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Anticipating Threat: Nuclear Safety and Early Warning

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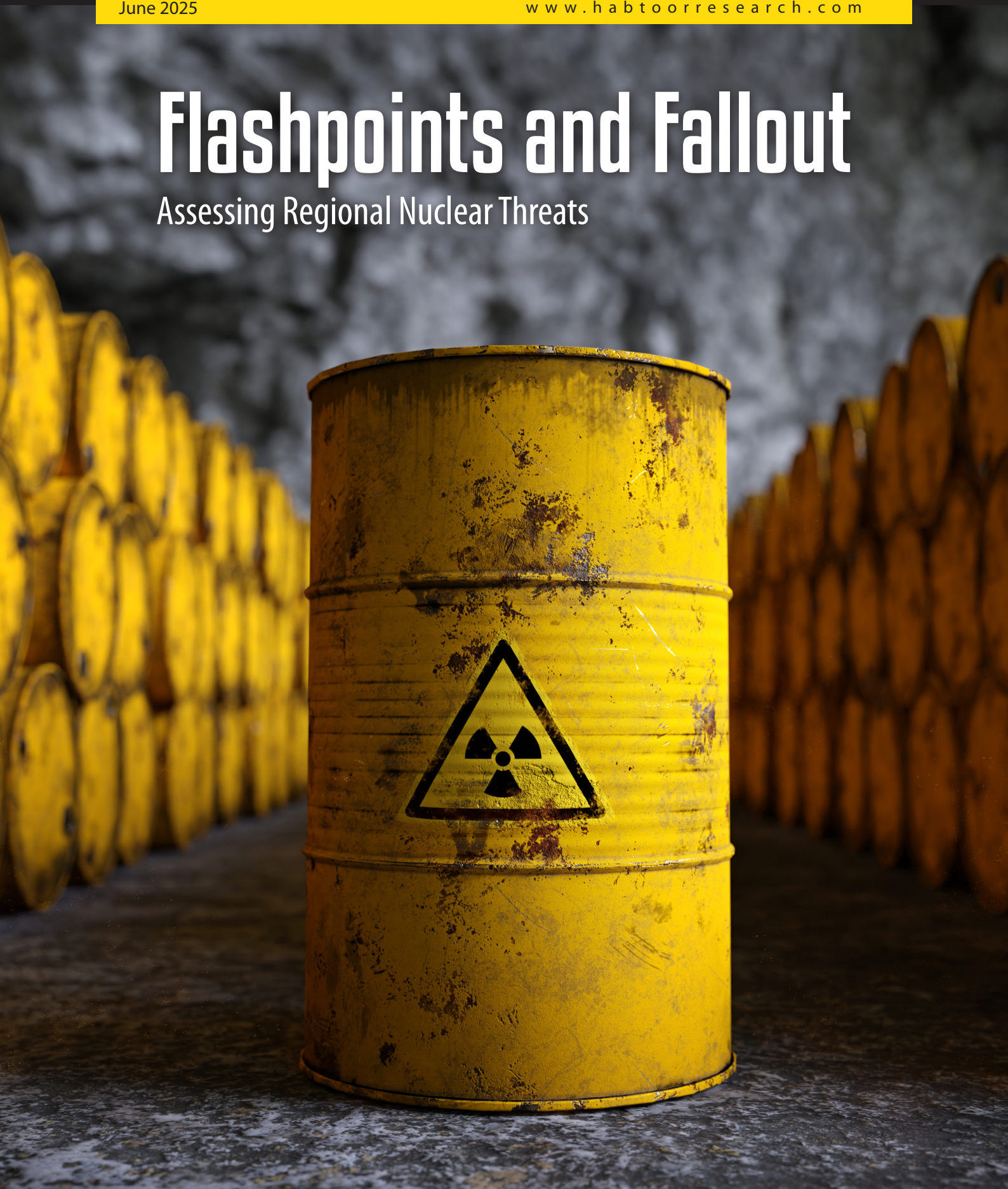
Flashpoints and Fallout

Assessing Regional Nuclear Threats



This paper is part of the «**Anticipating Threat: Nuclear Safety and Early Warning**" initiative by Al Habtoor Research Centre, which explores global nuclear developments and their regional implications, including issues related to security, safety, and other emerging dynamics relevant to current events.

The threat of nuclear weapons, once seemingly receding with the end of the Cold War, has resurged with alarming intensity. A renewed nuclear arms race and a dangerous erosion of the norms and treaties that have, for decades, helped prevent the unthinkable are being witnessed by the world. Since Feb. 2022, Russia's invasion of Ukraine and the accompanying rhetoric—including overt and subtly veiled threats to employ nuclear weapons—have broken the post-Cold War taboo. Russia's nuclear weapon posture in Belarus increases tensions even more and normalises the debate about nuclear war. The invasion has had a ripple effect globally, with countries like South Korea, Germany, and Poland expressing renewed interest in nuclear deterrence, either through their own programmes or by hosting US nuclear weapons. Poland's consideration of joining Belgium, Germany, Italy, the Netherlands, and Turkey as a host for US nuclear weapons highlights this dangerous trend. Meanwhile, North Korea's continued, unchecked development of its nuclear arsenal and the persistent nuclear belligerence between India and Pakistan serve as concrete examples of the ongoing global threat.

The nuclear shadow over the Middle East has deepened in the aftermath of the October 7 events, which sharply re-escalated regional tensions and exposed the fragility of the existing security order. As Israel's military operations in Gaza risk broadening into a wider regional confrontation, concerns about the potential use and further proliferation of nuclear weapons have intensified. The director general of the International Atomic Energy Agency (IAEA) has recently warned that the intensification of hostilities in the region could acquire "nuclear dimensions," underscoring the urgent need for full-scope safeguards and renewed diplomatic engagement to prevent further escalation. In this increasingly volatile context, the nuclear issue remains deeply intertwined with broader political and security dynamics, raising the spectre of a dangerous tipping point in regional proliferation. With the renewed conflict between Israel and Iran, talk of nuclear targets and their impact on the region has returned.

