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The Effect of Risk Communication Management By Brin on Public Understanding and Trust in the Cesium-137 Contamination Issue in Cikande: A Mixed-Method Study

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ABSTRACT

Radiological contamination represents an invisible and technically complex hazard that may heighten public concern, particularly when institutional communication is delayed or unclear. This study examined the association between risk communication management by Indonesia's National Research and Innovation Agency (Badan Riset dan Inovasi Nasional, BRIN) and public understanding and trust regarding the cesium-137 (Cs-137) contamination incident in Cikande, Indonesia. It also explored how residents interpreted information about Cs-137 and the factors influencing their trust in BRIN. A sequential explanatory mixed-methods design was employed. Questionnaire data collected from 40 residents of Kampung Barengkok were analyzed using correlation and simple linear regression analyses, while interviews with a local resident and BRIN representatives were conducted to contextualize the quantitative findings. Risk communication management was strongly and positively correlated with public understanding ($r = 0.839$; $R^2 = 0.704$) and trust ($r = 0.861$; $R^2 = 0.742$), while understanding and trust were also strongly correlated ($r = 0.830$). The qualitative findings suggested that direct community engagement, accessible language, demonstrations of radiation measurements, and empathetic communication helped address misconceptions and concerns associated with circulating rumors. However, participants perceived that official information was disseminated later than unofficial reports. These findings highlighted the importance of integrating timely, transparent, and accessible risk communication into radiological incident management to strengthen public understanding and institutional trust.

INTRODUCTION

Advances in science and technology have expanded the applications of nuclear technology in healthcare, agriculture, industry, food processing, environmental management, and scientific research. Radiation-based technologies are used in cancer radiotherapy, medical equipment sterilization, food irradiation, plant breeding, nondestructive material testing, and industrial thickness measurement. However, like other high-risk technologies (Perrow, 1999), applications involving radioactive materials may pose significant hazards when radioactive sources are improperly managed, monitored, stored, handled, or disposed of. Nuclear safety therefore encompasses not only technological benefits but also regulatory oversight, environmental protection, institutional preparedness, and effective government communication during radiological incidents (Nugroho, 2025; Shafary et al., 2024).

A major challenge in communicating nuclear and radiological risks is the public's limited familiarity with radiation-related concepts. Terms such as radiation, radioactivity, exposure, and contamination are frequently used interchangeably despite their distinct scientific meanings. Radiation refers to energy transmitted as particles or electromagnetic waves, whereas radioactivity describes the spontaneous transformation of unstable atomic nuclei. Radiation exposure occurs when an individual or object is subjected to ionizing radiation, while radioactive contamination involves the unintended presence of radioactive substances on surfaces, in environmental materials, or within the human body. Individuals may therefore be exposed to radiation, such as during diagnostic X-ray examinations, without becoming contaminated. Radiological health risks must be evaluated by considering radionuclide activity and concentration, radiation type and energy, exposure duration, distance, exposure pathways, and protective measures rather than the mere detection of radioactive material (International Commission on Radiological Protection [ICRP], 2007; International Atomic Energy Agency [IAEA], 2020; United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR], 2014, 2021).

Cesium-137 (Cs-137) is a radioactive isotope primarily produced through nuclear fission, with a physical half-life of approximately 30 years. It undergoes beta decay to barium-137m, which subsequently emits penetrating gamma radiation as it transitions to a stable nuclear state. Sealed Cs-137 sources have been used in industrial density and thickness gauges, radiation instrument calibration, and certain medical and research applications. However, uncontrolled radioactive sources may pose significant hazards when they are lost, damaged, improperly discarded, or inadvertently incorporated into scrap metal. Because ionizing radiation cannot be directly detected through human senses, communities rely on radiation monitoring instruments, scientific expertise, and institutional communication to understand potential exposure and associated health risks. Scientific institutions therefore play an important role in translating technical radiological information into accessible public guidance.

Public perceptions of risk are influenced not only by the probability and severity of potential harm but also by qualitative characteristics of the hazard. Nuclear and radiological hazards are frequently perceived as dread risks because they may be viewed as frightening, involuntary, unfamiliar, and difficult to control (Slovic, 1987, 2000; Breakwell, 2014; Fischhoff, 1995). Risk communication involves the exchange of information and perspectives among individuals, communities, and institutions concerning potential hazards and their consequences (National Research Council, 1989). Its objectives include improving public understanding, supporting informed protective decisions, and strengthening trust in responsible institutions (Covello, 2003; Covello & Sandman, 2001; Heath & O'Hair, 2009; Morgan et al., 2002). Effective risk communication requires timely, accurate, transparent, understandable, empathetic, and consistent messages that respond to the concerns and information needs of affected communities (Centers for Disease Control and Prevention [CDC], 2018; Coombs, 2015; Frewer, 2004; Lindell & Perry, 2004; Sandman, 1993; Sellnow & Seeger, 2013; Griffin et al., 2019; Littlejohn et al., 2017).

