TECHNOLOGICAL DISASTERS IN ASIA: EPIDEMIOLOGICAL PROFILE FROM THE YEAR 2000 TO 2021

Authors:

- ANDREA FERNÁNDEZ GARCÍA[1]
- RICK KYE GAN[1]
- JOSÉ ANTONIO CERNUDA MARTÍNEZ[1*]
- PEDRO ARCOS GONZÁLEZ[1]

[1.] Unit for Research in Emergency and Disaster, Department of Preventive Medicine and Public Health, Universidad de Oviedo, 33006 Oviedo, Spain. Tel +34985103545.

***Corresponding author**: José Antonio Cernuda Martínez (jacernudam@gmail.com) +34660611862

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Abstract

Technological disasters in Asia have significant public health and environmental implications, but there is limited epidemiological analysis of these events. The objective of this research was to characterize the epidemiological profile of technological disasters in Asia from 2000 to 2021, focusing on morbidity and mortality trends. A cross-sectional study was conducted using data from EM-DAT, DesInventar, NatCAt, and Sigma. The study categorized disasters into transport, industrial, and miscellaneous accidents. Statistical analyses were used to examine frequencies, trends, and correlations among the different disaster types.

From 2000 to 2021, Asia experienced 2 333 technological disasters, with transport accidents being the most frequent (55.77%), followed by industrial (26.10%) and miscellaneous accidents (18.13%). The overall trend showed a statistically significant decrease in the frequency of these disasters and in average mortality and injury rates. The study highlighted the varying impact of different disaster types, with industrial accidents causing the highest fatality and affected rates despite being less frequent than transport accidents. The study indicates a declining trend in the frequency and severity of technological disasters in Asia, reflecting improved safety measures and disaster management. However, the high impact of industrial accidents underscores the need for targeted prevention strategies. The research also points to the necessity of standardized data collection criteria to enhance the comparability and reliability of disaster-related research outcomes.

Keywords

Technological disasters; morbidity; mortality; epidemiology

Introduction

A disaster represents a significant disruption in the functioning of a community or society, occurring at various scales and resulting from hazardous events that interact with existing conditions of exposure, vulnerability, and capacity. This interaction can lead to a range of losses and impacts, including human, material, economic, and environmental. The effects of such a disaster can be

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immediate and localized but often extend to be widespread and persist over an extended period. These events frequently challenge or surpass the ability of a community or society to manage with its own resources, necessitating external assistance that may come from neighbouring areas, national authorities, or international bodies.[1] There are two broad categories of disasters: those caused by natural hazards and technological hazards.[2]

Technological hazards stem from industrial or technological activities, unsafe processes, infrastructure breakdowns, or human actions.[3] Although occasionally, they may also occur as a result of a natural hazard, in such cases referred to as Natural Hazards Triggering Technological Accidents (Natech).[4] Technological disasters encompass transport (terrestrial, maritime, and aviation), industrial (such as gas leaks, oil spills, or explosions at chemical or nuclear facilities)[3,5], as well as miscellaneous accidents, such as the failure of various structures like bridges, mines, or buildings. [3] Contributing factors to these disasters include rapid demographic expansion and increases in urbanization and motor vehicle usage.[6]

Furthermore, technological disasters result in significant economic losses and, in some instances, release contaminants into the environment that cause health problems among the exposed population.[7,8] For instance, the industrial accident in Seveso on July 10, 1976, in Lombardy, Italy, led to the most significant known residential exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin.[9] While technological disasters are relatively frequent and have considerable impacts, the number of studies concerning this type of disaster is smaller compared to those caused by natural hazards.[10]

In recent decades, Asia has experienced a high frequency of significant technological disasters. Between 2000 and 2019, it was the continent with the most technological disasters.[3] Notable among these was the collapse of the Savar building (Rana Plaza) in Bangladesh in 2013, resulting in 1 200 deaths and approximately 2 500 injuries.[11] Other significant events include a 2015 explosion at a chemical products warehouse in Tianjin, China, causing 178 deaths and 677 injuries, as well as severe environmental contamination.[12] In 2017, an explosion at a coal mine in Zemestanyurt, Iran, killed 42 people, and at least 75 were injured[13], and in the same year, the fire and collapse of the Plasco building led to 26 deaths and over 200 injuries.[14] In 2019, an explosion at the chemical industrial park in Xiangshui, China, resulted in dozens of deaths and significant economic losses.[15] More recently, in August 2020, the Beirut port explosion in Lebanon resulted in 220 fatalities and around 7,000 injuries, in addition to the destruction of several health centers and the need for international health assistance.[16]

This study aims to characterize the epidemiological profile of technological disasters that have occurred in Asia from the year 2000 to 2021, in terms of morbidity and mortality produced, as well as to analyze their temporal trends.

Methodology

This study involved a retrospective descriptive observational analysis of technological disasters on the Asian continent, adhering to the definition of technological disaster according to IRDR.[17] Data were sourced from various databases, including EM-DAT-CRED[3], DesInventar[18], NatCAt[19], and Sigma.[20]

A descriptive analysis of the distribution of episodes was performed using absolute and relative frequencies by year and for the total period studied, employing measures of central tendency (mean) and dispersion (standard deviation), as well as average rates of affected, injured, and deceased per year per million inhabitants. The chi-square test was applied to compare the frequencies of each type of technological disaster.

The ANOVA test was applied to compare the average annual rates from 2000 to 2021 per million inhabitants of fatalities, injuries, and those affected according to the type of technological disaster. The Mann-Kendall test was used to verify the existence of temporal trends in the average mortality rate per million inhabitants, the average rate of affected per million inhabitants, and the average rate of injuries per million inhabitants for each type of technological disaster. The augmented Dickey-Fuller test was employed to check if the time series exhibited stationarity. Pearson's correlation coefficient was utilized to analyze the relationship between the average mortality rates per million

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inhabitants, the average affected rate per million inhabitants, and the average injury rate per million inhabitants. Confidence intervals of 95% (CI95) were calculated. Exponential smoothing was used to forecast the annual number of technological disasters of each type up to the year 2032, based on the absolute frequency of disasters, along with their corresponding CI95%. An alpha value of 0.5 was used as the smoothing constant. All calculations were performed using the Stata v.15 statistical package.