Against this backdrop, this paper examines the various forms of nuclear threats and assesses the vulnerability of selected case study countries. These cases—Egypt, the United Arab Emirates, Saudi Arabia, and Jordan—were chosen based on their susceptibility to nuclear disasters, primarily determined by the presence of nuclear facilities that could be potential sources of risk. Geopolitical significance was also a key factor in the selection process. The threats are grouped into two main categories: the first relates to the dangers posed by nuclear warfare, while the second focuses on risks associated with nuclear or radioactive leaks. Each scenario is further broken down into sub-scenarios that analyse the projected impacts on the selected cases, including estimated fatalities and casualties. The primary criterion guiding case selection and analysis is human loss, with specific cities chosen based on population density, and consequences evaluated accordingly.

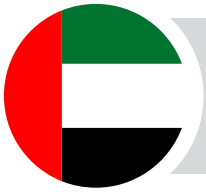
By evaluating projected impacts—including human loss and disruption to critical infrastructure—this paper aims to provide a comprehensive assessment of nuclear vulnerability in these key states. In doing so, it highlights how the evolving nuclear landscape in the Middle East region is shaped not only by technological and strategic factors but also by the interplay of domestic ambitions and external pressures. The findings underscore the urgent need for robust safeguards, regional cooperation, and international engagement to mitigate the growing risks posed by nuclear weapons and technology in an increasingly unstable global environment.

Strategic Case Selection

Identifying Nuclear Risk Hubs in MENA

Given their different degrees of participation with civilian nuclear energy projects, Egypt, the United Arab Emirates, the Kingdom of Saudi Arabia, and Jordan have become especially prominent players in this setting. Egypt and the UAE have advanced significantly; Egypt is building its second reactor while the UAE runs the Barakah Nuclear Power Plant. Saudi Arabia and Jordan are simultaneously pursuing nuclear energy projects; Saudi Arabia is looking for indigenous uranium enrichment capabilities and Jordan is concentrating on Small Modular Reactors (SMRs), especially for critical water desalination projects. These nuclear paths are connected to the larger development plans of every country as well as with regional power dynamics.

Based on a multifarious assessment of their nuclear energy trajectories, geopolitical relevance, and urban risk profiles, Jordan, Egypt, Saudi Arabia, and the United Arab Emirates (UAE) were chosen as focal countries for a nuclear vulnerability analysis. Every country serves as a vital link in the Middle Eastern security architecture since their growth and stability have significant local and worldwide consequences.



United Arab Emirates

Being the first newcomer in 27 years to build and run a nuclear power plant, the United Arab Emirates has set itself out as a leader in the scene of nuclear energy in the region. Four APR-1400 reactors make up its Barakah Nuclear Power Plant. Once completely running, the Barakah plant is expected to produce 5.6 gigabytes of carbon-free electricity for more than six decades, so contributing 6% to the total energy mix of the UAE. Having accepted all pertinent safeguard agreements and signed many bilateral nuclear cooperation agreements with nations including France, the U.S., South Korea, and Saudi Arabia, the UAE, a member of the IAEA since 1976, has shown a great dedication to operational transparency, non-proliferation, and nuclear safety. The UAE has gone through several IAEA review missions and actively supports worldwide projects meant to stop illegal nuclear materials trafficking, so demonstrating its compliance with international norms.

Even if direct nuclear material acquisition is not the main goal, this is especially true for non-state actors or rival powers trying to upset its increasing regional influence. With its mostly dependent on global connectivity, international trade, and foreign investment economic model, the UAE means that an attack on its main metropolitan hubs like Dubai or Abu Dhabi would immediately and severely affect world economy. These cities are global hubs for business, trade, and logistics; any disturbance would flow through international supply chains, financial markets, and corporate operations, so making them high-value targets for an enemy trying to cause broad economic disturbance outside direct casualties.

Additionally, Important hubs in the global system and possible targets, the UAE's urban centres are distinguished by their advanced infrastructure, global connectivity, and varied economic roles.

Dubai, known worldwide for business, tourism, and entertainment, advanced logistics system and central geographic location have made it a strategic beneficiary of changes in global trade. It is a major platform for distribution, logistics, and value-added manufacturing, connecting markets across the Middle East, Africa, South Asia, and Europe. Though specific population data is not provided, it is implied to be the largest city in the UAE.

As the more rich and powerful sister emirate, **Abu Dhabi** is the main driver behind the UAE's rise as a significant regional power. It is also home to Khalifa Port, one of the most advanced deep-water ports in the Middle East. The emirate boasts pro-business laws, government incentives, and significant investments in clean energy, AI,

and smart infrastructure.

With almost 96% of its economy non-oil-based, **Sharjah,** the third most populous city in the UAE, is a major site for manufacturing, services, and finance. It hosts six specialised free zones and gives business sustainability top priority.

Often referred to as the hidden gem of the United Arab Emirates, **Ajman** is fast becoming a hub for sustainable development and innovation. Strategic importance within the Belt and Road Initiative, it is a desirable location for small-scale industry and logistics because of its compact urban structure and reduced operating costs.

Often referred to as the "Nature Emirate," **Ras Al Khaimah** is the largest city and capital of its emirate. It is also an industrial hub with a varied manufacturing base and major logistical benefits. Global tourism and foreign investment are shining light on this city.

