# QUANTITATIVE RISK ASSESSMENT


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# Content

- Difference between hazard and risk
- What is meant by risk assessment and its aim
- Risk assessment steps
- **Methods of quantitative risk analysis**
- Hierarchy of occupational disease prevention

# Hazard vs. Risk


# We must ask 4 questions about any potential hazard

**1. Does it cause harm to human health ?**

**2. Effect ?**

How does it change with change in quantity, quality & way of exposure..etc

**3. Extent ?**

Distribution, severity

**4. Overall magnitude?**

Socially, economically & politically

# The aim of the risk assessment process is to

- **Evaluate hazards, then Remove that hazard or minimize the level of its risk**
- by adding control measures, as necessary.
- so, we create a safer and healthier workplace.

# Steps of risk assesment

1- Hazard Identification

2-Exposure assessment

3-Dose response relationship

4-risk characterization (risk analysis)

5-uncertainty analysis

6-Estimating total risk

7-Risk control

# 1-Hazard Identification

- **Define hazards associated with a certain process, job, or procedure.**

- **job hazard analysis :**
- is a systematic examination and documentation of every task within each job to identify health and safety hazards, and the steps to control each task
- **It identifys hazards before they occur(proactive)**

- **It focuses on the relationship between**

**1. The worker +**

**2.The task +**

**3.The tools +**

**4.The work environment.**

- A job hazard analysis can be conducted on many jobs in workplace.
- **Priority should go to the following types of jobs:**

- Jobs with the highest injury or illness rates
- Jobs with the potential to cause severe or disabling injuries or illness, even if there is no history of previous accidents
- Jobs in which one simple human error could lead to a severe accident or injury
- Jobs that are new to your operation or have undergone changes in processes and procedures
- Jobs complex enough to require written instructions.