Results

Between 2000 and 2021, a total of 2 333 technological disasters were recorded in Asia. Of these, 1 301 (55.77%) were transport accidents, 609 (26.10%) were industrial accidents, and 423 (18.13%) were miscellaneous accidents. Table 1 shows the absolute and relative frequencies of each type of disaster by year of occurrence and the average annual mortality rates, affected rates, and injury rates per million inhabitants, including their standard deviations. No statistically significant differences were found between the average rates of fatalities, affected, and injuries per million inhabitants.

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Table 1: Absolute and relative frequencies of each type of disaster by year of occurrence and the average annual mortality rates, affected rates, and injury rates per million inhabitants with their standard deviations (SD)

	Transport Accidents							Industrial Accidents							Miscellaneous Accidents						
Year	n (%)	Mortality Rate		Affected Rate		Injure Rate		n (%)	Mortality Rate		Affected Rate		Injure Rate		n (%)	Mortality Rate		Affected Rate		Injure Rate	
		Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	Mean	SD		Mean	DS	Mean	SD	Mean	SD
2000	100 (65, 36)	1413.91	6295.35	0.16	1.53	1828.15	14639.67	30 (19, 61)	1063.07	5416.33	1346.30	6439.51	2350.42	7977.48	23 (15, 03)	175.58	325.84	0.74	3.45	126468.10	603686.90
2001	81 (57, 45)	227.21	843.21	0.00	0.03	446.12	2783.41	36 (25, 53)	633.29	3168.66	0.00	0.00	1003.83	5703.80	24 (17, 02)	174.25	475.39	4725.77	22746.73	237.15	508.80
2002	97 (61, 39)	211.51	637.34	0.11	1.09	115.84	330.76	37 (23, 42)	3147.04	17972.83	0.00	0.00	19.47	54.44	24 (15, 19)	25.63	46.63	202.61	992.60	57.69	149.01
2003	96 (58, 18)	488.24	2099.58	131.20	1257.08	163.79	981.40	45 (27, 27)	100.57	286.80	355.28	1948.57	14.26	46.80	24 (14, 55)	811.97	3155.76	0.00	0.00	177.73	552.65
2004	86 (47, 78)	821.40	2665.83	3094.69	26389.65	793.27	3028.11	66 (36, 67)	2988.64	22560.85	7813.22	63119.33	513.92	3070.86	28 (15, 56)	173.77	424.19	0.00	0.00	1240.13	5830.31
2005	98 (50, 26)	1181.98	5000.14	4.83	37.59	360.68	1274.62	65 (33, 33)	2011.95	15161.77	32.42	148.73	51.07	238.82	32 (16, 41)	242.55	838.55	125.17	692.54	345.10	889.56
2006	62 (48, 82)	209.20	749.57	4.73	23.78	98.56	470.50	48 (37, 80)	1207.55	8093.22	2104.41	11315.89	13.05	35.41	17 (13, 39)	68.56	127.24	0.00	0.00	66.70	141.69
200	65	152	1159	1.32	9.35	71.6	303.	37	94.6	205.	130.8	516.6	167.	834.	18	32.	74.7	110.	363.	28.45	98.31

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7	(54, 17)	3.52	0.89			7	76	(30, 83)	1	11	0	4	91	53	(15, 00)	51	8	67	77		
2008	53 (54, 64)	3042.41	14119.25	261.00	1420.42	219.72	865.41	29 (29, 90)	33.72	117.44	13.05	69.59	30.07	141.64	15 (15, 46)	155.24	462.78	14.81	57.38	272.47	745.28
2009	50 (54, 35)	221.82	781.56	580.13	3647.86	8.36	22.85	30 (32, 61)	59.17	138.07	289.98	1388.03	9.75	24.10	12 (13, 04)	206.29	517.87	0.00	0.00	319.47	893.51
2010	60 (51, 28)	228.03	811.04	18.76	111.66	151.50	744.65	26 (22, 22)	37.59	58.36	101.00	463.40	66.02	227.64	31 (26, 50)	272.35	883.74	10.86	60.10	320.33	1485.77
2011	59 (61, 46)	144.89	392.02	4.40	23.96	26.35	107.26	20 (20, 83)	19.95	45.63	0.20	0.78	20.02	56.66	17 (17, 71)	96.35	207.20	5.65	18.60	47.59	70.23
2012	37 (53, 62)	277.62	1099.78	3.62	19.71	35.71	180.06	21 (30, 43)	171.05	464.88	0.37	10582.00	1555.80	5226.87	11 (15, 94)	111.41	289.58	294.27	975.98	114.57	352.35
2013	44 (61, 11)	206.95	970.74	19.59	128.04	245.86	1603.23	13 (18, 06)	173.19	317.35	3239.70	11658.35	165.68	301.11	15 (20, 83)	109.30	234.32	0.00	0.00	78.52	237.60
2014	50 (57, 47)	1749.93	8581.53	46.62	209.99	56.07	251.64	18 (20, 69)	396.62	936.69	128933.10	547016.80	128.35	333.57	19 (21, 84)	31.20	85.91	9.40	40.98	31.64	88.19
2015	44 (52, 38)	477.22	1833.54	227.53	1227.78	29.08	69.32	17 (20, 24)	55.98	118.80	2.51	9.50	7.94	19.77	23 (27, 38)	388.39	1682.85	1419.09	6805.71	335.31	1004.81
2016	50 (55. 56)	609.70	2629.69	5.08	33.83	685.83	4427.08	19 (21, 11)	188.87	464.08	37055.79	161522.50	265.59	1046.15	21 (23, 33)	152.69	581.98	0.00	0.00	315.64	1196.35
201	45	79.0	163.	3.46	19.4	101.	389.	15	487.	1125	0.00	0.00	807.	249	22	120	341.	136	6400	57.70	166.5

