bok	189.47	0.54	44.00	1.25	2.17	0.89	High level
Ban Phalan	153.38	0.94	49.00	1.25	2.08	0.88	High level
Ban Nong Hin	86.84	1.98	44.00	1.25	1.77	0.85	High level
Ban Sawang	100.61	4.86	28.00	0.75	1.88	0.86	High level
Ban Kham Hai Yai	102.63	0.83	28.00	1.25	1.67	0.84	Medium level
Ban Nong Kung Yai	101.02	2.39	42.00	1.00	1.91	0.87	High level
Ban Kham Wa	86.84	1.40	42.00	1.00	1.85	0.86	High level
Ban Khok Tub Chang	110.71	2.00	44.00	1.25	1.86	0.86	High level
Ban Non Hin Kong	155.79	1.22	28.00	1.50	1.77	0.85	High level
Ban Thung Nong Bua	94.51	6.82	30.00	1.00	1.76	0.85	High level
Ban Colan	75.19	5.17	34.00	1.50	1.51	0.81	Medium level
Ban Knang	81.58	4.77	36.00	0.75	1.88	0.86	High level
Ban Pa Son	181.05	10.74	50.00	1.75	1.99	0.88	High level
Ban Non Sawan	193.68	7.00	28.00	1.00	2.14	0.89	High level
Ban Lak Muang	94.59	6.14	34.00	1.50	1.59	0.83	Medium level
Ban Nong Song Hong	72.64	4.42	34.00	1.00	1.72	0.84	Medium level
Ban Nayia	110.53	1.56	34.00	1.25	1.76	0.85	High level
Ban Don Pong	118.42	1.65	50.00	1.75	1.74	0.85	High level
Ban Muang	73.31	4.50	34.00	0.75	1.83	0.86	High level
Ban Nong Khok	75.19	5.54	44.00	100	1.83	0.86	High level
Ban Khao Pun	102.63	1.60	50.00	1.50	1.78	0.85	High level

Table II showed that 63 sites experienced a high level (78.75%), while the remaining 17 sites (21.25%) had a medium level of impact.

IV. CONCLUSION

The equations for predicting environmental and health impacts in communities surrounding the location of landfill solid waste sites are as follows:

Predictive equations in the form of raw scores (Unstandardized Score)

$$y = 1.509+0.004(CI)+0.001(Pw)+0.010(I)-0.427(HP) \text{ or}$$

Predictive equations in the form of standard scores (Standardized Score)

$$Z = 0.155\ (CI) + 0.003\ (Pw) + 0.102\ (I) - 0.161\ (HP)$$

In conclusion, this study has significantly advanced the prediction of environmental and health impacts on communities near landfill sites. The p-value for a 95% confidence interval is found to be 0.047. There was a significant correlation of 0.05 (p =0.044). A detailed model was used, incorporating variables such as the Cleanliness Index (CI), Waste Production Rate (*Pw*), Environmental Impact Index (I), and Community Health Problems (*HP*). The investigation revealed important interactions between these variables and their effects on the quality of solid waste landfill sites. Specifically, CI, Pw, and I were found to have positive correlations with environmental and health impacts, underscoring their importance in assessing the overall influence of landfill sites.

In contrast, HP demonstrated a negative correlation, indicating its pivotal role in reducing environmental and health risks in these communities. Although the variables showed consistent trends, none achieved statistical significance at 0.05. Nonetheless, each variable is essential for comprehending and addressing the challenges at solid waste landfill sites.

The study also highlights the need for ongoing collection of long-term health data to improve predictive models and support the development of a spatial web for decision-making. This approach could more accurately distinguish between environmental and health impacts, leading to better strategies for managing solid waste landfills. Moreover, the research identified additional factors like proximity to villages, water sources, and road networks, intensifying the environmental impacts of unsanitary landfill sites. These findings emphasize the importance of thorough assessments when selecting landfill sites near residential areas. This research enhances our understanding of the multifaceted issues associated with solid waste landfills and their impacts on the environment and health, advocating for continuous monitoring and management. These insights are crucial for formulating effective policies and operational strategies for solid waste management, promoting the well-being of surrounding communities. Future research should focus on developing forecasting equations that consider variables such as the cumulative amount of residual waste, daily waste influx, size of the disposal area, daily management practices, and sensitivity to environmental contamination like groundwater and surface water quality. Verification requires statistical samples of physical checks for human health.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Surasak Suksai and Phatcharee Srikuta formulated the conceptualization and methodology. Surasak Suksai conducted the research, analyzed the data, and drafted the manuscript. Phatcharee Srikuta supervised the study and revised and finalized the manuscript. All authors have read and agreed to the published version of the manuscript.Surasak Suksai and Phatcharee Srikuta formulated the conceptualization and methodology. Surasak Suksai conducted the research, analyzed the data, and drafted the manuscript. Phatcharee Srikuta supervised the study and revised and finalized the manuscript. All authors have read and agreed to the published version of the manuscript.

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