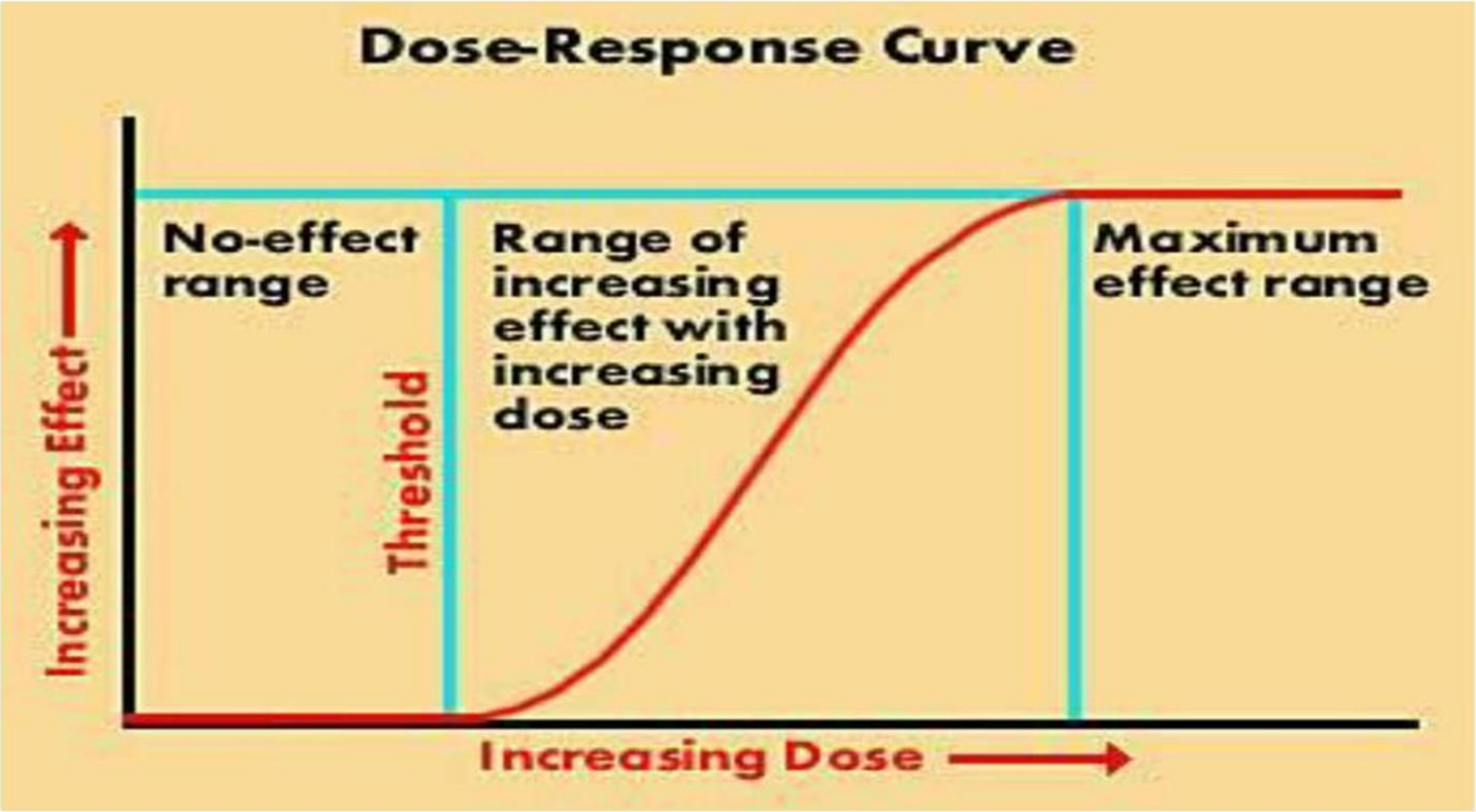
# 2-Exposure assesment

- Exposure assessment is the process of characterizing, estimating, measuring, and modelling the magnitude, frequency, and duration of contact with an agent as well as the number and characteristics of the population exposed.

# 3-Dose response relationship

- Measure or estimate the actual exposure levels at different sites of exposure for the people potentially affected, Qualitative &/or Quantitative including all sectors of general population including all subgroups & the workforce
- **Dose (exposure) - Response (effect) relationship**

# The Dose Response Curve



# *Explanation of the Diagram:*

- **X-axis (Dose/Exposure):** Amount of exposure to the agent
- **Y-axis (Health Effect):** Severity or probability of adverse health effect
- At **low doses**, no observable adverse effect may occur
- After a **threshold**, risk begins to increase
- At **higher doses**, the probability or severity of harm increases
- **Slope Factor:** Risk per unit dose for carcinogens

# 4-Risk charachterization

- **Risk analysis**

Probability and Severity that an adverse outcome will occur in a person or a group that is exposed to a particular concentration or dose of a hazardous chemical, physical or biological agents

- **Risk evaluation**

The process of comparing an estimated risk against given risk criteria to determine the significance of the risk.

# Risk analysis


- **What Does Risk Analysis Involve?**
- Risk analysis focuses on three main elements:
- Sources of risk : Where risks come from
- Consequences of risk :What could happen if the risk occurs
- Likelihood of occurrence : How probable it is that the consequences will happen

- **Purpose of Risk Analysis**
- The goal is to develop a clear and comprehensive understanding of risk within an organization & help organizations differentiate between acceptable (minor) risks and unacceptable (major) risks that require action
- **Role in Decision-Making**
- **Risk analysis provides essential information that supports:**
- Risk evaluation
- Planning control measures
- Reducing or managing risks effectively
- **Most important method:** **Risk matrix method**

# Risk matrix method

- **The Risk Matrix is a common tool used to:**
- Estimate risk level
- Compare different risks
- Rank risks by priority
- **It is based on two main variables:**
- Severity of consequences
- Likelihood (probability) of occurrence

# Most common Scoring System in public health

## 1. Consequence (Impact) Scoring System

Risk consequences are commonly classified using a five-level severity scale:

- Insignificant / Negligible (1)
- Minor (2)
- Moderate (3)
- Major (4)
- Catastrophic (5)
- **Impact is scored from 1 to 5,** where 5 represents the most severe outcome.
- **Standardizing consequence levels** is essential to compare risks consistently and prioritize risks appropriately
- **Each level** is linked to **clear definitions** and examples **(e.g., catastrophic =death; major = serious injury or long-term disability).**

## 1. Likelihood Scoring

- Likelihood Expressed as: Score (1–5),

| Probability | score |
|---|---|
| Rare/Remote | 1 |
| Unlikely | 2 |
| Possible | 3 |
| Likely | 4 |
| Almost Certain | 5 |

# Methods for Risk Rating Estimation based on risk matrix method

- Organizations must choose an appropriate method to estimate risk levels.
- There are three main approaches:

### 1. Quantitative Methods

Use numerical data to calculate risk

Risk = numerical values for probability and impact

More precise and objective

Require reliable data, time, and expertise

**RISK MATRIX**

| PROBABILITY ↑ | | | | | |
|---|---|---|---|---|---|
| Very Likely - 5 | 4 | 10 | 15 | 20 | 25 |
| Likely - 4 | 4 | 8 | 12 | 16 | 20 |
| Possible - 3 | 3 | 6 | 9 | 12 | 15 |
| Unlikely - 2 | 2 | 4 | 6 | 8 | 10 |
| Very Likely - 1 | 1 | 2 | 3 | 4 | 5 |
| | 1 | 2 | 3 | 4 | 5 |
| | Negligible | Slightly | Moderate | High | Very High |
| | *SEVERITY →* | | | | |

| Risk | Risk level | Condition |
|---|---|---|
| 1 to 6 | Low Risk | *May be acceptable but review task to see if risk can be reduced further.* |
| 8 to 12 | Medium Risk | *Task should only be executing with appropriate management authorization after consulting with specialist personal.* |
| 15 to 25 | High Risk | *Task must not proceed, until adequate action taken to minimize the risk.* |