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7	(56, 25)	1	13		2	25	91	(16, 25)	98	.52			91	8.89	(27, 50)	.41	96	4.69	.95		0
201 8	44 (70, 97)	193. 01	539. 57	0.38	1.77	47.3 3	106. 26	8 (12, 90)	35.3 1	38.4 4	0.00	0.00	12.2 0	18.0 6	10 (16, 13)	87. 93	220. 23	0.00	0.00	253.1 4	779.1 1
201 9	32 (53, 33)	123. 71	328. 52	0.00	0.00	75.9 2	170. 41	17 (28, 33)	155. 56	217. 40	4.60	18.50	105. 27	240. 01	11 (18, 33)	8.4 1	15.8 1	500. 00	1658 .31	72.00	207.7 9
202 0	19 (55, 88)	55.5 5	93.9 2	1.70	7.38	53.3 2	156. 60	7 (20, 59)	88.3 2	105. 61	0.00	0.00	845. 37	134 8.34	8 (23, 53)	54. 92	76.7 5	0.00	0.00	52.69	127.1 4
202 1	29 (53, 70)	524. 77	2482 .29	251. 90	1353 .41	124. 80	370. 87	7 (12, 96)	59.5 7	71.9 9	34.74	76.44	79.8 1	148. 18	18 (33, 33)	89. 88	277. 38	141 5.20	5486 .31	31.63	70.78
TOT AL	130 1 (55, 77)	700. 13	4926 .10	266. 36	6864 .91	344. 02	4328 .42	609 (26, 10)	980. 47	1030 0.91	6172. 51	1004 19.20	355. 59	271 8.87	423 (18, 13)	186 .43	951. 88	527. 32	5959 .44	7113. 82	1407 93.70

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Analysis of the time series revealed that the average mortality rate (t= -2.83; p= 0.005), injury rate (t=-99.64; p< 0.000) and affected rate (t= -4.84; p< 0.000) were found to be stationary. Statistically significant decreasing trends were observed in the average mortality rate (tau= -0.56; p < 0.000) and the injury rate (tau=-0.41; p=0.008) annually. However, the average affected rate per year did not exhibit a statistically significant trend. Additionally, decreasing and statistically significant trends were also identified in the overall count of technological disasters (tau=-0.7489; p<0.000), as well as in each disaster category: transport accidents (tau= -0.75; p<0.000), industrial accidents (tau= -0.71; p<0.000), and miscellaneous accidents (tau=-0.38; p = 0.015).
Figure 1 illustrates the distribution of each type of technological disaster by country, while Figure 2 displays the rate of technological disasters per country per million inhabitants over the study period on a logarithmic scale.

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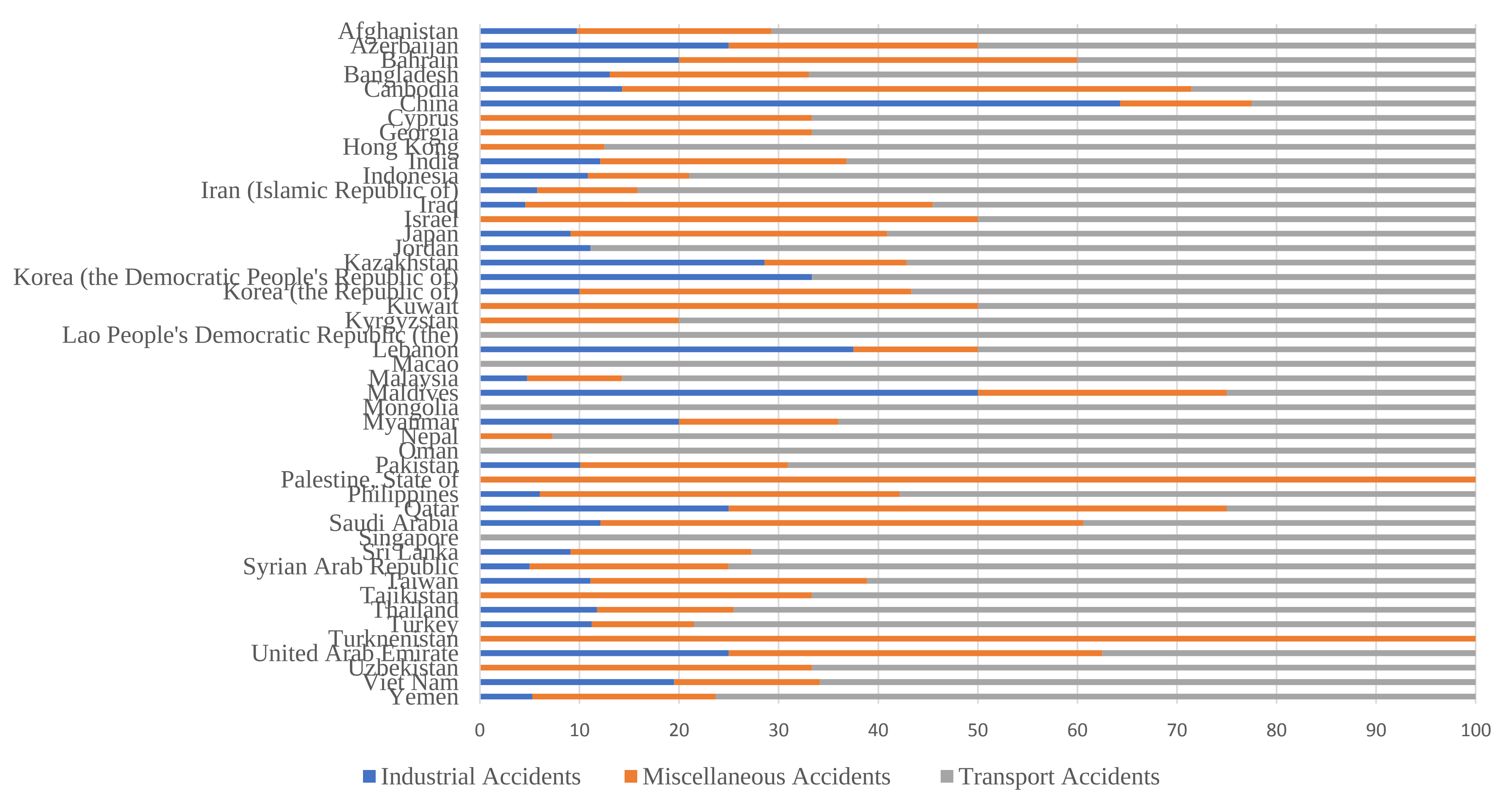
Figure 1: Frequency distribution of technological disasters in Asia in the period 2000-2021 by type and country.