The UAE's economic model, heavily reliant on global connectivity, international trade, and foreign investment, means that an attack on its key urban centres like Dubai or Abu Dhabi would trigger immediate and severe global economic repercussions. These cities are explicitly described as "global hubs" for business, trade, and logistics, and the UAE is a "strategic beneficiary" of global trade shifts, having invested billions in infrastructure to expand its influence. An attack on these cities would not only cause direct damage but also severely disrupt global supply chains, financial markets, and international business operations, as the UAE serves as a critical node in the global economy.

This makes them attractive targets for an adversary seeking to inflict widespread economic pain beyond the immediate region. Furthermore, despite the UAE's explicit commitment to non-proliferation and nuclear safety, exemplified by its Barakah Nuclear Power Plant, any nuclear attack on its territory would likely involve conventional weapons targeting its highly concentrated and interconnected critical infrastructure, rather than its safeguarded nuclear facilities. The UAE's nuclear program is presented as a "Gold Standard" for non-proliferation, with strict IAEA safeguards and transparent operations. However, the extensive and valuable non-nuclear critical infrastructure—including ports, financial centers, industrial zones, and tourism hubs — would be the primary targets for an adversary aiming to inflict maximum economic and societal disruption, rather than attempting to weaponize or contaminate from the Barakah plant.

Egypt

Having started a large nuclear energy program, Egypt is a major actor in the Middle East. With building on its second reactor starting in 2023, the country is said to be a "newcomer" in the nuclear power scene. Designed to house four VVER-1200 reactors, together producing 4,800 megawatts of electricity, the flagship El-Dabaa Nuclear Power Plant project is a joint effort with Russia. With all of the reactors expected to be online by 2030, a calculated step to diversify Egypt's energy mix and lower the country's reliance on fossil fuels, the first reactor is scheduled for operation in 2028. Apart from its main Russian alliance, Egypt has also signed nuclear cooperation agreements with China (2006) and South Korea (2013), so signifying a global involvement in its nuclear goals.

One cannot quite overestimate Egypt's geopolitical relevance. Located strategically at the meeting point of Africa and Asia, it controls the Suez Canal, a vital marine choke point enabling a significant amount of world trade and oil shipments. Egypt, with almost 102 million people among the Arab world, is a major political, cultural, and educational leader among the MENA countries, so having great impact inside the Arab League. Its continuing peace treaty with Israel and strong strategic alliances with Western countries, especially the U.S., highlight even more its central influence in Middle Eastern politics and peace projects. Thus, the stability and policy orientation of the Egyptian government directly affect initiatives against terrorism and regional security.

Though major, Egypt's nuclear program seems to be driven more by a basic need for energy diversification and to satisfy growing domestic demand than by overt proliferation goals. This view is supported by constant interaction with international agencies including the International IAEA and framing of the El-Dabaa project as a "strategic pillar for environmental sustainability" and a means to fulfil international climate commitments. This strategy stands out from the more dubious nuclear stances taken by some other regional players since it implies a clear driving force for its nuclear expansion. But the effective running of the El-Dabaa plant will surely result in a new target for critical infrastructure. The plant's strategic location close to the globally important Suez Canal increases its vulnerability since an attack could not only disrupt Egypt's energy supply but also cause extensive radioactive contamination, so severely upsetting world supply networks depending on this important waterway. Importantly, Egypt's main urban centres are high-value targets since they are essential for its national function and regional influence.

Cairo is Egypt's main political, cultural, and religious centre as the capital and among the biggest cities in Africa. It hosts important government buildings. Its historical function as the capital over several Egyptian eras emphasises its continuous relevance as the core of the country. Although the snippets do not include a precise population count, it is suggested that this is Egypt's biggest city.

Alexandria Major Mediterranean coast port second in size among Egyptian cities after Cairo. Historically, it has been a major trading hub tying Egypt to the Eastern Mediterranean, Europe, Arabia, and India. It was a major exporter of cotton and grain as well as the hub for medicine and logistics. Its strategic importance is reinforced by its long history as vital cross-roads for trade and culture.

Port Said its strategic relevance is clearly related to its position at the northern Suez Canal entrance. Reflecting the strategic value of Suez city, this posture makes it a critical choke point for marine traffic and a major port for international trade.

Strategically important, Suez is a seaport city close to the southern end of the Suez Canal since it directly connects with this world marine choke point. Generating billions of incomes for Egypt, the Suez Canal facilitates 12–15% of world trade, 30% of global container traffic, and major flows of oil and liquefied natural gas (LNG). Any disturbance of the canal has immediate, worldwide economic consequences. demographic.

Al-Mansurah: has historical strategic significance especially in military settings since it was a major goal for Nile Delta control through its rivers.

The Suez Canal's strategic value directly increases Suez's and Port Said's vulnerability. Given the canal is routinely described as a "vital waterway for global trade and energy security" and a "maritime choke point," an attack on these cities could destroy worldwide trade and energy supply chains. Far more than the direct damage to the cities themselves, the disturbance of this vital artery would have immediate and severe worldwide economic consequences, thus making them top targets for any opponent wishing to undermine world systems. Moreover, Cairo's position as the political and cultural centre of the Arab world together with its large population make it a target not only for physical damage but also for great symbolic and psychological impact over the whole area. An attack on Cairo would affect regional stability by means of a profound psychological and political shockwave spanning the Arab and Islamic worlds, so transcending physical damage and perhaps inspiring widespread disturbance or reprisals.

Saudi Arabia

The nuclear energy ambitions of Saudi Arabia are several. Declaring its right under the NPT to enrich uranium for peaceful domestic energy needs, the Kingdom demands fair treatment relative to countries like India, Japan, and even Iran. Leveraging its large domestic uranium reserves, the goal to lessen reliance on outside nuclear fuel suppliers drives a great part of this ambition. But the most convincing reason comes from Iran's allegedly existential threat presented by growing nuclear capability. Saudi officials have specifically said they would be ready to develop their own nuclear capacity as a strategic deterrent should Iran weaponize.