# **Practical application:** a study conducted on health care organization

| PROBABILITY | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Expected to occur in most circumstances | 0,9 | 0,09 | 0,27 | 0,45 | 0,63 | 0,81 |
| | Will probably occur in most circumstances | 0,7 | 0,07 | 0,21 | 0,35 | 0,49 | 0,63 |
| | Might occur occasionally | 0,5 | 0,05 | 0,15 | 0,25 | 0,35 | 0,45 |
| | Could happen some time | 0,3 | 0,03 | 0,09 | 0,15 | 0,21 | 0,27 |
| | May happen only in exceptional circumstances | 0,1 | 0,01 | 0,03 | 0,05 | 0,07 | 0,09 |
| | | | 0,1 | 0,3 | 0,5 | 0,7 | 0,9 |
| | | | Injuries requiring no treatment or first aid | Minor injury, first aid only required | Injury requiring medical treatment and some lost time | Serious injury, hospital treatment required | Death or permanent disability |
| | | | IMPACT | | | | |

| RISK EXAMPLE | PROBABILITY | IMPACT | RISK LEVEL | RISK GRADING |
|---|---|---|---|---|
| PATIENT INJURY | 0,3 | 0,5 | 0,15 | MODERATE |

| RISK GRADING COLORS | | | | |
|---|---|---|---|---|
| 0,01-0,03<br>VERY LOW RISK | 0,05-0,07<br>LOW RISK | 0,09-0,27<br>MODERATE RISK | 0,35-0,49<br>HIGH RISK | 0,63-0,81<br>VERY HIGH RISK |

## 2.Qualitative Methods

Use descriptive scales (e.g., low, medium, high)

Based on judgment rather than numbers

Easier to apply when data are limited

Less accurate and more subjective

| LIKELIHOOD DESCRIPTORS | | IMPACT/CONSEQUENCE LEVELS | | | | |
|---|---|---|---|---|---|---|
| | | SLIGHT / NEGLIGIBLE | MINOR | MODERATE | MAJOR | CATASTROPHIC |
| | | Injuries requiring no treatment or first aid | Minor injury, first aid only required | Injury requiring medical treatment and some lost time | Serious injury, hospital treatment required | Death or permanent disability |
| RARE / REMOTE | May happen only in exceptional circumstances | VERY LOW | VERY LOW | LOW | LOW | MODERATE |
| UNLIKELY | Could happen some time | VERY LOW | LOW | MODERATE | MODERATE | MODERATE |
| POSSIBLE / OCCASIONALLY | Might occur occasionally | LOW | MODERATE | MODERATE | MODERATE | HIGH |
| LIKELY | Will probably occur in most circumstances | LOW | MODERATE | MODERATE | HIGH | VERY HIGH |
| ALMOST CERTAIN | Expected to occur in most circumstances | MODERATE | MODERATE | HIGH | VERY HIGH | VERY HIGH |

| RISK EXAMPLE | LIKELIHOOD | IMPACT | RISK GRADING |
|---|---|---|---|
| PATIENT INJURY | UNLIKELY | MAJOR | MODERATE |

| RISK GRADING COLORS | | | | |
|---|---|---|---|---|
| VERY LOW RISK | LOW RISK | MODERATE RISK | HIGH RISK | VERY HIGH RISK |

### 3. Semi-Quantitative Methods

- A hybrid approach between qualitative and quantitative
- Use scoring systems to rank risks
- Numerically convert expert judgment into ordered categories
- Help prioritize risks in a structured way

**Why It's Widely Used?**

- Balances simplicity and measurability
- Reduces weaknesses of purely qualitative methods
- Requires fewer data than full quantitative analysis
- Many organizations prefer the semi-quantitative approach because it offers a practical compromise between accuracy and feasibility, although it cannot fully match the precision of quantitative models.

| LIKELIHOOD DESCRIPTORS | | IMPACT/CONSEQUENCE LEVELS | | | | |
|---|---|---|---|---|---|---|
| | | **SLIGHT / NEGLIGIBLE [1]** | **MINOR [2]** | **MODERATE [3]** | **MAJOR [4]** | **CATASTROPHIC [5]** |
| | | Injuries requiring no treatment or first aid | Minor injury, first aid only required | Injury requiring medical treatment and some lost time | Serious injury, hospital treatment required | Death or permanent disability |
| **RARE / REMOTE [1]** | May happen only in exceptional circumstances | 1 VERY LOW | 2 VERY LOW | 3 LOW | 4 MODERATE | 5 MODERATE |
| **UNLIKELY [2]** | Could happen some time | 2 VERY LOW | 4 LOW | 6 MODERATE | 8 MODERATE | 10 MODERATE |
| **POSSIBLE / OCCASIONALLY [3]** | Might occur occasionally | 3 LOW | 6 MODERATE | 9 MODERATE | 12 MODERATE | 15 HIGH |
| **LIKELY [4]** | Will probably occur in most circumstances | 4 LOW | 8 MODERATE | 12 MODERATE | 16 HIGH | 20 VERY HIGH |
| **ALMOST CERTAIN [5]** | Expected to occur in most circumstances | 5 MODERATE | 10 MODERATE | 15 HIGH | 20 VERY HIGH | 25 VERY HIGH |