Afghanistan
Azerbaijan
Bahrain
Bangladesh
Cambodia
China
Cyprus
Georgia
Hong Kong
India
Indonesia
Iran (Islamic Republic of)
Iraq
Israel
Japan
Jordan
Kazakhstan
Korea (the Democratic People's Republic of)
Korea (the Republic of)
Kuwait
Kyrgyzstan
Lao People's Democratic Republic (the)
Lebanon
Macao
Malaysia
Maldives
Mongolia
Myanmar
Nepal
Oman
Pakistan
Palestine, State of
Philippines
Qatar
Saudi Arabia
Singapore
Sri Lanka
Syrian Arab Republic
Taiwan
Tajikistan
Thailand
Turkey
Turkmenistan
United Arab Emirate
Uzbekistan
Viet Nam
Yemen
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80
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100
Industrial Accidents
Miscellaneous Accidents
Transport Accidents

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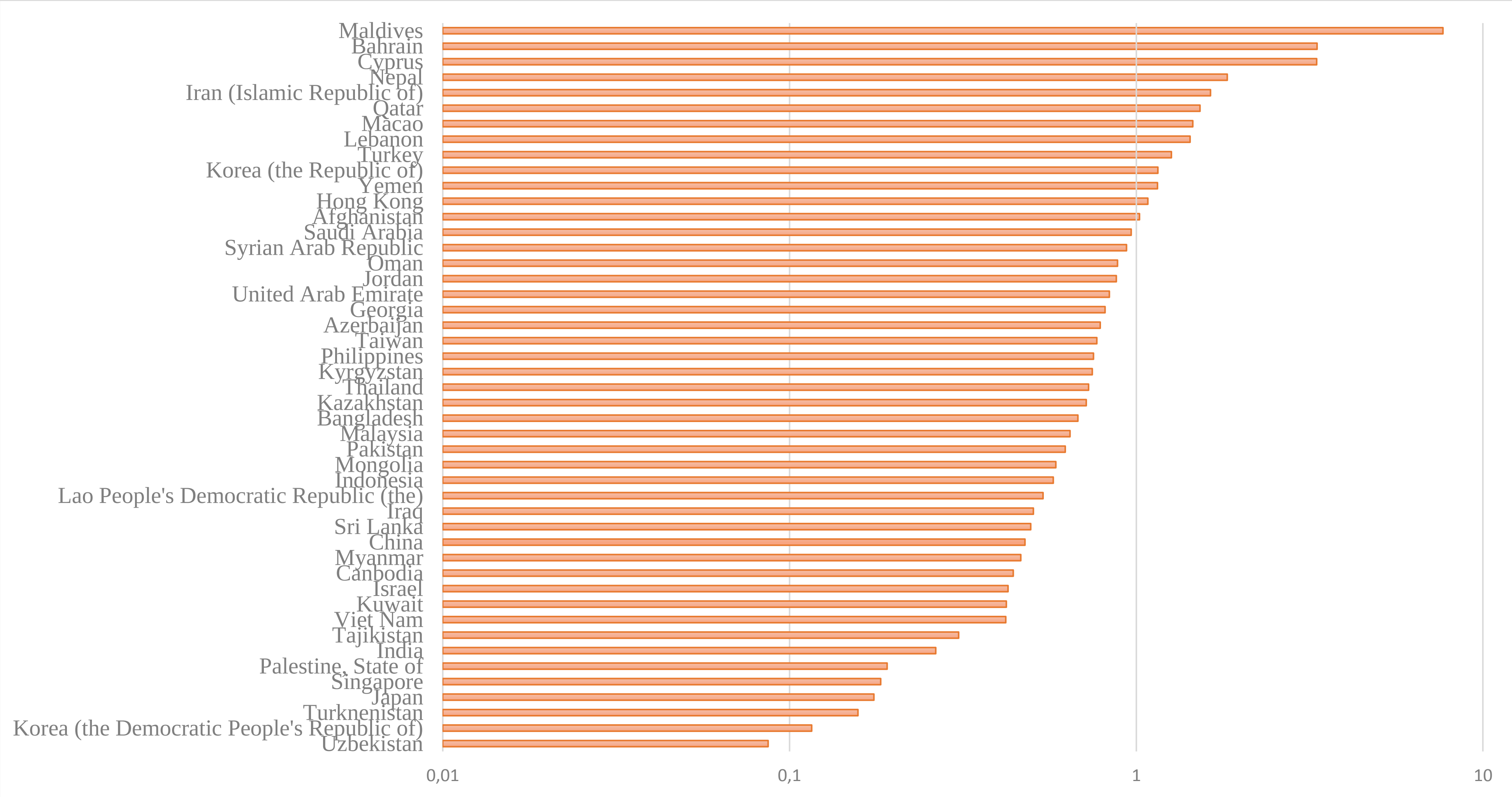
Figure 2: Rate of technological disasters by Asian country per million inhabitants, in the period 2000-2021, on a logarithmic scale with a base of 10



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Figures 3, 4 and 5 display, respectively, the forecasted absolute frequency of transport, industrial, and miscellaneous accidents, along with their 95% confidence intervals until 2032.

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Figures 3: Forecasted absolute frequency of transport accidents, along with their 95% confidence intervals until 2032.