The Social Amplification of Risk Framework (SARF) explains how information transmitted through media, social networks, personal experiences, and institutional interactions may amplify or attenuate public perceptions of hazards, potentially generating broader social and economic consequences beyond their direct physical effects (Kasperson et al., 1988; Kasperson, 2014). Institutional trust is particularly important in radiological incidents because members of the public often cannot independently evaluate technical measurements or scientific assessments. Consequently, their acceptance of official information may depend on perceived institutional competence, honesty, concern, and reliability (Earle & Cvetkovich, 1995; Lofstedt, 2005; Peters et al., 1997; Siegrist, 2000). Public understanding can also be examined through the public understanding of science perspective (Bauer et al., 2007; Miller,

2001), which emphasizes the importance of accessible scientific knowledge in supporting informed decisions, appropriate protective behavior, and the ability to distinguish credible information from misinformation.

These communication challenges became particularly relevant following reports of Cs-137 contamination associated with industrial activities in Cikande, Serang Regency, Banten Province, Indonesia. The incident attracted public attention after United States authorities detected Cs-137 in samples of frozen shrimp originating from Indonesia, prompting investigations into shrimp-processing facilities and the surrounding industrial environment. Indonesia's Nuclear Energy Regulatory Agency (Badan Pengawas Tenaga Nuklir, 2020) reported that coordinated radiation monitoring identified Cs-137 contamination near a shrimp-processing facility and elevated radiation levels at a scrap metal collection site. During September 2025, authorities conducted radiological assessments and radioactive material management activities at several locations within the Modern Cikande Industrial Estate, followed by decontamination activities in October 2025. The incident raised concerns extending beyond food safety to radioactive source control, industrial waste management, environmental contamination, and community protection.

Kampung Barengkok, located in Sukatani Village, was among the communities situated near the affected industrial area. Some residents relied on agricultural activities conducted on industrial estate land under informal or permitted land-use arrangements, while educational backgrounds reportedly ranged primarily from elementary to secondary school. These circumstances highlighted the importance of communicating radiological information in clear, accessible, and locally relevant language. According to a resident informant, initial information about the contamination circulated through neighbors, journalists, and social media before residents received official explanations. Indonesia's National Research and Innovation Agency (Badan Riset dan Inovasi Nasional, BRIN) participated alongside BAPETEN, the Ministry of Environment, and other institutions in radiological surveys, environmental mapping, radioactive material management, and technical assessments. BAPETEN held regulatory responsibilities for licensing, inspection, and oversight of nuclear energy utilization (Badan Pengawas Tenaga Nuklir, 2020, 2021; Republik Indonesia, 1997), whereas BRIN provided scientific expertise, measurement capabilities, laboratory analysis, research support, and technical communication (Republik Indonesia, 2021). Within this institutional arrangement, BRIN's contributions encompassed scientific knowledge production and validation, technical assessment and operational support, and communication of radiological findings to affected communities.

In this study, BRIN's risk communication management encompassed more than the dissemination of official announcements. It included communication planning, spokesperson selection, interagency coordination, simplification of technical information, communication channel selection, engagement with community representatives, direct interaction with residents, responses to questions and misinformation, and updates throughout incident management. Previous research has emphasized the importance of credible information sources, empathy, and institutional preparedness in radiation risk communication (Crick, 2021). Tateno and Yokoyama (2013) examined the roles of information intermediaries in shaping anxiety and trust following the Fukushima Daiichi nuclear accident, while Rasmussen et al. (2022) investigated public communication needs during a hypothetical nuclear accident using mixed methods. Perko (2011) also highlighted the importance of risk communication during and after nuclear emergencies. However, these studies did not specifically examine the relationship between risk communication management by an Indonesian scientific institution and public understanding and trust during an actual local radiological contamination incident. The present study sought to address this contextual research gap.

The study addressed five research questions: (1) To what extent was BRIN's risk communication management associated with public understanding of the Cs-137 contamination incident? (2) To what extent was it associated with public trust in BRIN? (3) How were risk communication management, public understanding, and public trust related? (4) What factors influenced residents' trust or distrust of BRIN? and (5) How did residents interpret information concerning Cs-137 contamination? Three hypotheses were examined: H1, BRIN's risk communication management was positively and significantly associated with public understanding; H2, BRIN's risk communication management was positively and significantly associated with public trust; and H3, BRIN's risk communication management was jointly associated with public understanding and trust.

METHOD

This study employed a sequential explanatory mixed-methods design (Creswell, 2014, 2015; Creswell & Creswell, 2018; Creswell & Plano Clark, 2018; Sugiyono, 2022). Quantitative data were collected and analyzed first, followed by qualitative data to provide further context and explanations for the statistical findings. This approach enabled the examination of relationships among risk communication management, public understanding, and institutional trust while exploring residents' perceptions and experiences (Kriyantono, 2020; Neuman, 2014). The study adopted a postpositivist perspective, recognizing that quantitative findings required interpretation within the broader social context.

The study was conducted in Kampung Barengkok, Sukatani Village, Cikande District, Serang Regency, Banten Province, Indonesia, near the affected industrial estate. The target population comprised residents potentially affected by the cesium-137 (Cs-137) contamination incident who had attended BRIN's public information sessions. According to a local informant, the community consisted of 20 households, and 53 residents had attended the information sessions. A total of 40 residents were selected through purposive sampling based on their participation in BRIN's Cs-137 information sessions. Complete population coverage was not achieved because some residents were absent during data collection, while others had been evacuated and had not yet returned (Sugiyono, 2019).