| RISK EXAMPLE | LIKELIHOOD | IMPACT | RISK LEVEL | RISK GRADING |
|---|---|---|---|---|
| PATIENT INJURY | LIKELY [4] | MAJOR [4] | 16 | HIGH |

| RISK GRADING COLORS | | | | |
|---|---|---|---|---|
| 1-2 VERY LOW RISK | 3-4 LOW RISK | 5-12 MODERATE RISK | 15-16 HIGH RISK | 20-25 VERY HIGH RISK |

# Comparison between qualitative and quantitative method

| Qualitative or subjective | Quantitative |
|---|---|
| Subjective oriented assessment | Objective oriented approach |
| Using non numerical values to define risk factors | Using numerical values to define risk factors |
| Likelihood and impacts with definite values based on individual judgement of an expertise | Likelihood and impacts with definite numbers based on history of events |
| Requiring no specialist skills or complicated techniques | Requiring specialist skills and complicated techniques<br>Commonly used in the high technology industries |

- **Advantages of risk matrix method**

Simple and easy to use

Visual and intuitive

Useful even when data are limited

Does not require advanced technical expertise

- **Limitations & Considerations:**

Requires clear definitions of risk categories,

May oversimplify complex situations (subjective),

Effectiveness depends on proper design and consistent use

# Applications in Public Health

- **Environmental Health:** Setting standards for air pollutants (PM2.5, ozone), water contaminants (lead, PFAS), and soil cleanup levels.
- **Food Safety:** Determining safe levels of pesticides, veterinary drug residues, and food additives (e.g., by JECFA, EFSA).
- **Infectious Disease:** Modeling epidemic/pandemic risks (e.g., COVID-19), estimating vaccine impact, and planning for bioterrorism threats.
- **Occupational Health:** Establishing workplace exposure limits for chemicals and noise (e.g., by OSHA, ACGIH).
- **Lifestyle & Behavioral Risks:** Quantifying the health impact of smoking, poor diet, physical inactivity, and alcohol use (leading to major reports like the Global Burden of Disease).

# Special considerations

- **Complex and Multiple Consequences**
- •A single risk may lead to multiple consequences across different domains(e.g., patient harm + reputational damage + legal involvement)
- In such cases, **a multi-risk analysis** may be needed to assess combined or interacting risks
- **Consider events occurring simultaneously or sequentially**

# Are consequence scores fixed across all studies?

- **It varies depending on the study and context.**
- **It depends on:**
- The sector (health, industry, environment, chemicals, occupational safety)
- The purpose of the study (HRA, QRA, EIA, Occupational Risk Assessment)
- The types of consequences of interest (fatalities, injuries, financial loss, reputation, environmental damage)
- **Example:**

**A single fatality:**

- In an **occupational safety** study may be classified as Catastrophic
- In an **environmental risk** study, it may be only one component of a broader ecosystem impact

# *Are probability scores fixed across all studies?*

- It is **also not fixed.**
- **It depends on:**
- The time frame considered (per year, project lifetime, per shift)
- The data source (historical data, statistics, expert judgment)
- The level of analysis (qualitative, semi-quantitative, quantitative)
- **Example:**