Constant advocating the acceptance of the Comprehensive Safeguards Agreement (CSA) and the Small Quantities Protocol (SQP), the IAEA sees Saudi Arabia's current nuclear protections as insufficient for its aspirations. Saudi Arabia has firmly opposed signing and ratifying the IAEA's Additional Protocol (AP), which offers improved verification tools, even while it has lately indicated compliance with these, in line with the almost completion of a research reactor. This posture mirrors Egypt's, which also links AP ratification to Israel's NPT accession. Moreover, Saudi Arabia's cooperation on uranium mining with China has attracted global attention.

Geopolitically, Saudi Arabia is progressively changing its global and regional profile. It aims to negotiate difficult great power rivalries and reduce its reliance on conventional allies like the U.S. at the same times. To increase its geopolitical impact, the Kingdom deliberately uses its great economic strength—mostly derived from oil dominance but progressively diversified through Vision 2030 initiatives—and its unmatched religious legitimacy as the guardian of Mecca and Medina. Pursuing a diplomatic balance, Riyadh builds ties with the European Union, China, and Russia as strategic counterweights to U.S. approach. It also significantly helps to moderate regional tensions and settle disputes.

Saudi Arabia's declared peaceful nuclear ambitions and its strong opposition to complete IAEA safeguards—especially the Additional Protocol—exude a critical tension. The clear connection of its nuclear program to Iran's nuclear developments aggravates this situation. This raises a major proliferation risk since the Kingdom's conditional quest of nuclear capability suggests a possible regional arms race. This scenario would drastically change the Middle Eastern nuclear scene and maybe inspire reactive nuclear projects by other regional players including Turkey and Egypt.

Important targets for Saudi Arabia's urban centres are not only population centres but also centres of great political, religious, and financial relevance.

Riyadh, the capital and biggest city, is the economic powerhouse and central hub of Saudi Arabia's oil industry; it is therefore essential for Vision 2030, the ambitious plan for economic diversification and attracting major foreign direct investment to be implemented.

Jeddah, which is on the Red Sea, is Saudi Arabia's main port and has historically been the gateway for Muslim pilgrims en route to Mecca and Medina. It is a major economic and cultural hub processing over 4,943,000 containers yearly and so important for the Kingdom's non-oil trade.

Mecca, the holiest city in Islam, Mecca is the worldwide focal point for the annual Hajj pilgrimage, drawing millions of Muslims from all around the world. Its spiritual significance is greatly entwined with its economic importance, historically as a major stopping point on caravan paths and currently through significant pilgrimage revenues. Control of Mecca is considered control over a cornerstone of Islamic spiritual life.

Medina, the second holiest city in Islam; home to the Prophet's Mosque; has great religious, cultural, and educational value; it was the historical site where the first Islamic state was founded and continues to draw tourists worldwide.

Dammam, is a strategic commercial and industrial hub mostly depending on oil and gas, with major petrochemical and manufacturing industries located on the Arabian Gulf coast. King Abdulaziz Port in Dammam is one of the biggest ports in the Middle East, so confirming its importance as a key logistical centre.

An attack on Mecca or Medina would not only result in catastrophic human loss but would also constitute an attack on the spiritual heart of Islam, potentially triggering a global religious and geopolitical crisis of unprecedented scale. Mecca is described as the "holiest Islamic city" and Medina as the "second holiest." The control of Mecca is explicitly linked to controlling a "cornerstone of Islamic spiritual life." Millions of pilgrims visit these cities annually. A nuclear attack on these sites would be perceived as an attack on the entire Muslim world, potentially uniting diverse Muslim populations against the perpetrator and leading to widespread, unpredictable global consequences, including religious extremism and international conflict. Furthermore, Riyadh's centrality to Vision 2030 and its economic diversification efforts make it a target whose destruction would not only cripple the Saudi economy but also severely undermine the Kingdom's long-term strategic vision and stability." An attack on Riyadh would directly target the command and control of the Saudi government and the core of its national development, causing a profound setback to its future and potentially leading to internal instability.

Jordan

Jordan is aggressively seeking nuclear power, focusing especially on SMRs. The country's extreme water shortage drives most of this strategic decision; SMRs are intended to run reverse osmosis desalination plants, so supplying necessary fresh water to the fast-expanding capital, Amman. Jordan highlights the important national security and humanitarian aspect of its nuclear program since it is among the first nations to consider a nuclear reactor just for desalination needs. With its SMR Platform and expert missions and seminars to help Jordan's development, the IAEA offers significant support. Jordan follows the NPT as a non-nuclear weapon state with safeguarded facilities and has easily available uranium supplies.

Jordan is a vital link between the Middle East and the West and a major strategic point at the junction of Asia and Africa. This geographical location, despite its limited natural resources, gives Jordan great significance in regional and international politics, so establishing it as a hub for diplomatic conferences and a major actor in issues of regional security. Jordan's proximity to conflict areas including Iraq, Syria, and the Israeli-Palestinian conflict makes Jordan a well-known source of stability in a turbulent area actively supporting international counter-terrorism initiatives. Its peace settlements with Israel confirm even more its stabilising function. For its financial stability, the country mostly depends on foreign donor support—especially from the U.S. and Gulf countries—but Jordan's particular water crisis greatly influences its nuclear energy program, transforming SMR development from an energy diversification tactic into a critical national security and humanitarian concern. With SMRs explicitly targeted for desalination to meet Jordan's "smallest available water resources in the world," any attack affecting this infrastructure would immediately and severely affect humanitarian conditions, much beyond the direct physical damage. Moreover, Jordan's established position as a "bridge" and an "island of stability" in a volatile area combined with its dependence on outside help make its nuclear program a delicate topic for world security. Any disturbance to Jordan's stability—from a direct attack on its cities or critical infrastructure—would not only cause great domestic damage but also set off a major worldwide humanitarian and security crisis, so possibly destabilising a major regional ally and calling for major worldwide intervention.

