

Hazard Literacy Center

Hazard Literacy Education Program

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Chemical Spills: Calculating the Danger Using Distance and Wind



1. Program Overview

This education program is designed to help learners understand why the harm from a chemical-spill accident appears differently from place to place. Even when the same amount leaks out, "physical conditions"-how much, how far, in which wind direction, and when it was released-and "social conditions"-where the factory is located, whether people live nearby, and the circumstances of that area-work together, so that the extent and severity of harm differ. Learners do not stop at vaguely sensing this difference; they build a model of it directly using numbers, graphs, and coordinates.

Specifically, learners graph how concentration changes with distance, and by adding wind direction as a variable they draw the risk zone on a map. Using the Ministry of Environment's Pollutant Release and Transfer Register (PRTR) data, they devise and calculate for themselves a formula that assigns each business a "risk score." They then exchange the prediction problems they have created with other groups and solve them, experiencing first-hand how a model built with mathematics and science can serve as a tool for predicting and explaining disaster risk. At the same time, they consider what this model cannot capture-how easily one can obtain risk information, whether one can evacuate on one's own, what kind of housing one lives in, and so on. Through this, learners come to view the question of where to site hazardous facilities critically, from the perspectives of environmental justice and disaster justice.

Grade Level	Middle and high school students	Instructional Methods	Lecture, case study, mathematical and scientific modelling
Learning Environment	Regular classroom (a space that allows group work)	Duration	100 minutes total (50 min × 2 sessions, including a role-play activity)
Required Materials	Activity sheets; writing tools; smart devices (phone or tablet); case materials (videos and photos); slides		

2. Learning Objectives (Hazards Literacy Framework)

① Understand and explain the causes and progression of a chemical-spill accident from the standpoint of variables such as leak volume, distance, wind direction, and time.

② Compare domestic and overseas cases of chemical spills to analyse, with graphs and data, how-even in the same accident-harm appears differently according to physical conditions (distance, wind direction, etc.) and social conditions (siting, housing environment, etc.).

③ Using the concentration-distance relationship and PRTR data, design a "risk-radius prediction model(a risk-score function)," and exchange the prediction problems you create with other groups to solve them.

④ Point out the social variables the model cannot explain, and understand the problem of inequality in the siting of hazardous facilities from the perspectives of environmental justice and disaster justice.

Learning Objectives	Knowledge & Understanding		Reasoning & Skills					Values & Attitudes			Psychology & Emotion			Behavioral & Practical Enagement		
	A1	A2	B1	B2	B3	B4	B5	C1	C2	C3	D1	D2	D3	E1	E2	E3
Objective ①	O	O				O										
Objective ②		O	O	O	O	O										
Objective ③				O	O		O	O						O		O
Objective ④							O	O	O			O			O	

3. Key Concpets

- How a chemical-spill accident arises (risk factors in storage, transport, and handling)
- The concentration-distance relationship and dispersion models (changes in exposure concentration with distance, wind direction, and time)
- Quantitative representation of the risk radius and risk zone (graphs, coordinates, concentric circles/ellipse)
- Designing a "risk-score" function using variables and weights, and quantitative comparison
- Environmental justice and the inequality of hazardous-facility siting
- Disaster justice and the right to know
- The limits of a model: social variables that numbers do not capture (information access, evacuation capacity)

4. Program Sequence

Learning Activities	
Introduction	·Present news videos and cases of chemical spills to spark interest. ·Pose the question: "Even when the same amount leaks out, why does the extent of harm differ?" ·Note variables such as distance, wind direction, and time, and explain that risk can be handled with "numbers and graphs."
Activity1	·Understand the causes of a spill (storage and transport accidents, ageing facilities, poor management) and how it progresses. ·Graph concentration-distance data and interpret, via the slope, how concentration changes as distance increases. ·Extract together the "variables that amplified the danger" from domestic and overseas cases.
Activity2	·Add wind direction and time as variables to correct the risk zone from a "concentric circle to an ellipse" and express it in coordinates. ·Search the Ministry of Environment's PRTR for release information on businesses in our region. ·Design a "risk-score" function using release volume, distance, and hazard as variables, and calculate and compare three businesses.
Activity2	·Each group makes a "risk-radius prediction problem," exchanges it with another group to solve, and shares the solutions. ·Distinguish what the model explains from what it does not. ·Discuss "variables that numbers do not capture," such as information access and evacuation capacity, from the perspectives of environmental justice and disaster justice.
Wrap-up	·Understand that a mathematical and scientific model can be a tool for predicting and explaining disaster risk. ·At the same time, know the limits of a model and understand that more vulnerable groups should be protected first. ·View a disaster in an integrated way, from the perspectives of both a scientific phenomenon and a social problem.