**A likelihood score of 3:**

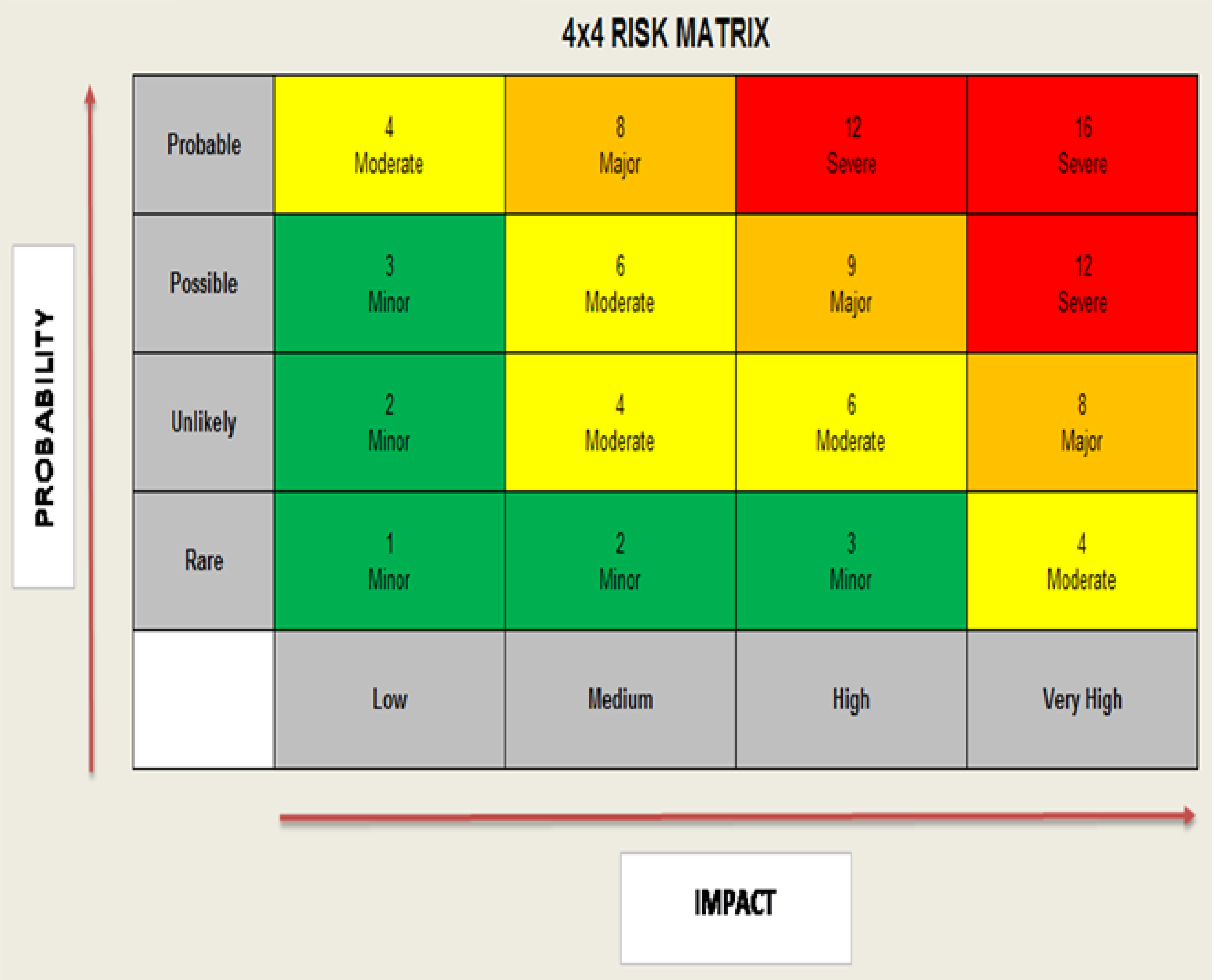
- In one risk matrix may mean Occasional
- In another matrix may mean Possible
- Even though the numeric score is the same, the interpretation is different.

The number of levels is **not fixed** either:

- Some studies use a **3×3** matrix
- Others use **4×4** or **5×5** matrices

3x3 RISK MATRIX

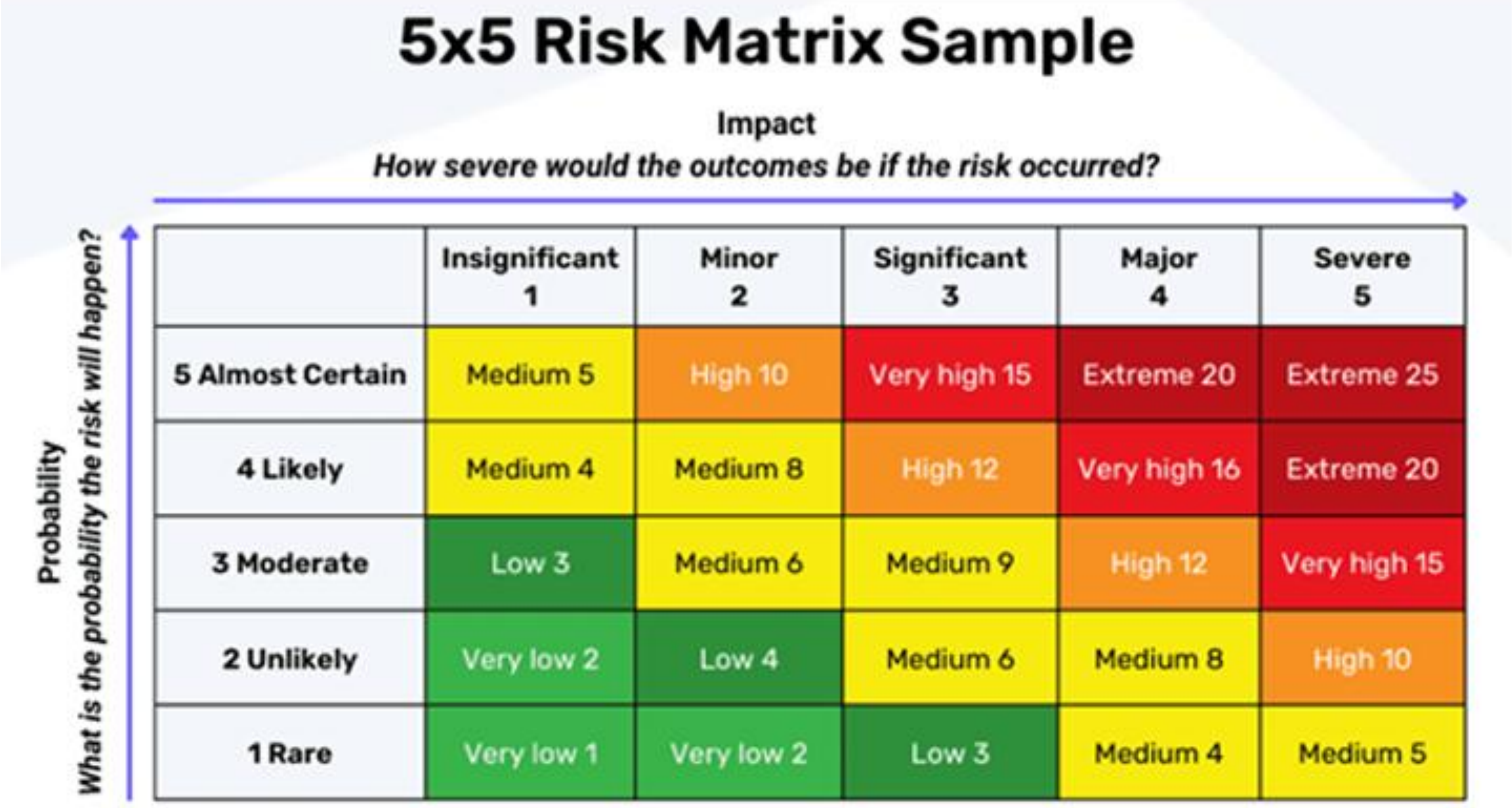
| LIKELIHOOD ↓ \ SEVERITY → | 1 | 2 | 3 |
|---|---|---|---|
| 1 | LOW - 1 - | LOW - 2 - | MEDIUM - 3 - |
| 2 | LOW - 2 - | MEDIUM - 4 - | HIGH - 6 - |
| 3 | MEDIUM - 3 - | HIGH - 6 - | HIGH - 9 - |