Despite their smaller scale than some regional counterparts, Jordan's urban centres have great strategic value because of their functions in national infrastructure, economy, and regional stability.

As Jordan's capital and biggest city, **Amman** acts as the political, economic, and cultural centre and is therefore very important for regional diplomacy and world relations. It hosts international organisations, foreign embassies, and major governmental buildings. Amman is also the intended recipient of desalinated water from upcoming SMR projects; thus, its water infrastructure is a major national security asset.

Zarqa having 50% of Jordan's factories and only one oil refinery, Zarqa is the second most populous city in the nation known as its industrial hub. Having the Muwaffaq Salti Air Base and the headquarters of the Jordanian Arab Legion, it also has great military value.

Irbid rising as the second biggest city in Jordan, Irbid is a vibrant city with a rich past serving as a hub on the trade route of the ancient King. Its diversified economy is driven by education, industry, and agriculture as well as by Its position close to the West Bank and Israel's borders gives its cultural and strategic scene a special dynamic.

Russeifa is well-known for its several phosphate mineral deposits and for the existence of the Jordanian Phosphate Mines corporation. Strategically placed on the Amman-Al Mafraq axis, Russeifa is a vital transit checkpoint that greatly benefits the national economy by means of its several sectors, including heavy industry.

Al-Quaysimah a fast-growing residential centre inside the Greater Amman Municipality, Al-Quaysimah is a relevant urban centre in terms of vulnerability based on population increase and its natural relationship with the infrastructure of the capital.

Jordan's strong dependence on foreign aid and its established function as a source of regional stability mean that an attack on its main cities would cause not only domestic destruction but also a major international humanitarian and security crisis. Said to be "resource-and- export-poor" the nation mostly depends on foreign donor support. Along with hosting millions of migrants, it acts as a "strategic partner in the fight against terrorism and extremism." An attack would aggravate already existing vulnerabilities including economic contraction, high unemployment, and chronic water shortages, probably requiring significant worldwide intervention and greatly testing global humanitarian and security response systems. Zarqa is a double-use target because of its concentration of military and industrial assets as well as its near proximity to Amman. Along with military bases, Zarqa is highlighted as Jordan's "industrial centre which houses 50% of the total factories" and its "only oil refinery plant." Its location merely 22 kilometres northeast of Amman suggests that an attack could have direct or indirect impacts on the capital, so making it a highly efficient target for an adversary seeking to destroy Jordan's military and economic capability.

Nuclear Risks and Scenarios

Nuclear risk is a complex and subjective concept, often defined through the lens of a state's individual threat perception. At a retreat organized by the United Nations Institute for Disarmament Research (UNIDIR), experts from the P5 countries illustrated this diversity of perspectives. While representatives from China, Russia, and the U.S. emphasized specific actions by other states that could pose immediate threats to national security, experts from France and the United Kingdom highlighted broader systemic challenges to the stability of the global nuclear order.

Several factors contribute to the difficulty in defining nuclear risk. First, risk is inherently dynamic, shaped by shifting geopolitical contexts over time and across regions. What is considered a risk in one moment or location may not be perceived the same elsewhere. Second, nuclear risk often stems from multiple, interrelated drivers that can amplify each other. Third, a certain level of risk is intrinsic to nuclear deterrence itself. Discussions about nuclear risk often refer not to the total elimination of risk, but to managing it within acceptable or strategic boundaries. Moreover, risk perception is deeply subjective. States assess the risk of using nuclear weapons in comparison not only to the risk of abstaining from their use, but also to potential outcomes such as being subjected to a first strike, enduring prolonged conventional conflict, or facing threats to national survival. Finally, it must be acknowledged that the full spectrum of nuclear risks is neither entirely known nor fully knowable, adding another layer of uncertainty to any assessment.

The Arab region faces a distinct set of nuclear-related threats, which can be broadly classified into two main Scenarios. The first Scenario is the threat of nuclear war, either direct or indirect. Although a direct nuclear attack on an Arab country by a nuclear power is unlikely, it remains a theoretical possibility. More plausible, however, are indirect threats stemming from regional dynamics. Such conflicts could have spillover effects, potentially destabilizing parts of the Arab region. The second Scenario involves the risk of nuclear leaks. These leaks may result from various causes, including technical malfunctions, cyber-attacks, or environmental hazards. Such scenarios pose a significant threat to Arab countries that operate nuclear power plants.

Scenario 1
Nuclear Attacks

Nuclear attacks represent one of the most catastrophic forms of warfare, fundamentally different from conventional weapons or even radiological dispersal devices like "dirty bombs." Unlike dirty bombs, which use conventional explosives to scatter radioactive material, a nuclear attack involves a detonation that initiates an uncontrolled chain reaction of atomic fission. This process generates a massive release of energy in the form of intense heat, light, blast pressure, and initial radiation, followed by radioactive fallout. The energy released by such explosions is typically distributed as 50% shockwave, 35% thermal radiation, 5% initial nuclear radiation, and 10% fallout radiation, although this ratio can vary depending on the weapon's design and detonation altitude.

From a strategic and geopolitical standpoint, nuclear wars can be categorized into direct and indirect threats. **A direct nuclear war** refers to an attack or credible threat by a nuclear power against another state. In such scenarios, the primary consequences, blast damage, radiation exposure, and societal collapse, are concentrated in the targeted areas. While indirect nuclear wars are more of a regional possibility, their impact is insignificant in comparison to direct ones.