5. Theoretical Background and Activity Design for Disaster Education

In the course of industrialisation, Korea built many chemical complexes and industrial parks, and chemical-spill accidents caused by ageing facilities, poor management, and transport accidents have recurred. When a large quantity of hazardous material is released into the atmosphere in a short time-as in the 2012 Gumi hydrofluoric-acid leak-it has wide-ranging effects on the respiratory health of nearby residents, on crops, and on soil and water quality. Here, because the exposure concentration and the risk radius depend not only on the leak volume but also on physical variables such as the distance between the factory and residential areas, the wind direction, and the time of the leak, handling these with numbers and graphs makes it possible to explain quantitatively "why harm appears differently."

At the same time, because chemical factories tend to be sited in industrial parks or in nearby low-income residential areas, even the same accident produces different patterns and scales of harm according to the socio-economic conditions of the place of residence. The phenomenon of hazardous facilities being concentrated in vulnerable areas has long been discussed from the perspective of environmental justice (Bullard, 1990; Mohai, Pellow, & Roberts, 2009); and the fact that disaster harm and the opportunities for recovery appear differently among members of society can be interpreted, in distributive, procedural, and interactional terms, from the perspective of disaster justice, which takes a social-justice framework as its theoretical foundation (Lukasiewicz & Baldwin, 2014).

This program organises the analysis of chemical spills into two stages: ① Session 1 (extracting variables from the film Dark Waters (2019) and Ministry of Environment materials, and building cognition and the basis of a model through concentration-distance graphs and wind-direction plotting) and ② Session 2 ("risk-radius prediction modelling PBL"). Session 2 proceeds through five steps: defining the variables-designing the risk-score function-applying and calculating real PRTR data-making and exchanging prediction problems to solve-validating the model and discussing its limits. Learners predict risk with the model they have built, exchange and solve the problems they have made, and finally examine critically, from the perspective of disaster justice, the social variables the model fails to capture.

6. Instructional Considerations

- Make clear that the risk-score function does not have "a single correct answer." The choice of variables and weights may differ from group to group, and emphasise that what matters is not the resulting value but the reasoning for "why it was designed that way."
- So that students who lack confidence in calculation or plotting can also take part, provide step-by-step examples for reading graphs and marking coordinates, and have groups divide roles (data search, calculation, plotting, presentation).
- Avoid reducing the cause of a spill to a single factor such as facility ageing or worker error, and guide learners to understand that various factors-siting, safety management, information-disclosure institutions, housing environment-operate together.
- Make clear that the model deals only with "risk that numbers can capture," and guide learners to recognise social variables such as information access and evacuation capacity as problems of structural conditions rather than individual responsibility.
- When dealing with real data such as PRTR, take care that it does not drift into one-sided blame of a particular company or region, and guide learners to interpret it on the basis of verified primary sources.

7. References

- Bullard, R. D. (1990). Dumping in Dixie: Race, class, and environmental quality. Westview Press.
  Mohai, P., Pellow, D., & Roberts, J. T. (2009). Environmental justice. Annual Review of Environment and Resources, 34, 405-430.
- Lukasiewicz, A., & Baldwin, C. (2014). Voice, power, and history: Ensuring social justice for all stakeholders in water decision-making. Local Environment: The International Journal of Justice and Sustainability, DOI: 10.1080/13549839.2014.942261

Session 1: Same Amount Spilled — So Why Are the Danger Zones Different?



Topic	Chemical dispersion seen through distance, wind direction, and time
What will we learn?	① Understand the causes and progression of a chemical spill in terms of variables. ② Use a concentration–distance graph and a wind-direction diagram to explain quantitatively why the danger zone changes.