Three variables were assessed (Table 1): BRIN's risk communication management (X), measured using seven indicators and 21 items; public understanding (Y1), measured using four indicators and 12 items; and public trust (Y2), measured using five indicators and 11 items. The questionnaire comprised 44 items rated on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Mean scores were classified as very low (1.00–1.80), low (1.81–2.60), moderate (2.61–3.40), high (3.41–4.20), or very high (4.21–5.00).

Table 1. Research variables, indicators, and number of items

Variable	Indicators	Items
Risk communication management by BRIN (X)	Message clarity, information speed, openness, source credibility, message consistency, communication empathy, information accessibility	21 (3 per indicator)
Public understanding (Y1)	Basic knowledge, risk understanding, understanding of handling measures, ability to distinguish information	12 (3 per indicator)
Public trust (Y2)	Competence, integrity, openness, care, reliability	11 (2, 2, 2, 2, and 3)

Note: all items use a five-point Likert scale (1–5).

Before the main analysis, preliminary instrument validity and reliability assessments were conducted using simulated responses from 10 participants. Item validity was assessed using corrected item–total correlations, while internal consistency was evaluated using

Cronbach's alpha. For the preliminary correlation analysis (n = 10; df = 8), the critical correlation coefficient was 0.632 at the 5% significance level. The main quantitative analysis included descriptive statistics, Shapiro–Wilk normality tests, multicollinearity diagnostics using tolerance and variance inflation factors (VIF), the Breusch–Pagan test for heteroscedasticity, Pearson correlation analysis, and simple linear regression. Regression coefficients were evaluated using t-tests, overall model significance was assessed using F-tests, and explanatory power was examined using the coefficient of determination (R^2), with a significance level of $\alpha = 0.05$ (Field, 2018; Hair et al., 2019; Priyatno, 2018). The total risk communication management score (X) was used as the sole predictor in two separate regression models, with public understanding (Y1) and public trust (Y2) as the respective dependent variables.

Qualitative data were collected through in-depth interviews with four informants: one local resident (a 30-year-old tenant farmer), one BRIN technical representative, and two BRIN field communication representatives. Interviews were supplemented by field observations and document review. Informants were identified by their roles, and interview excerpts were translated from Indonesian into English. Data analysis involved transcription, data reduction, categorization, coding, data display, and interpretation (Baxter & Jack, 2008; Miles et al., 2014; Patton, 2015). Trustworthiness was addressed through source and methodological triangulation, negative case analysis, prolonged engagement with the data, detailed contextual descriptions, an audit trail, and researcher reflexivity (Lincoln & Guba, 1985). Formal member checking was not conducted. Quantitative and qualitative findings were integrated using a joint display to examine how interview evidence contextualized the statistical results.

RESULTS AND DISCUSSION

Respondent Characteristics

Respondents were aged 20 to 45 years, with a mean of about 28.2 years and a median of 28 years, so the sample was dominated by young productive-age adults (Table 2). Most had elementary to secondary education. Productive-age residents interpret the Cs-137 issue not only as a health problem but also as a threat to livelihood, the environment, and the family's future, as illustrated by the resident informant, whose worry concerned both his children's health and his willingness to return to the rice field.

Group mean scores were uniformly high (Table 3). Female respondents scored slightly higher than male respondents on all variables, most visibly on understanding (4.44 versus 4.23), but because no difference test was run this pattern is a contextual reading rather than a causal conclusion. Respondents with elementary education also scored relatively high (4.49, 4.50, and 4.42), as did those with junior high school education (4.36, 4.35, and 4.39), and the youngest group (20–24 years) had the highest scores (4.57, 4.65, and 4.59), although groups aged 35 years and above were too small to generalize. Formal education therefore does not appear to be the only determinant of understanding and trust; direct communication, simple language, demonstration of instruments, and opportunities to ask questions probably helped respondents of different educational backgrounds grasp the message, in line with the practice described by field informants, who delivered education gradually and informally.

Table 2. Respondent characteristics (N = 40)

Characteristic	Category	n	%
Age (years)	20–24	12	30.0
	25–29	11	27.5
	30–34	13	32.5
	35–45	4	10.0
Sex	Male	22	55.0
	Female	18	45.0
Education	Elementary school	8	20.0
	Junior high school	16	40.0
	Senior high school	14	35.0
	Vocational high school	1	2.5
	Equivalency program (Paket B)	1	2.5

Note: the 35–45 group is the remainder of the 40 respondents after the three larger age groups.

Table 3. Mean scores of risk communication (X), understanding (Y1), and trust (Y2) by respondent group

Group	n	X	Y1	Y2
Male	22	4.32	4.23	4.30
Female	18	4.38	4.44	4.40
Age 20–24 years	12	4.57	4.65	4.59
Elementary school	8	4.49	4.50	4.42
Junior high school	16	4.36	4.35	4.39
Senior high school	14	4.26	4.21	4.26
Vocational high school	1	3.95	4.08	4.00
Equivalency program (Paket B)	1	4.52	4.50	4.55

Note: Likert scale 1–5; no difference tests were conducted.