Sub-Scenario 1

Direct Nuclear War: Affected Population in Each Nuclear Blast Zone

This case models the estimated number of individuals within six concentric nuclear damage zones if a 500-kiloton surface nuclear detonation was to strike the urban centre of each of the 20 most populous Arab cities. By multiplying each city's population density by the area of the respective damage zones, we simulate how many people would fall within the critical ranges of vaporization, blast impact, radiation, and thermal injury. The objective is to quantify and compare the vulnerability of urban populations in Arab megacities under a uniform nuclear threat scenario, thus supporting national preparedness, civil defence planning, and comparative urban risk analysis.

Blast Zone Definitions

Zone Type	Radius (km)	Area (km^2)	Effect Description
Fireball	1.06	3.54	Total vaporization of materials and people.
Heavy Blast (20 psi)	1.73	9.37	Destruction of reinforced structures. Near-100% fatality.
Radiation (500 rem)	2.29	16.5	Lethal ionizing radiation exposure.
Moderate Blast (5 psi)	3.63	41.5	Collapse of residential buildings. High injury/fatality rate.
Thermal Radiation	7.91	196	Severe third-degree burns. Widespread fires.
Light Blast (1 psi)	9.34	274	Structural damage, flying debris, glass injuries.

The exposed population in each zone is estimated by:

"Estimated population zone = population density city × zone area." This is based on the assumption that population is evenly distributed within the urban boundary. While real cities exhibit clustering, this simplification enables macro-level comparison across regions.

Results

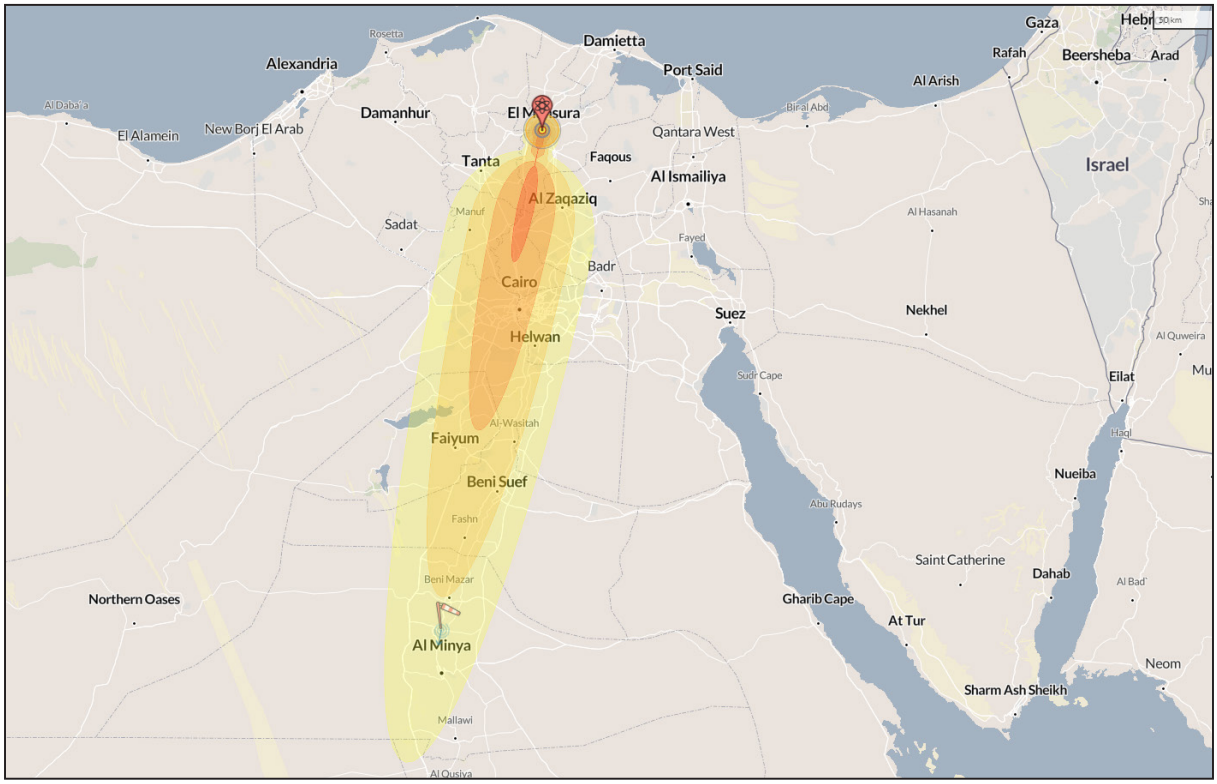
City	Pop. Density ($/km^2$)	Fireball	Heavy Blast	Radiation	Moderate Blast	Thermal	Light Blast
Cairo	8,440	29,877	79,080	139,255	350,248	1.65M	2.31M
Alexandria	2,061	7,295	19,309	34,002	85,519	403,897	564,631
Al-Mansurah	21,515	76,163	201,596	354,998	892,872	4.22M	5.90M
Irbid	8,355	29,577	78,279	137,859	347,733	1.64M	2.29M
Russeifa	8,594	30,434	80,590	141,801	357,670	1.68M	2.36M
Suez	78	275	727	1,280	3,219	15,202	21,252
Ras Al Khaimah	161	570	1,506	2,655	6,674	31,536	44,038
Amman	617	2,184	5,772	10,180	25,639	121,661	169,435