Resources: Trailer for the film Dark Waters (2019) · Chemical spill news (Oct. 2025, MBC Chungbuk) · Ministry of Environment Pollutant Release and Transfer Register (PRTR), icis.mcee.go.kr/prtr

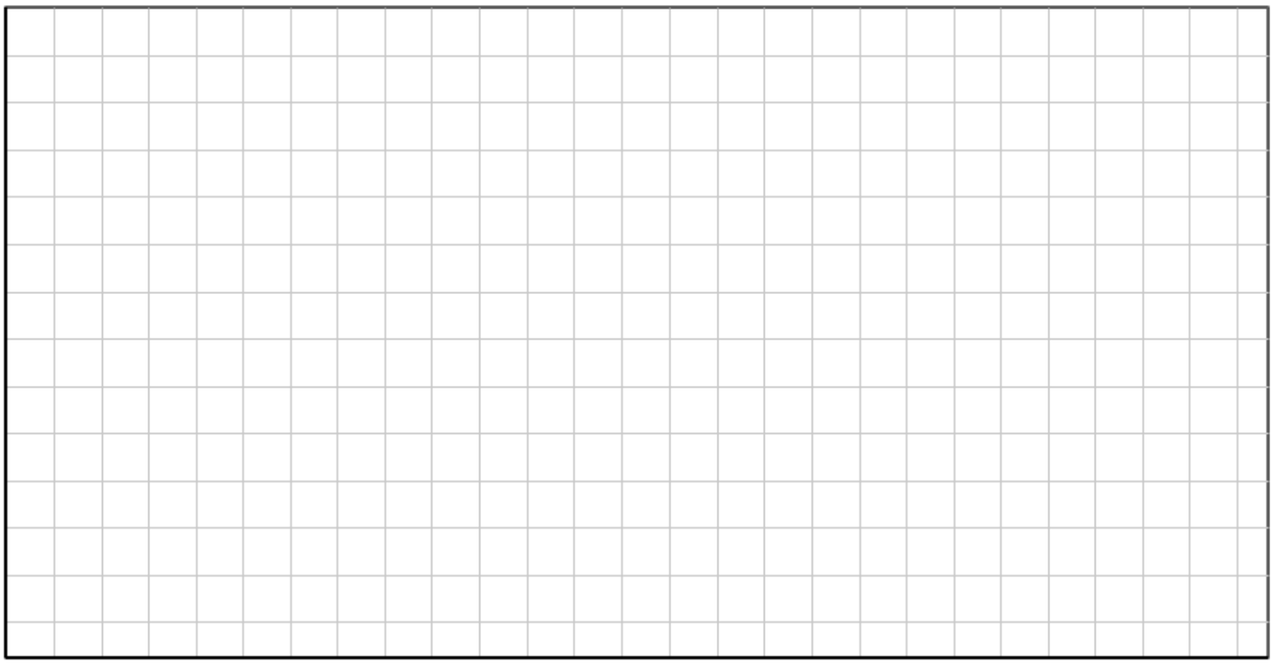
1 Case File — Finding the 'Variables' That Amplified the Danger

- Watch the video and list the variables that made the damage worse — focus on things you can measure with numbers, not just a 'feeling.' Write three variables that determined how large the damage was, and mark whether the danger increases or decreases as each variable grows.

Variable (something measurable)	As it grows, danger? (↑ / ↓)

2 Concentration–Distance Graph — How Much It Thins Out with Distance

- Plot the 'distance–concentration' data your teacher provides on graph paper. (x-axis: distance, y-axis: concentration)