Public Assessment of BRIN's Risk Communication Management

All seven indicators of risk communication management fell in the very high category (Table 4). Communication empathy had the highest mean (4.47) and the highest share of positive answers (90.8%), while information accessibility had the lowest mean (4.21), at the threshold of the very high category. The pattern suggests that the main strength of BRIN's communication lay in interpersonal approach and field conduct, while distribution of information through multiple channels remained room for improvement.

Table 4. Indicators of risk communication management by BRIN (X)

Indicator	Mean	Category	Positive answers (%)	Notable item (mean)
Communication empathy	4.47	Very high	90.8	Showing concern for residents' worries (4.62)
Message clarity	4.45	Very high	87.5	—
Information speed	4.37	Very high	85.8	Information given quickly when the issue emerged (4.15)
Openness	4.35	Very high	89.2	Complete explanation (4.17)
Message consistency	4.29	Very high	87.5	Consistent across channels (4.03)
Source credibility	4.28	Very high	90.0	—
Information accessibility	4.21	Very high	86.7	Available in various media (4.10)

Note: each indicator has three items (120 answers); positive = agree and strongly agree.

Message clarity (4.45) rested on 57.5% strongly agree, 30.0% agree, and 12.5% neutral answers, with no negative answers; the neutral share is understandable because terms such as Cs-137, exposure, contamination, dose, and decontamination are hard for lay audiences. A BRIN technical informant stressed that technical language had to be simplified and that analogies help people imagine the real risk without being frightened. Information speed (4.37) had the lowest share of positive answers among the X indicators (85.8%), and its lowest item, that BRIN provided information quickly when the Cs-137 issue emerged, averaged only 4.15, in the high rather than very high category. Qualitative data clarify this weakness: the resident informant said that false news had already spread before BRIN arrived, and field informants described an abrupt situation involving many institutions in which communication roles were not fully structured from the start. In crisis communication, speed is directly tied to controlling uncertainty, because a vacuum of official information is filled by rumor (Coombs, 2015; Sandman, 1993).

Openness (4.35) was rated positively, although the item on complete explanations averaged 4.17. Openness here does not mean releasing raw technical data but conveying relevant facts and the progress of handling without creating the impression that important information is concealed. Credibility (4.28) received 90.0% positive answers, among the highest, but its mean was lower because "agree" outnumbered "strongly agree"; credibility is strong but not accepted without distance by all respondents. Consistency (4.29) was lowest on the item about consistent information across channels (4.03), which fits an arrangement in which official external statements were issued through a single door by the Task Force spokesperson while BRIN reinforced technical explanations. Empathy was highest on the item that BRIN showed concern for residents' worries (4.62). The resident informant said that officers did not lecture but first asked what residents felt, had heard, and were worried about, and field informants described greeting families, talking with children, and asking neighborhood heads for help so that residents felt safe to open up.

Public Understanding and Trust

Both dependent variables were also very high (Table 5). Understanding was strongest in basic knowledge (4.43), such as recognizing Cs-137 as a radioactive substance, and weakest in understanding of handling measures (4.28), implying that residents grasp basic information more easily than the whole handling process. Trust had an overall mean of 4.35 and was strongest in care (4.55; 96.2% positive), meaning residents judged BRIN not only as a technical body but as an institution attentive to their safety and worries. Integrity had the lowest mean (4.23) and the largest neutral share (17.5%), while the item on using BRIN information as the main reference was relatively lower, showing that transparency and reference status can still be strengthened.

Table 5. Indicators of public understanding (Y1) and public trust (Y2)

Variable	Indicator	Mean	Positive answers (%)
Understanding (Y1)	Basic knowledge	4.43	90.0
	Ability to distinguish information	4.31	85.8
	Risk understanding	4.29	84.2
	Understanding of handling measures	4.28	87.5
Trust (Y2)	Care	4.55	96.2
	Competence	4.39	88.8
	Reliability	4.33	89.2
	Openness	4.25	85.0
	Integrity	4.23	81.2

Note: all indicators fall in the very high category (4.21–5.00).

Item-level data qualify the picture of understanding (Table 6). The highest item was "I know that Cs-137 is a radioactive substance" (4.60), showing that the most basic explanation had reached residents, while the lowest was "I understand the potential danger of Cs-137" (4.20), at the upper edge of the high category. Understanding of handling measures had the lowest indicator mean (4.28), and the item on knowing BRIN's handling steps averaged 4.23, probably because handling involves many technical stages and institutions: radiation survey, mapping, boundary lines, health data collection and checks, decontamination, Task Force coordination, and waste management. Field informants described coordinating with the military, police, BAPETEN, the Ministry of Environment, sub-district and village governments, and the social agency while collecting data for health checks. The ability to distinguish information (4.31) is illustrated by the resident informant, who no longer believed social media immediately, checked official sources, and sometimes re-explained BRIN's information to neighbors. Across all 480 Y1 answers, 48.8% were strongly agree, 38.1% agree, 10.2% neutral, and 2.9% disagree, with a Y1 mean of 4.33. Residents thus find it easier to know what Cs-137 is than to judge how large the risk is, how the hazard pathway works, or which handling steps follow.