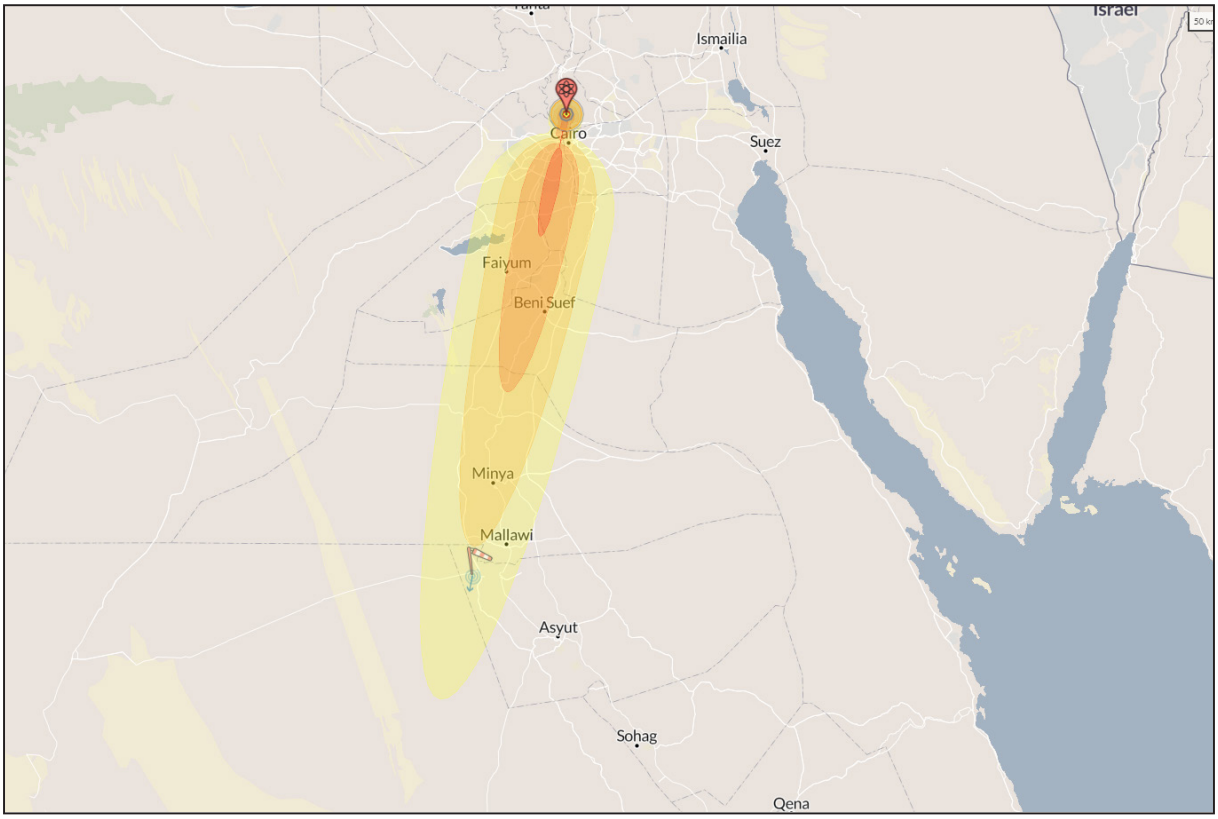
Cities like Al-Mansurah, Cairo, Russeifa, and Irbid exhibit catastrophic risk profiles. In each, over 1.5 million people would be injured or killed in the thermal and light blast zones alone. The following maps show each city's total affected population segmented by zone. Thermal and light blast zones consistently dominate total impact across cities due to their large areas. Cities with low density (e.g., Suez, Ras Al Khaimah) exhibit minimal affected populations even in broader zones.

The numerical findings reveal a stark variation in urban vulnerability across the studied cities. Al-Mansurah, Cairo, Russeifa, and Irbid emerge as high-risk zones, where thermal and blast effects alone could result in over 1.5 million casualties. These cities exhibit dense urban cores that magnify the destructive potential of a nuclear detonation. In contrast, Alexandria, Sharjah, Abu Dhabi, and Jeddah fall into a moderate-risk category, where outer-zone damage is significant due to spread-out thermal effects, but inner-circle fatalities are comparatively lower, likely owing to mid-range population density and infrastructure distribution. Suez, Ras Al Khaimah, and Ajman appear more resilient, with minimal exposure in the most lethal zones—suggesting that low-density planning or urban sprawl indirectly contributes to survivability.