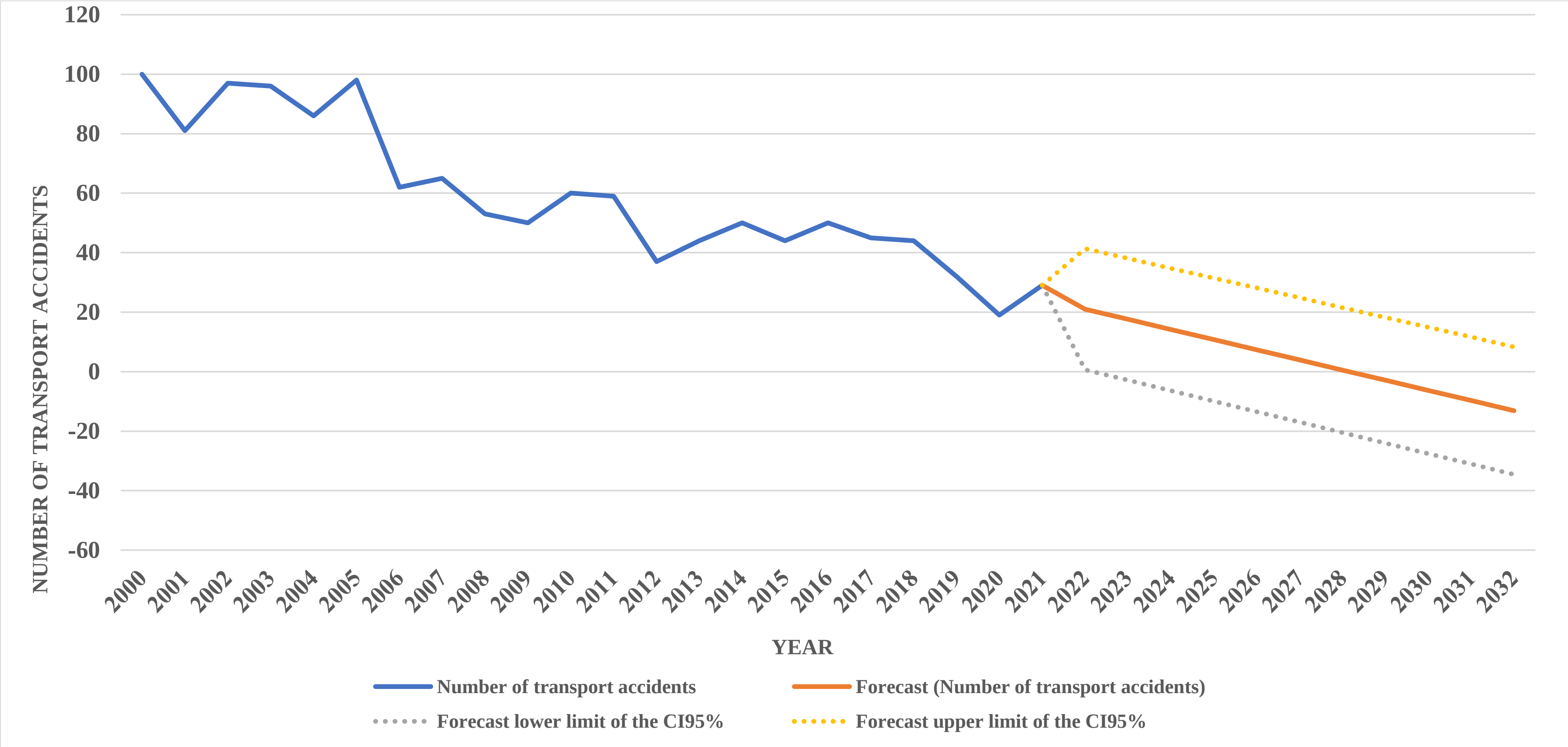

Figure 4: Forecasted absolute frequency of industrial accidents, along with their 95% confidence intervals until 2032.

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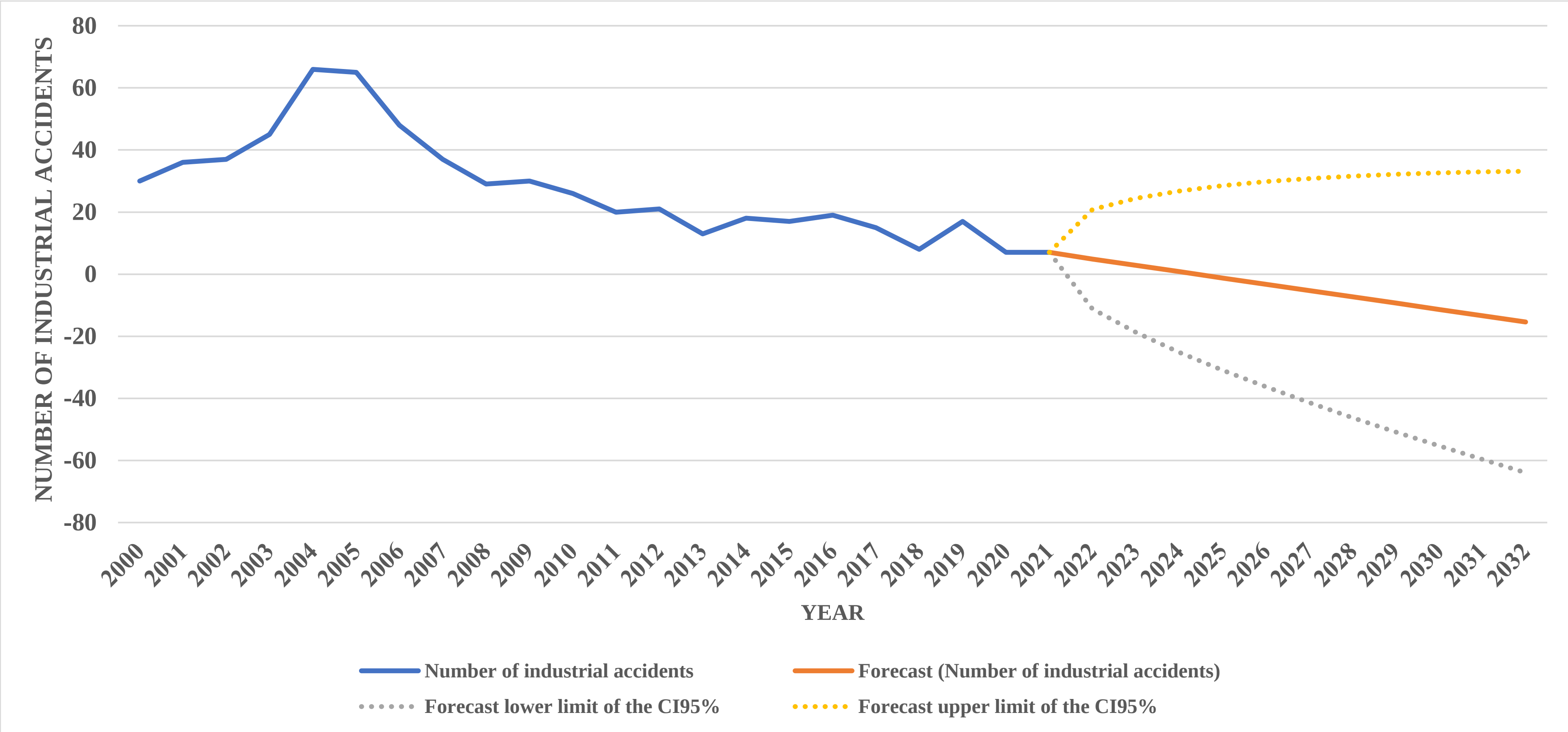

Figure 5: Forecasted absolute frequency of miscellaneous accidents, along with their 95% confidence intervals until 2032.