Table 6. Answer distribution of public understanding indicators (Y1), number of answers (%)

Indicator	Strongly agree	Agree	Neutral	Disagree	Positive (%)
Basic knowledge	66 (55.0)	42 (35.0)	9 (7.5)	3 (2.5)	90.0
Risk understanding	60 (50.0)	41 (34.2)	13 (10.8)	6 (5.0)	84.2
Understanding of handling measures	52 (43.3)	53 (44.2)	12 (10.0)	3 (2.5)	87.5
Ability to distinguish information	56 (46.7)	47 (39.2)	15 (12.5)	2 (1.7)	85.8
All Y1 items	234 (48.8)	183 (38.1)	49 (10.2)	14 (2.9)	86.9

Note: each indicator has 120 answers (480 for all Y1 items); no strongly disagree answers were recorded.

Trust showed a similar pattern (Table 7). Care drew 58.8% strongly agree and 37.5% agree answers, with only 3.8% neutral and no negative answers, whereas integrity drew 42.5% and 38.8%, with 17.5% neutral and 1.2% disagree answers; competence (51.2% strongly agree) and openness (41.2% strongly agree and 13.8% neutral) fell in between. Across all 440 Y2 answers, 47.7% were strongly agree, 40.5% agree, 10.5% neutral, and 1.4% disagree, giving 88.2% positive answers and no strongly disagree answers. Trust was thus strong but not uniformly formed across its dimensions: residents felt most strongly that BRIN cared about their safety and worries, while the conviction that nothing important was being concealed left a little more room for doubt.

Table 7. Answer distribution of public trust indicators (Y2), number of answers (%)

Indicator	Strongly agree	Agree	Neutral	Disagree	Positive (%)
Competence	41 (51.2)	30 (37.5)	8 (10.0)	1 (1.2)	88.8
Integrity	34 (42.5)	31 (38.8)	14 (17.5)	1 (1.2)	81.2
Openness	33 (41.2)	35 (43.8)	11 (13.8)	1 (1.2)	85.0
Care	47 (58.8)	30 (37.5)	3 (3.8)	0 (0.0)	96.2
Reliability	55 (45.8)	52 (43.3)	10 (8.3)	3 (2.5)	89.2
All Y2 items	210 (47.7)	178 (40.5)	46 (10.5)	6 (1.4)	88.2

Note: competence, integrity, openness, and care have 80 answers each, reliability 120, and all Y2 items 440; reliability counts were obtained by subtracting the other four indicators from the all-item totals; no strongly disagree answers were recorded.

Instrument Quality and Assumption Tests

All 44 items were valid, with corrected item–total correlations of 0.867–0.990 against the critical value of 0.632, and all variables were highly reliable (Cronbach's alpha 0.986–0.998; Table 8). Values this close to 1.00 may also reflect items of similar meaning or uniform answer patterns, so instrument testing is best treated as evidence of feasibility rather than a main finding. The instrument test used simulated data from only 10 respondents.

Table 8. Results of instrument validity and reliability tests

Variable	Items	Range of r	Critical r	Cronbach's alpha
X: Risk communication management	21	0.869–0.990	0.632	0.997
Y1: Public understanding	12	0.867–0.973	0.632	0.991
Y2: Public trust	11	0.884–0.963	0.632	0.986
All items	44	0.867–0.990	0.632	0.998

Note: all items valid and all variables reliable (N = 10 simulated respondents).

The assumption tests (Table 9) showed that scores on X, Y1, and Y2 and the residuals of both models were not normally distributed ($p < 0.05$), which is understandable because most answers clustered at "agree" and "strongly agree." The regression results should therefore be read cautiously and strengthened by qualitative interpretation. Multicollinearity was not an issue because only one predictor was used, and neither model showed heteroscedasticity. Using the total X score as the main predictor is also reasonable because residents appeared to experience BRIN's communication as a whole (whether BRIN was present, explained clearly, was open, caring, credible, and accessible) rather than as separate dimensions.

Table 9. Results of normality, multicollinearity, and heteroscedasticity tests

Test	Variable/model	Statistic	Sig.	Decision
Shapiro–Wilk	X	0.877	0.000	Not normal
	Y1	0.840	0.000	Not normal
	Y2	0.914	0.005	Not normal
Shapiro–Wilk (residual)	X → Y1	0.796	0.000	Not normal
	X → Y2	0.914	0.005	Not normal
Tolerance / VIF	X → Y1 and X → Y2	1.000 / 1.000	—	No multicollinearity
Breusch–Pagan	X → Y1	—	0.117	No heteroscedasticity
	X → Y2	—	0.256	No heteroscedasticity

Effect of Risk Communication Management on Understanding and Trust

All three correlations were very strong, positive, and significant (Table 10). The better residents judged BRIN's risk communication management, the higher their understanding and trust, and understanding and trust reinforced each other: residents who understood the risk were more inclined to trust BRIN because fear and uncertainty decreased, and those who trusted BRIN were more willing to accept its scientific explanations.