4x4 RISK MATRIX

| PROBABILITY | | | | |
|---|---|---|---|---|
| Probable | 4 Moderate | 8 Major | 12 Severe | 16 Severe |
| Possible | 3 Minor | 6 Moderate | 9 Major | 12 Severe |
| Unlikely | 2 Minor | 4 Moderate | 6 Moderate | 8 Major |
| Rare | 1 Minor | 2 Minor | 3 Minor | 4 Moderate |
| | Low | Medium | High | Very High |

IMPACT



5x5 Risk Matrix Sample

Impact

*How severe would the outcomes be if the risk occurred?*

Probability

*What is the probability the risk will happen?*

| | Insignificant 1 | Minor 2 | Significant 3 | Major 4 | Severe 5 |
|---|---|---|---|---|---|
| 5 Almost Certain | Medium 5 | High 10 | Very high 15 | Extreme 20 | Extreme 25 |
| 4 Likely | Medium 4 | Medium 8 | High 12 | Very high 16 | Extreme 20 |
| 3 Moderate | Low 3 | Medium 6 | Medium 9 | High 12 | Very high 15 |
| 2 Unlikely | Very low 2 | Low 4 | Medium 6 | Medium 8 | High 10 |
| 1 Rare | Very low 1 | Very low 2 | Low 3 | Medium 4 | Medium 5 |