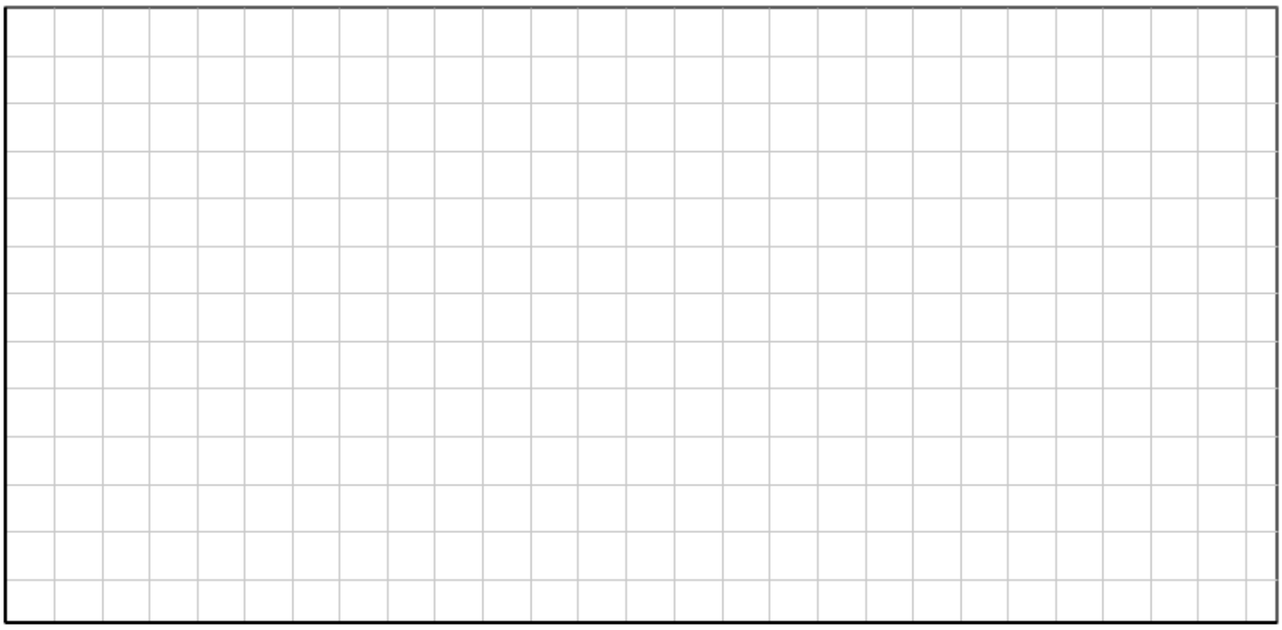


1) How does the concentration change when the distance doubles? Explain using the slope of the graph.

2) If there is a safety-threshold concentration, show how you would read the 'safe distance' off the graph.

3 The Wind-Direction Variable — From Concentric Circles to an Ellipse

- When the wind blows, the danger zone stretches to one side rather than staying a circle. Place your school (or a facility) at the origin, set up coordinates, and draw the danger zone with the wind direction included.



1) Explain, using wind direction, why the danger zone should be drawn as an 'ellipse' rather than 'concentric circles.'

2) Choose the coordinates of a point in the downwind direction (where the wind is heading) and write why that spot is more dangerous.

4 Building a Danger Score — Quantitative Comparison with PRTR

- Search for facilities in your area on the Ministry of Environment PRTR public system (icis.mcee.go.kr/prtr). Rate 'emissions, distance, and hazard level' from 1 to 3 each, and score three facilities.

Facility	Emissions (1–3)	Distance score (1–3)	Hazard (1–3) · Total

1) Which facility has the highest score, and who mainly lives nearby?

5 One-Line Prediction — The Danger Radius in Our Neighborhood

- Using the graph, diagram, and scores you made today, predict in one line 'the spot in our neighborhood to watch most closely, and why.' (This leads into the Session 2 modeling PBL.)

Session 2: Building a Danger-Radius Prediction Model

Topic	A danger-radius prediction model built from variables and functions
What will we learn?	① Design a 'danger-score function' using variables and weights, and apply it to real PRTR data. ② Exchange and solve prediction problems you created, and examine the model's limits from a disaster-justice perspective.

1 Defining Variables — The Inputs to Our Model

- Define the variables that determine danger. Decide the meaning, unit, and range of values for each.

Symbol	Variable name · meaning	Unit / range of values
Q	Amount released	
d	Facility–residence distance	
v	Wind speed (or wind-direction correction)	
h	Hazard level of the substance	

2 Designing the Danger-Score Function

- Combine the variables above to build a 'danger-score' formula. There is no single right answer — what matters is your reasoning for the design.

① Our group's danger-score formula (e.g., Score = Q×h ÷ d^2)

② Why is distance d placed in the 'denominator'? (Explain by linking to the Session 1 concentration–distance graph.)

③ How did you build wind direction into the formula? (e.g., a correction factor or directional weight)

3 Applying Real Data — Calculations for Three PRTR Facilities

▸ Find the values for three facilities in your area on the Ministry of Environment PRTR (icis.mcee.go.kr/prtr), substitute them into your function, and calculate the danger score and expected danger radius.

Facility	Q	d	h	Danger score · radius

4 Create and Exchange Prediction Problems

① The problem our group wrote (include the given conditions and what to find)

② Your solution to another group's problem (formula, answer, reasoning)

5 Validating the Model & Discussing Its Limits — What Numbers Can't Capture

- A model is powerful, but it can't capture everything. Discuss the following as a group and write your answers.

1) In an area our model scored as 'no danger,' who might actually be at greater risk? (e.g., people who get information late, people who cannot evacuate on their own)

2) List two 'social variables we couldn't include' in our model, and explain why they are hard to express as numbers.

3) From a disaster-justice perspective, propose in one sentence 'who, when, and how' should be able to access danger information for it to be fair.