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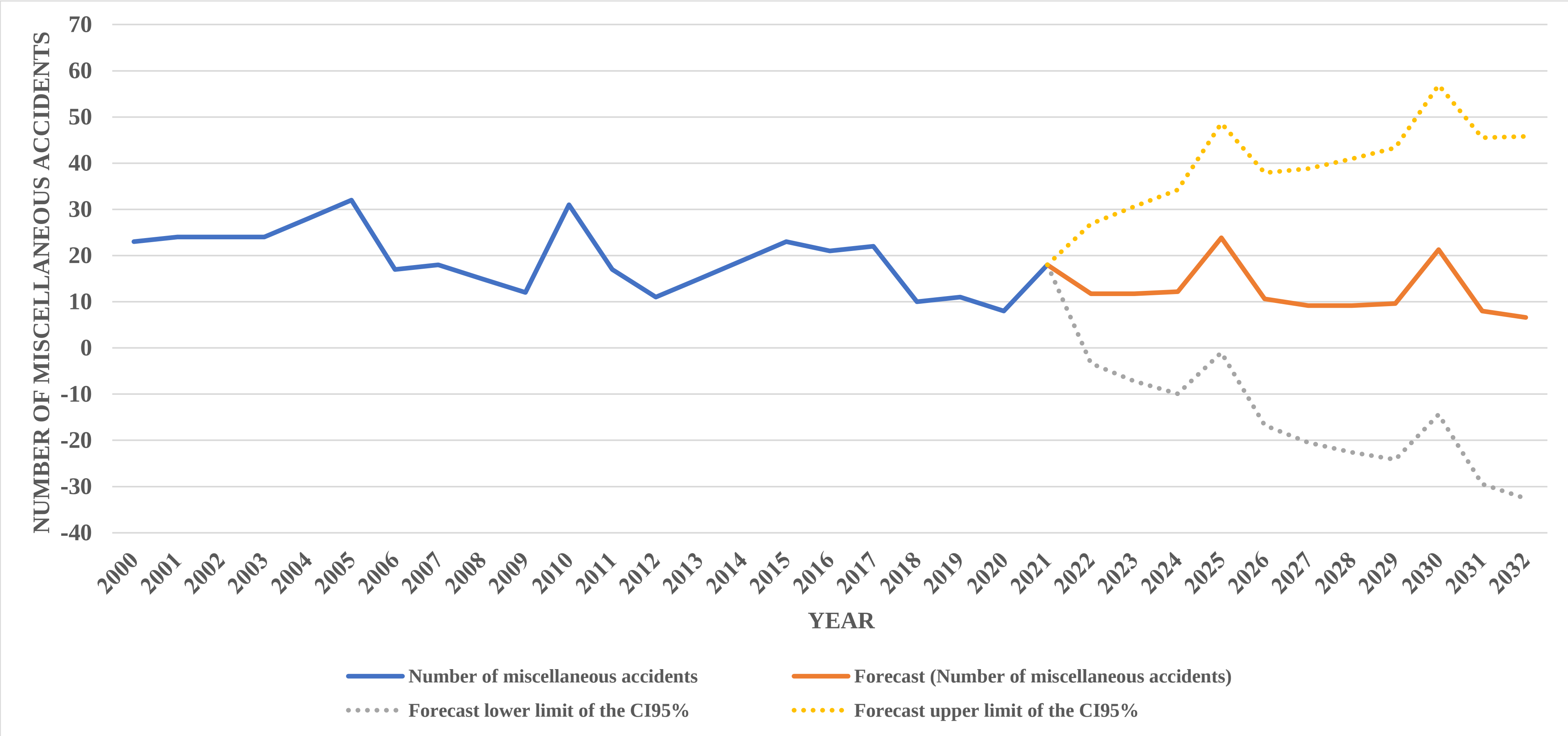

Discussion

In the context of technological disasters, existing literature often indicates an upward trend, particularly linked to the increasing rates of urbanization and industrialization.[6] Contrary to these findings, our study in Asia reveals a downward temporal trend across the spectrum of technological disasters, encompassing transport, industrial, and miscellaneous accidents. In the same way, the trends found for the average death rate and the average injury rate per year were also decreasing for the set of technological disasters.

In the period we analysed, transport accidents emerged as the predominant type of technological disaster. The decreasing trend for transport accidents found in this research is consistent with the results of a study in China on road traffic injuries between 2007 and 2016, which also found a decrease in the frequency of road traffic accidents in that period.[21] The study also noted a declining trend in traffic accident fatalities between 2007 and 2015[21], a trend consistent with our findings. Similarly, a study from South Korea examining the period from 1983 to 2017 reported a decline in mortality rates from traffic accidents since the early 2000s.[22]

While having the second-highest average mortality rate, transport accidents recorded the lowest average rates of injury and affected individuals. Research conducted in general hospitals in Southern Thailand highlighted a higher incidence of traffic-related fatalities among young men.[23] This aligns with the findings of a systematic review by Vinish et al.[24], on the prevalence of traffic accident injuries in Southeast and South Asia. The review found that the male mortality rate from traffic injuries was higher than that of females, with young adult males primarily affected by such accidents. A similar pattern was observed in a study conducted at a public hospital in Karachi, Pakistan, where males were predominantly affected in these accidents.[25]