# 3D risk matrix

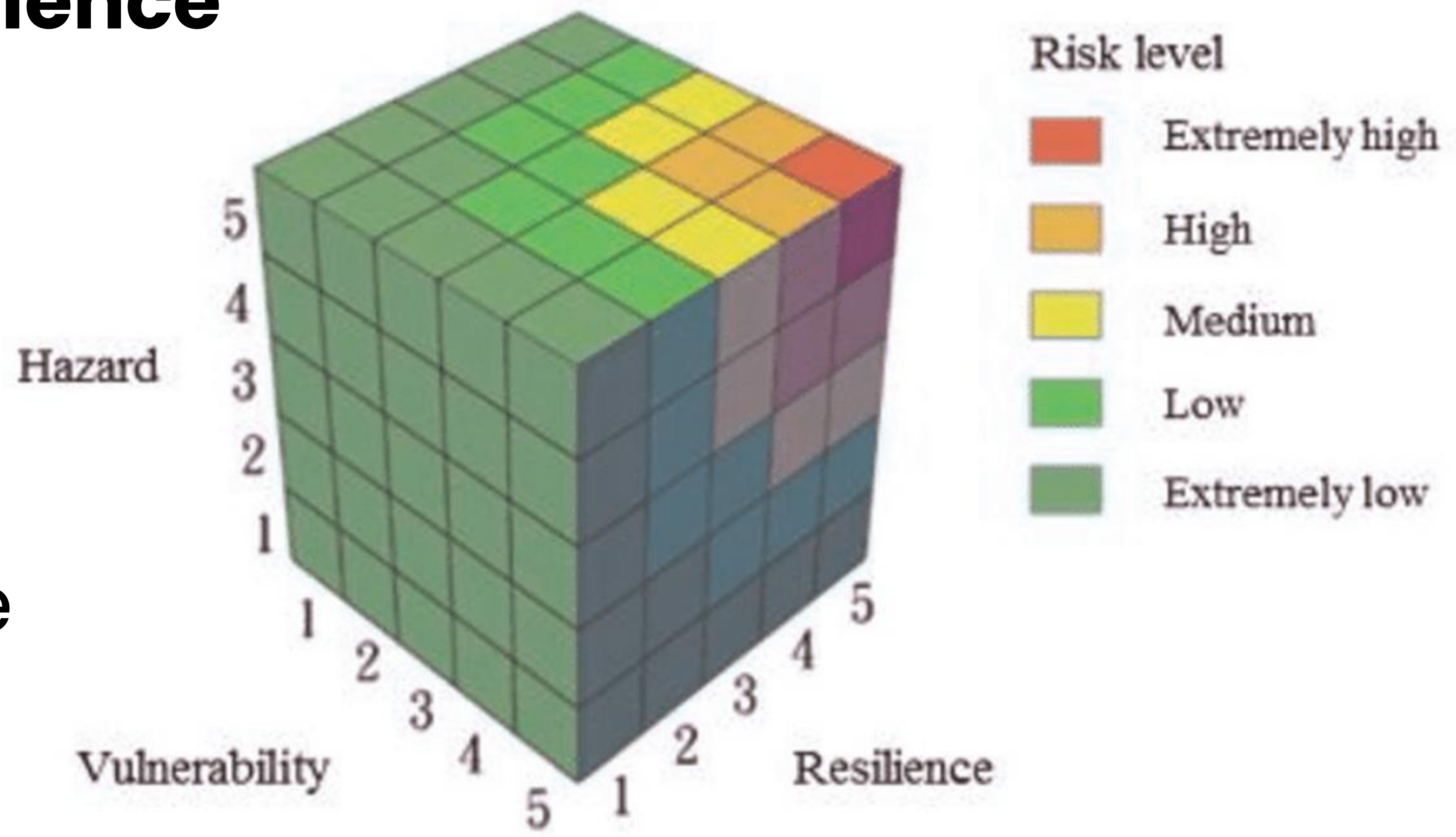
- The **3D Risk Matrix** is a **conceptual and flexible framework**, not a fixed formula.
- Risk can be modeled using **any three independent and relevant dimensions,** depending on the assessment context.

## 1. Classical 3D Model

**Hazard – Vulnerability – Community Resilience**

- **Widely used in:**
- Disaster Risk Reduction
- Climate Change Adaptation
- Public & Environmental Health

Risk Score=Hazard×Vulnerability /resilience



## 1. Alternetive 3 D models

**1. Hazard – Severity – Frequency (Probability)**

- **Common in:**
- Occupational Health & Safety
- Industrial Risk Assessment (HAZOP, FMEA)

Limited consideration of social context

**Risk = Hazard × Severity × Frequency**

**2-Hazard – Severity – Preventive (Control) Measures**

- **Used in:**
- Risk Management
- Engineering and Healthcare Settings

Risk decreases as **effectiveness of controls increases**

**Risk = Hazard × Severity / effectiveness of control**

## 3- Hazard – Exposure – Vulnerability

- **Applied in:**
- Environmental and Health Risk Assessment

Integrates **dose/exposure duration** and **susceptible populations**

**Risk = Hazard × Exposure × Vulnerability**

## 4. Hazard – Vulnerability – Capacity

- Capacity may substitute **Community Resilience**
- Reflects **available resources** and **response ability**

**Risk Score = Hazard × Vulnerability / community capacity**

# Key Quantitative Metrics & Tools in Public Health

- **Attributable Risk (AR):** The proportion of disease incidence in an exposed population that is due to the exposure.
- **Relative Risk (RR):** The ratio of disease risk in an exposed group to the risk in an unexposed group.
- **Disability-Adjusted Life Years (DALYs):**
- It measures the total burden of disease
- It combines Years of Life Lost (YLL) due to premature death with Years Lived with Disability (YLD).Formula: DALY = YLL + YLD
- **Quality-Adjusted Life Years (QALYs):**
- It measures both how long people live and how well they live. It is used in cost-effectiveness analysis to evaluate medical treatments. Formula: QALY=years of life *quality weight
- **Margin of Exposure (MOE):**
- Used in toxicology .It compares a harmful dose to the actual human exposure level
- Formula: MOE = Toxic Dose ÷ Human exposure dose

# 5 -Uncertainty analysis :

- It is to evaluate any bias or uncertainty occurred in the estimated values during the process of assessment like uncertainty about the values of : effective dose of hazard , the degree of hazard ..etc

# 6 – Total risk estimation

- The exposure data for the subgroups of the exposed population are combined with the dose effect/dose response relationships to calculate the likely health risk among this population.