Table 10. Pearson correlations among variables

Relationship	Pearson r	Sig.	Category
X with Y1	0.839	0.000	Very strong, positive
X with Y2	0.861	0.000	Very strong, positive
Y1 with Y2	0.830	0.000	Very strong, positive

Both regression models were significant (Table 11). The model for understanding was Y1 = −2.005 + 0.591X: each one-point rise in the total risk communication score was followed by a rise of about 0.591 points in understanding (t = 9.502; p = 0.000), and X explained 70.4% of its variance, leaving 29.6% to other factors such as education, personal experience, proximity to the affected location, social media exposure, and conversations among residents. The model for trust was Y2 = 5.163 + 0.467X (t = 10.454; p = 0.000), with X explaining 74.2% of variance and leaving 25.8% to other factors such as historical experience with government, perceptions of the Task Force, frequency of officer visits, and residents' social experience when the issue first emerged. H1 and H2 were therefore accepted. H3 was accepted substantively, based on the two significant models together with the very strong correlation between understanding and trust; no separate joint multivariate test was run.

Table 11. Results of simple linear regression

Component	X → Y1	X → Y2
Constant	−2.005	5.163
Regression coefficient (X)	0.591	0.467
t	9.502	10.454
Sig. t	0.000	0.000
F	90.280	109.300
Sig. F	0.000	0.000
R Square	0.704	0.742
Adjusted R Square	0.696	0.735

Note: both models significant at α = 0.05; hypotheses H1 and H2 accepted.

The slightly higher explanatory power for trust (74.2% versus 70.4%) can be interpreted to mean that BRIN's communication built a sense of trust more strongly than it conveyed the full technical complexity of Cs-137: understanding radiation requires complex knowledge, whereas trust can form more quickly through seeing competent officers at work. These results are consistent with risk communication theory, in which the aim is to help the public understand a hazard proportionally and use that understanding in decisions, and with the view that trust determines whether risk messages are accepted (Covello, 2003; National Research Council, 1989; Peters et al., 1997). They are also consistent with the finding of Crick (2021) that credibility of the source, clarity, and empathy are central in radiation risk communication.

How BRIN Managed Risk Communication: Institutional and Field Findings

Interviews with BRIN informants identified five institutional strategies. First, cross-institutional coordination: before information was published, BRIN coordinated with BAPETEN, local government, technical agencies, and estate managers so that the narrative remained consistent; official external statements went through a single door via the Task Force spokesperson, with BRIN strengthening the technical explanation. Second, evidence-based communication: every statement on radiation level, affected area, or decontamination was based on field measurement, laboratory analysis, and verified scientific study. Third, experts as main communicators, because residents accept information more easily from specialists who understand the technical substance. Fourth, multiple channels, including press conferences, the official website, social media, mass media, field socialization, and direct dialogue. Fifth, adaptive communication: after residents' worries emerged, the approach shifted from presenting scientific facts to dialogic education, clarification, and empathy. These strategies correspond with the quantitative indicators of consistency, credibility, accessibility, and empathy, and with crisis communication principles of coordination and credibility (CDC, 2018; Heath & O'Hair, 2009; Sellnow & Seeger, 2013).

At field level, five themes emerged: face-to-face dialogue; simplification of scientific language through everyday analogies, visual illustrations, and examples; trust-building through direct presence of researchers who explained how data were obtained and which instruments

were used; responsiveness to concerns about farmland, family health, livelihood, and regional stigma, in which officers listened before explaining; and continued assistance after socialization through coordination with local government. One field informant explained that "the education is not too formal; we put it gradually into everyday conversation, because if it is too formal people may become afraid." Officers still stated that radiation can be dangerous, but did so in simple language, without intimidation, and with practical guidance such as avoiding areas marked with boundary lines and having health checks.

Residents' Experience: From Rumor to Proportional Understanding

Before BRIN's explanation, the resident informant learned of the contamination from neighbors, then from journalists and social media, and heard that the soil in Barengkok was "poisoned." He pictured radiation as an atomic bomb, Hiroshima, or Chernobyl. His wife panicked, the family avoided well water and their own vegetables, children were kept from the rice field, and farm work was disrupted. This is a clear example of social amplification of risk: a technically limited hazard acquired a much larger meaning through rumor, media, and association with major nuclear disasters (Kasperson et al., 1988; Slovic, 1987), and misunderstanding had behavioral and economic consequences.

After BRIN spoke in simple language, repeated difficult terms with examples, showed measuring instruments, and measured radiation in front of residents, his understanding changed: radiation is not always deadly, a safe limit exists, not all areas are contaminated, and official information must be distinguished from rumor. In his words, he trusted BRIN more because officers showed the radiation meter and measured in front of residents. He also stopped believing social media immediately, checked official sources, and passed BRIN's explanation on to neighbors, becoming an informal communication agent. This illustrates what may be called evidence visibility, in which residents see how knowledge is produced, so that technical evidence works both as a basis for decisions and as a communication tool (Bauer et al., 2007; Miller, 2001).

The qualitative data also explain why residents trusted, or at first doubted, BRIN. Trust was shaped by perceived scientific competence (competence mean 4.39; 88.8% positive), openness, visible field evidence, care and empathy (care 4.55), continued presence (reliability 4.33), and the ability to explain science in plain language (clarity 4.45). Trust was relational and experience-based rather than abstract trust in an institution's name, consistent with models that treat trust as built from ability, integrity, and benevolence (Earle & Cvetkovich, 1995; Lofstedt, 2005; Siegrist, 2000). Early doubt arose mainly because official information was not yet fully present, so rumor and social media shaped perceptions first and residents feared that facts were being hidden; the one-door mechanism could also create distance if updates were not quickly translated to the village level. Distrust thus stemmed less from rejection of science or BRIN than from an information vacuum, unclear action, and rumors that moved faster than official information; trust strengthened when that uncertainty was filled with presence, evidence, dialogue, and verifiable explanation.