Industrial accidents ranked as the second most frequent type of technological disaster identified in this study. A global analysis of industrial disasters from 1995 to 2021 showed that Asia had the highest incidence of these events compared to other continents during this timeframe.[26] Industrial activities inherently elevate the risk of explosions, fires, and maritime or rail disasters, potentially leading to fatalities, injuries, and economic impacts.[27,28] Industrial accidents in this study had the highest measured rates of fatalities and affected individuals. Examples of industrial accidents include chemical spills, structural collapses, explosions, gas leaks, radiation incidents, and oil spills.[3]

The 1984 Bhopal gas disaster in India stands as one of the most severe chemical disasters globally[29], with its health impacts affecting survivors and their descendants for years.[30,31] A follow-up study examining the long-term health impacts on individuals who were exposed to the Bhopal gas disaster while still in utero or as children found higher adult cancer rates among those born within a year following the disaster, particularly among those residing near the site compared to those born before or in more distant areas. [31] The study also revealed that males who were in the womb at the time of the accident were more likely to suffer from disabilities impacting their employment 15 years later.[31] Additionally, a cross-sectional analysis carried out from 2018 to 2020 on a group of survivors from the Bhopal gas disaster revealed the persistence of respiratory health issues, even nearly forty years after the event.[30]

Oil spills lead to considerable health impacts, manifesting as respiratory, renal, hepatic, neurological, endocrine, and hematological disorders.[32] A 2013 oil pipeline rupture resulted in the spillage of over 50 000 litres of oil in the Gulf of Thailand.[33]

Investigations into the long-term effects of this incident revealed that, even after more than five years, some of the cleanup personnel were still experiencing alterations in their hematological, hepatic, and renal functions.[33] Complementing these findings, a study on individuals exposed to the 2007 Hebei Spirit oil spill in South Korea identified abnormalities in hematological parameters.[34]
In addition to their physical health impacts, technological disasters can significantly affect mental health.[26] It is observed that mental illnesses are more prevalent following technological disasters compared to natural disasters, a difference that might stem from the perceived inevitability of natural disasters.[35] When a disaster is attributed to human actions, the affected individuals often direct their fear and anger toward those deemed responsible. Victims and their families can experience significant emotional impact and struggle with feelings of anger, distrust, or guilt, potentially leading to long-term mental health disturbances.[36]
In the sphere of technological disasters, incidents involving radioactive or nuclear material are known to affect health significantly. The unpredictable nature of health effects from these invisible hazards, coupled with the uncertainty about the extent of exposure, contributes to these health implications.[37] In March 2011, the "3.11 Triple Disaster" occurred when the Great East Japan Earthquake led to a tsunami and the subsequent Fukushima nuclear accident.[38] Although the earthquake and tsunami were significant disasters in their own right, the mental health repercussions from the subsequent nuclear accident, which did not result in immediate fatalities, were notably more pronounced.[37]
A key limitation of this study is the variation in disaster inclusion criteria across existing databases, which limits the comparability of findings. This variation stems from each database being specifically tailored to focus on certain disaster-related aspects. This issue underscores the critical need for standardized criteria in disaster data collection to promote uniformity and facilitate more directly comparable research outcomes.
In conclusion, the data from current disaster databases consistently indicate a downward trend in the occurrence of all types of technological disasters in Asia over time, encompassing transport, industrial, and miscellaneous accidents. This declining trend is evident not only in the frequency of these disasters but also in the yearly average rates of mortality and injuries associated with them across the continent. It's noteworthy that while transport accidents are the most prevalent type of technological disaster in Asia, industrial accidents rank highest in terms of both fatalities and the number of people affected.
Research on disasters faces challenges due to the diverse criteria for including disasters in these databases. The establishment of a unified inclusion standard, especially concerning the quantitative impact of disasters, would significantly improve analysis and allow for better comparison of disaster research outcomes.

Conflict of Interest

The authors declare they have nothing to disclose.

References

1. United Nations. Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction.

https://www.undrr.org/publication/report-open-ended-intergovernmental-expert-working-group-indicators-and-terminology. 4 January 2024
2. Integrated Research on Disaster Risk. Peril Classification and Hazard Glossary. http://www.irdrinternational.org/knowledge_pool/publications/173. 4 January 2024.
3. Centre for Research on the Epidemiology of disasters. EM-DAT The International Disaster Database. https://www.emdat.be. 6 January 2024.
4. Cruz AM, Suarez-Paba MC. Advances in Natech research: An overview. Prog Disaster Sci. 2019;1. doi:10.1016/j.pdisas.2019.100013
5. United Nations Office for Disasters Risk Reduction, International Science Council. Hazard definition and classification review. Technical report. 2020. http://www.undrr.org/publication/hazard-definition-and-classification-review-technical-report. 7 January 2024.
6. Jafari H, Jafari A, Nekoei-Moghadam M, Goharinezhad S. Morbidity and mortality from technological disasters in Iran: A narrative review. J Educ Health Promot. 2019;8(1):147. doi:10.4103/jehp.jehp_401_18.
7. Centre for Research on the Epidemiology of Disasters. Technological Disasters: Trends and Transport Accidents. Report No. 65.. https://www.emdat.be. 8 January 2024.
8. Marui A, Gallardo AH. Managing groundwater radioactive contamination at the daiichi nuclear plant. Int J Environ Res Public Health. 2015;12(7):8498-8503. doi:10.3390/ijerph120708498.
9. Eskenazi B, Warner M, Brambilla P, Signorini S, Ames J, Mocarelli P. The Seveso accident: A look at 40 years of health research and beyond. Environ Int. 2018;121(Pt 1):71-84. doi:10.1016/j.envint.2018.08.051.
10. Centre for Research on the Epidemiology of Disasters. Technological disasters. Report No. 60. http://www.emdat.be. 9 January 2024.
11. Chowdhury R, Harshfield E, Roy S, et al. Life, health, and safety of industrial workers in bangladesh: should they be driven by economic rationale or moral imperative? J Occup Environ Med. 2014;56(4):e12-3. doi:10.1097/JOM.0000000000000126.
12. Zhang H, Duan H, Zuo J, et al. Characterization of post-disaster environmental management for Hazardous Materials Incidents: Lessons learnt from the Tianjin warehouse explosion, China. J Environ Manage. 2017;199:21-30. doi:10.1016/j.jenvman.2017.05.021
13. Cheng J, Zhang X, Ghosh A. Explosion risk assessment model for underground mine atmosphere. J Fire Sci. 2017;35(1):21-35. doi:10.1177/0734904116676495.
14. Shakib H, Pirizadeh M, Dardaei S, Zakersalehi M. Technical and Administrative assessement of Plasco building incident. Int J Civ Eng. 2018;9:1-13.
15. Wang G, Qiu G, Wei J, et al. Activated carbon enhanced traditional activated sludge process for chemical explosion accident wastewater treatment. Environ Res. 2023;225:115595. doi:10.1016/j.envres.2023.115595
16. Wolff E, Shankiti I, Salio F, Von Schreeb J. The Response by International Emergency Medical Teams Following the Beirut Harbor Explosion in 2020 - Who Were They, When Did They Arrive, What Did They Do, and Were They