# 7-Risk control:

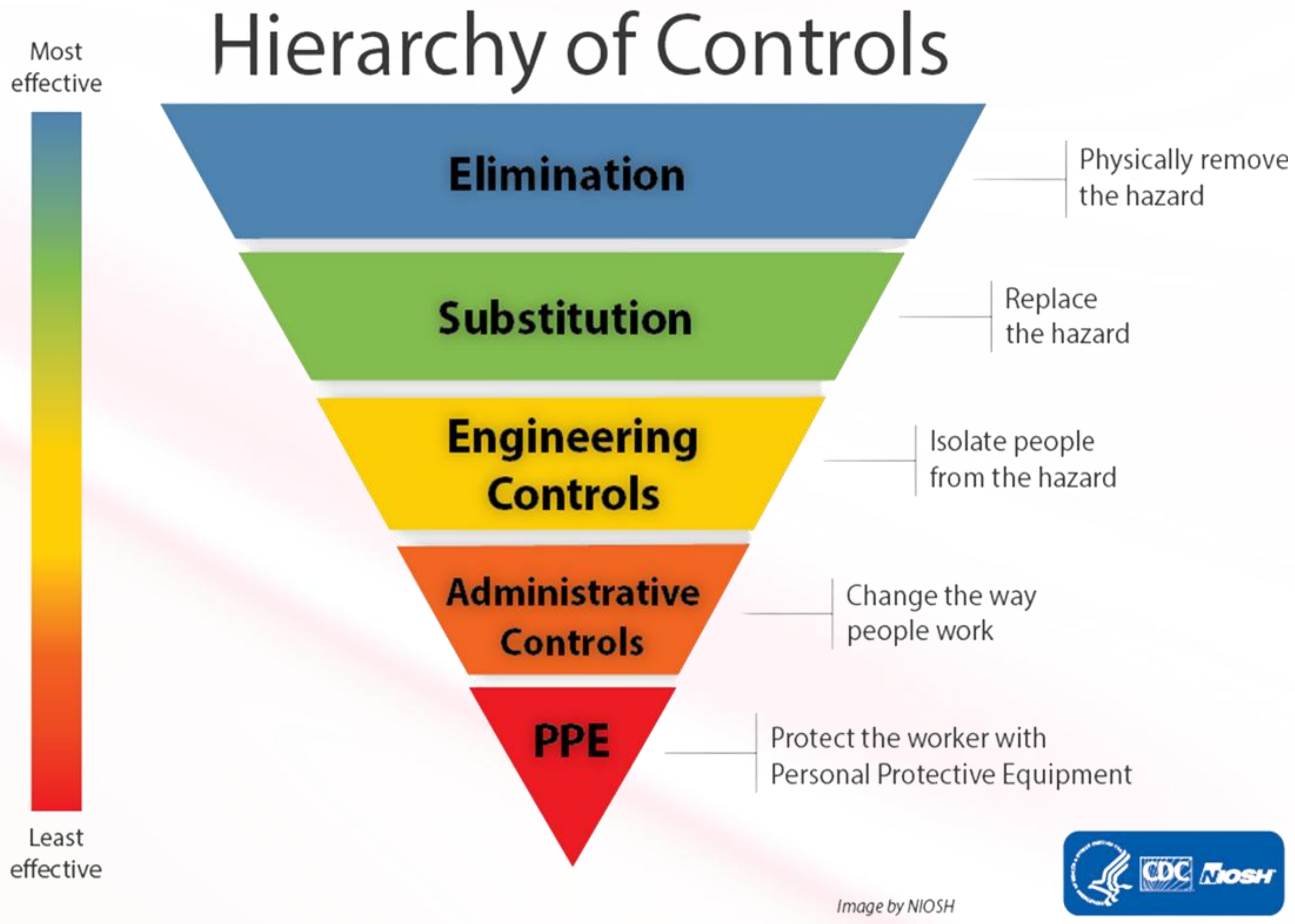
- Determine appropriate ways to eliminate the hazard, or control the risk when the hazard cannot be eliminated.

# Prevention of occupational hazards

# Primary prevention of occupational hazards

**Goal:** Prevent the disease before exposure occurs

- **Elimination:** Remove the hazard completely e.g., banning asbestos
- **Substitution:** Replace with a safer alternative e.g., water-based solvents instead of organic solvents
- **Engineering controls:** Isolate people from the hazard e.g., ventilation systems, machine guards
- **Administrative controls:** Reduce exposure through policies e.g., job rotation, work–rest cycles
- **Personal Protective Equipment (PPE):** Last line of defense e.g., masks, glove



# Secondery prevention

**Goal:** Detect disease early and prevent progression

- Pre-employment and periodic medical examinations
- Biological monitoring
- Health surveillance
- Screening test

# Tertiary Prevention

**Goal:** Reduce complications and disability

- Treatment and rehabilitation
- Job modification or redeployment

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thank you