Integration of Quantitative and Qualitative Findings

The two strands largely confirmed or complemented each other (Table 12). The qualitative strand also added a critical nuance: communication was rated very high and was effective once BRIN was present among residents, but early information was outpaced by rumor, and speed and accessibility were the weakest quantitative indicators.

Table 12. Joint display of quantitative and qualitative findings

Quantitative finding	Qualitative explanation	Integration pattern
X strongly affects Y1 (R^2 = 70.4%)	Residents understood Cs-137 after BRIN explained directly in simple language and showed measuring instruments	Mutually confirming
X strongly affects Y2 (R^2 = 74.2%)	Trust rose because BRIN was present, answered questions, was open, and showed technical competence	Mutually confirming
Y1 strongly correlated with Y2 (r = 0.830)	Understanding reduced fear and made residents trust BRIN more	Complementary
BRIN communication rated very high	Effective after BRIN arrived, but early information was outpaced by rumor	Critical nuance
High empathy and care indicators	Field officers used a humane, non-intimidating approach	Mutually reinforcing
Accessibility and speed relatively lower	Residents said information should be faster because hoaxes had already spread	Qualitative data clarify the weakness

Theoretical Implications

Risk communication theory was supported most clearly in its educational function. Communication did not only deliver a message but helped residents interpret risk: BRIN translated abstract scientific risk into concrete explanation through plain language, instrument demonstrations, and direct dialogue (Covello, 2003; Morgan et al., 2002; National Research Council, 1989). The part least optimally supported was speed. The resident informant said that false news had spread before BRIN arrived, so communication was effective once BRIN was present but not fully fast in the early phase, probably because of the complexity of Task Force coordination, the number of actors involved, and the lack of a rapid communication system at village level. In a local radiological risk, effectiveness thus depends not only on message accuracy but also on the physical presence of the communicator, the ability to translate technical language, and residents' experience of seeing evidence in the field; science-based risk communication should be dialogic, visual, and contextual.

In terms of crisis and emergency risk communication (CDC, 2018; Coombs, 2015; Sellnow & Seeger, 2013), the principles of empathy and credibility were strongly supported: empathy had the highest X mean (4.47), clarity was next (4.45), and residents trusted BRIN more when it showed instruments and explained measurement results. The "be first" principle was not fully met, since speed was among the relatively lower indicators and the single-door mechanism, although important for consistency, could make responses to residents feel slower than the spread of rumor. In science-based crises, speed should therefore be combined with being easy to understand and being present in person, and formal single-door communication should be paired with dialogic field communication.

The social amplification of risk was strongly supported. Before BRIN's explanation, residents obtained information from neighbors, journalists, social media, Facebook, and YouTube, which claimed that the soil was "poisoned," that radiation could spread through the air, and that all crops were dangerous; the issue grew into a threat to well water, rice fields, food, children's health, social relations, and the family's future (Kasperson et al., 1988; Kasperson, 2014; Slovic, 1987). What was not supported was strong resistance to official information, which can occur when people already believe rumor. Here it was not dominant, probably because BRIN's approach was empathic and evidence-based and because local figures such as neighborhood heads opened communication channels. Amplification can thus be reduced when a scientific institution is present in residents' social space, and rumor correction through formal channels alone is not enough; it needs interpersonal communication that residents trust.

Source credibility and public trust were also supported. Because residents cannot verify radiation data themselves, they need a source perceived as expert, and BRIN's competence (4.39) mattered; a BRIN technical informant described BRIN as the main technical reference in the Task Force because of its instruments, experience, and ability to give technical recommendations. Yet care was the highest trust indicator (4.55), which extends the credibility reading: in a local risk context, credibility is built from expertise combined with benevolence, so BRIN was trusted not only because it was an expert but because it was present, explained, measured, and listened (Earle & Cvetkovich, 1995; Peters et al., 1997; Siegrist, 2000). Integrity was the weakest dimension, and some respondents remained neutral about whether BRIN concealed important facts, probably because of the sensitivity of a radiological crisis, limited early information, and rumor reaching residents first. Trust is thus the product of concrete interaction between an institution and affected residents rather than institutional reputation alone, and it can form faster than technical understanding because residents can see signs of competence, care, and openness.

For the public understanding of science (Bauer et al., 2007; Miller, 2001), the findings show that a technical issue such as Cs-137 is hard to grasp without simplified scientific explanation, and that BRIN bridged the gap between science and residents' experience, shifting the resident informant's picture of radiation from imagined nuclear disaster to the notion of a safe limit and uncontaminated areas. Deep understanding of the technical aspects of risk and of all handling stages was not yet strong, probably because of varied science literacy, the complexity of radiation, limited interaction time, and deliberate avoidance of explanations so technical that they could cause excessive fear. In a crisis, the goal of science communication is not to make residents understand every technical aspect but to make them understand enough to take safe and proportional action, so public understanding is practical, situational, and based on residents' needs. Table 13 summarizes how the findings relate to theory.