Needed? Prehosp Disaster Med. 2022;37(4):529-534. doi:10.1017/S1049023X22000784
17. International Strategy for Disaster Reduction. Terminology: Basic Terms of Disaster Risk Reduction. http://www.unisdr.org/files/7817_7819isdrterminology11.pdf. 11 January 2024
18. The Network of Social Studies on Disaster Prevention in Latin America. http://www.desinventar.org/. 13 January 2024.
19. Munich Re. NatCat Service the natural catastrophe loss database. http://www.munichre.com. 15 January 2024.
20. Swiss Re Institute. Sigma. http://www.swissre.com/.15 January 2024.
21. Wang X, Yu H, Nie C, Zhou Y, Wang H, Shi X. Road traffic injuries in China from 2007 to 2016: the epidemiological characteristics, trends and influencing factors. PeerJ. 2019;7:e7423. doi:10.7717/peerj.7423
22. Eun SJ. Trends in mortality from road traffic injuries in South Korea, 1983-2017: Joinpoint regression and age-period-cohort analyses. Accid Anal Prev. 2020;134:105325. doi:10.1016/j.aap.2019.105325
23. Kraonual S, Lim A, Ueranantasun A, Kakchapati S. Patient and injury characteristics associated with road traffic mortality in general hospitals in southern Thailand. Asian Biomedicine. 2019;13(2):71-77. doi:10.1515/abm-2019-0042
24. Vinish V, Chakrabarty J, Vijayan S, et al. Prevalence of road traffic injuries in South East and South Asian region - A systematic review. J Neurosci Rural Pract. 2023;14(2):214-223. doi:10.25259/JNRP_25_2022.
25. Muhammad K, Shaikh S, Ashraf J, Hayat S. Characteristics, reasons and patterns of Road Traffic Injuries presenting in emergency department of a tertiary care public hospital in Karachi. Pak J Med Sci. 2022;38(4Part-II):862-867. doi:10.12669/pjms.38.4.4490.
26. Tin D, Cheng L, Hata R, Hertelendy AJ, Hart A, Ciottone G. Descriptive Analysis of the Healthcare Aspects of Industrial Disasters Around the World. Disaster Med Public Health Prep. 2023;17:e400. doi:10.1017/dmp.2023.64.
27. Maltais D, Cherblanc J, Cadell S, et al. Factors Associated with Complicated Grief Following a Railway Tragedy. Illn Crises Loss. 2023;31(3):467-487. doi:10.1177/10541373221088393.
28. Zhang L, Luo Y, Xu M, Wang G, Liang W, Xiang Y. Relative Risk of High-Danger Industries in China from 2004 to 2016. Int J Environ Res Public Health. 2020;17(9). doi:10.3390/ijerph17093017.
29. Dhara VR. Investigating the Medical Aspects of the World's Worst Industrial Disaster. New Solut. 2023;33(2-3):113-118. doi:10.1177/10482911231190583.
30. De S, Banerjee N, Sabde Y. Respiratory morbidities and lung function abnormalities in survivors of Bhopal Gas Disaster: A cross-sectional study. Respir Investig. 2022;60(2):284-292. doi:10.1016/j.resinv.2021.09.008.
31. McCord GC, Bharadwaj P, McDougal L, Kaushik A, Raj A. Long-term health and human capital effects of in utero exposure to an industrial disaster: a spatial difference-in-differences analysis of the Bhopal gas tragedy. BMJ Open. 2023;13(6):e066733. doi:10.1136/bmjopen-2022-066733.

32. Laffon B, Pásaro E, Valdiglesias V. Effects of exposure to oil spills on human health: Updated review. J Toxicol Environ Health B Crit Rev. 2016;19(3-4):105-128. doi:10.1080/10937404.2016.1168730.
33. Owusu BA, Lim A, Pongsiri N, et al. Latent Trajectories of Haematological, Hepatic, and Renal Profiles after Oil Spill Exposure: A Longitudinal Analysis. Int J Environ Res Public Health. 2023;20(4). doi:10.3390/ijerph20042871.
34. Choi YH, Hong JY, Lee MS. A Retrospective Mid- and Long-term Follow-up Study on the Changes in Hematologic Parameters in the Highly Exposed Residents of the Hebei Spirit Oil Spill in Taean, South Korea. Osong Public Health Res Perspect. 2017;8(5):358-366. doi:10.24171/j.phrp.2017.8.5.10.
35. Cernuda Martínez JA, Arcos González P, Castro Delgado R. Impact of disasters on the mental health. Rev Enferm. 2013;36(12):50-56.
36. Cho SM, Jeong A, Ha JH, Kim EY. Social relationship changes in victim families due to a social disaster: Experiences of student victims' families in the South Korean Sewol ferry disaster. PLoS One. 2017;12(12):e0188699. doi:10.1371/journal.pone.0188699.
37. Lagergren Lindberg M, Hedman C, Lindberg K, Valentin J, Stenke L. Mental health and psychosocial consequences linked to radiation emergencies-increasingly recognised concerns. J Radiol Prot. 2022;42(3). doi:10.1088/1361-6498/ac7d19.
38. Leppold C, Gibbs L, Block K, Reifels L, Quinn P. Public health implications of multiple disaster exposures. Lancet Public Health. 2022;7(3):e274-e286. doi:10.1016/S2468-2667(21)00255-3.