Table 13. Theoretical implications of the findings

Theory	Supported part	Not fully supported	Possible cause
Risk communication	Communication improved public understanding	Initial speed of information not optimal	Rumors spread faster than official information
Crisis and emergency risk communication	Empathy, clarity, credibility, and accuracy strongly supported	"Be first" principle not fully met	Task Force coordination and one-door communication
Social amplification of risk	Rumors and social media amplified initial fear	Resistance to official information not dominant	BRIN present directly and used measurement evidence
Source credibility	BRIN's competence strengthened message acceptance	Integrity not entirely free of doubt	Sensitivity of the radiation issue and unclear early information
Public trust	Trust formed by competence, care, openness, and reliability	Openness and integrity still need strengthening	Residents feared information was being concealed
Public understanding of science	Simple language and technical demonstration increased understanding	Deep technical understanding not yet strong	Complexity of radiation and varied science literacy

Practical and Policy Implications

Practically, BRIN needs to treat risk communication as an integral part of handling science-based cases. Technical measures such as measurement, mapping, and examination are not enough without clear public communication that tells residents what is being done, why, what the risks are, and what they should do. The main strengths found here, namely direct communication, empathy, credible speakers, and simplification of scientific messages, should

be maintained, and researchers and technical informants should be trained in risk communication, crisis communication, empathic communication, and message simplification (Centers for Disease Control and Prevention, 2018; Frewer, 2004; Perko, 2011). At the policy level, risk communication should be included in contingency plans rather than started after an issue becomes public, with protocols that govern initial messages, spokespersons, official channels, interagency coordination, and rumor clarification (International Atomic Energy Agency, 2015, 2018).

Cross-institutional coordination of narratives involving BRIN, BAPETEN, local government, the Task Force, and estate managers is necessary, but single-door coordination must remain responsive so that information does not reach affected residents late; message consistency and speed of response have to be combined. Continuous education on radiation, nuclear safety, environmental risk, and how to recognize official information is also needed, not only during a crisis. Socially, affected residents should be positioned as subjects with experiences, fears, and information needs rather than as passive recipients, because communication that listens proved more effective than one-way communication; dialogue, involvement of local figures, and direct explanation are part of social protection in risk situations (Heath & O'Hair, 2009; Lindell & Perry, 2004).

Several limitations need acknowledgment. The sample was small (40 residents) and purposive, so findings cannot be generalized statistically; the quantitative data are perception-based and may not reflect objective knowledge; score distributions and residuals were not normal; the instrument was tested on simulated data from 10 respondents; the qualitative informants were limited and did not cover groups such as women, older residents, industrial workers, business owners, health workers, or religious figures; and media content and social media framing were not analyzed. Behavioral outcomes such as compliance with safety directives were also not measured.

CONCLUSION

This study found strong, positive, and statistically significant associations between BRIN's risk communication management and public understanding ($r = 0.839$; $R^2 = 0.704$; $p < 0.001$) and public trust ($r = 0.861$; $R^2 = 0.742$; $p < 0.001$) regarding the cesium-137 (Cs-137) contamination incident in Cikande. Public understanding and trust were also strongly correlated ($r = 0.830$). The qualitative findings provided further context for these relationships, indicating that residents who initially relied on rumors, social media, and informal community discussions developed a clearer understanding of radiological risks following BRIN's use of accessible language, demonstrations of radiation monitoring instruments, direct responses to community questions, and empathetic communication. Institutional trust was associated with perceptions of BRIN's technical competence, accessibility, scientific credibility, concern, and reliability. Conversely, distrust was primarily linked to delays in official communication during the initial response phase, when misinformation circulated more rapidly than verified information. These findings highlighted the importance of integrating clear, credible, empathetic, and community-centered communication into radiological incident management, while identifying the timeliness and accessibility of initial information as areas requiring improvement. However, the findings were limited by the small purposively selected sample of 40 residents, reliance on self-reported perceptions, non-normal score distributions, preliminary instrument testing using simulated responses from only 10 participants, and the limited number of qualitative informants. Consequently, the results should be interpreted cautiously and cannot be statistically generalized to the broader population.

Future research should involve larger, more representative samples encompassing diverse community groups, including women, older adults, industrial workers, business

owners, healthcare professionals, and religious leaders. Additional variables, such as media exposure, scientific literacy, and adherence to radiological safety instructions, should be examined to provide a more comprehensive understanding of risk communication outcomes. Longitudinal studies could investigate changes in public understanding and institutional trust across the initial response, incident management, and recovery phases, while media content analyses could clarify the influence of news coverage and social media narratives. Future studies should also employ appropriate multivariate statistical methods to formally examine the joint relationship between risk communication management, public understanding, and trust, as the simultaneous hypothesis (H3) was not formally tested in the present study. From a practical perspective, BRIN should establish standardized, evidence-based risk communication protocols emphasizing timely information dissemination, accessible scientific explanations, and sustained community engagement. Training researchers in crisis and public communication, incorporating visual educational materials, and maintaining direct, empathetic interactions with affected residents could further strengthen communication practices. Local governments and the Nuclear Energy Regulatory Agency (Badan Pengawas Tenaga Nuklir, BAPETEN) should also strengthen interagency coordination, engage trusted community representatives, and systematically monitor misinformation to improve message consistency, responsiveness, and public confidence.

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