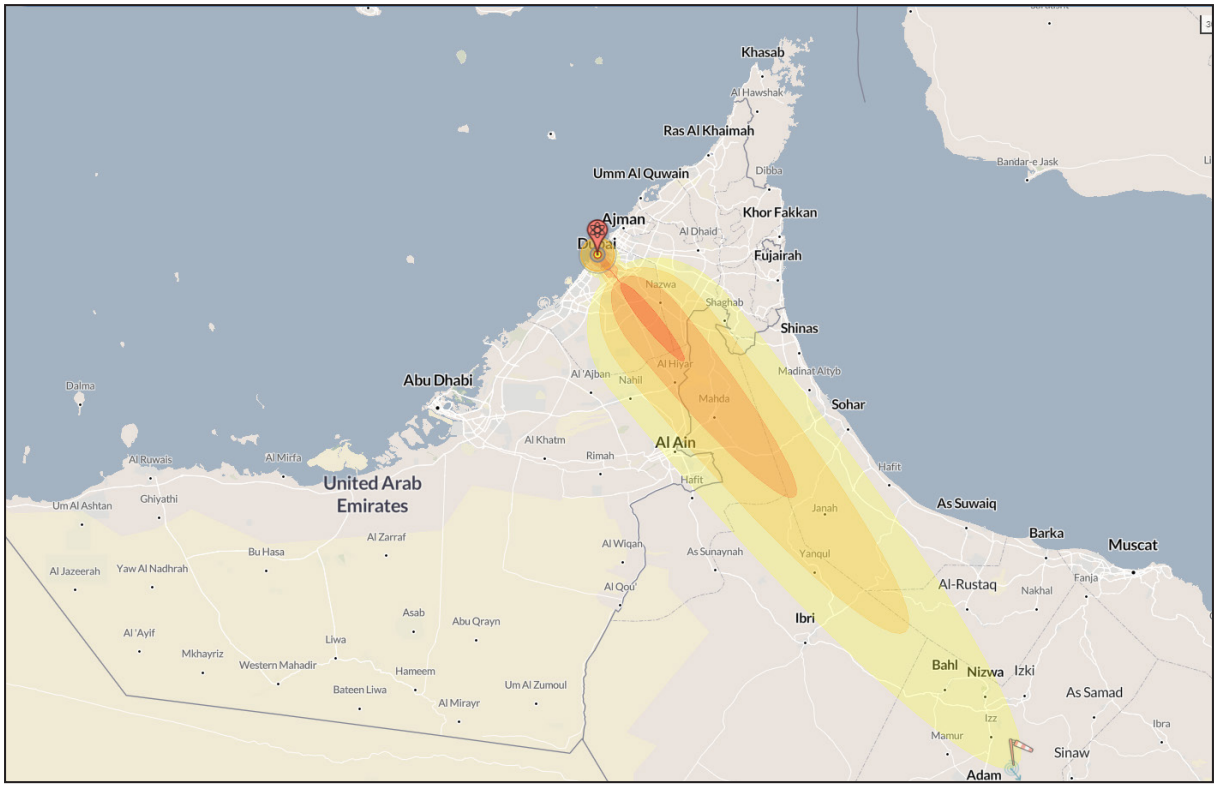
These risk assessments carry critical implications for civil defence, urban policy, and regional security planning. Immediate priority should be given to high-risk cities for evacuation protocols, shelter development, and resource prepositioning. Over the longer-term, urban decentralization and infrastructure dispersion can serve as buffers against mass casualties. Additionally, from a national security perspective, the concentration of population and infrastructure in select cities creates vulnerability to strategic coercion. A single detonation could induce systemic collapse, underscoring the urgent need to integrate blast zone analytics into national resilience strategies.

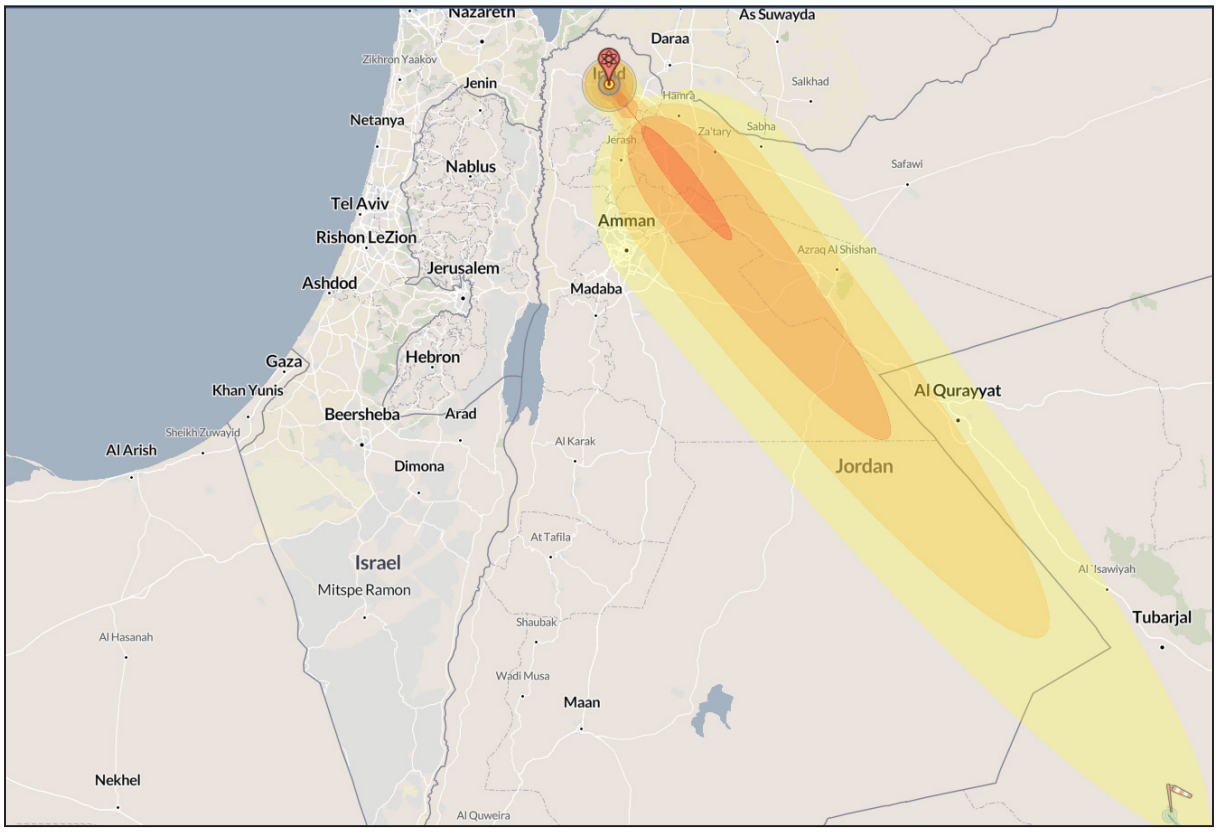
Most Vulnerable Cities





Source: Nukemap





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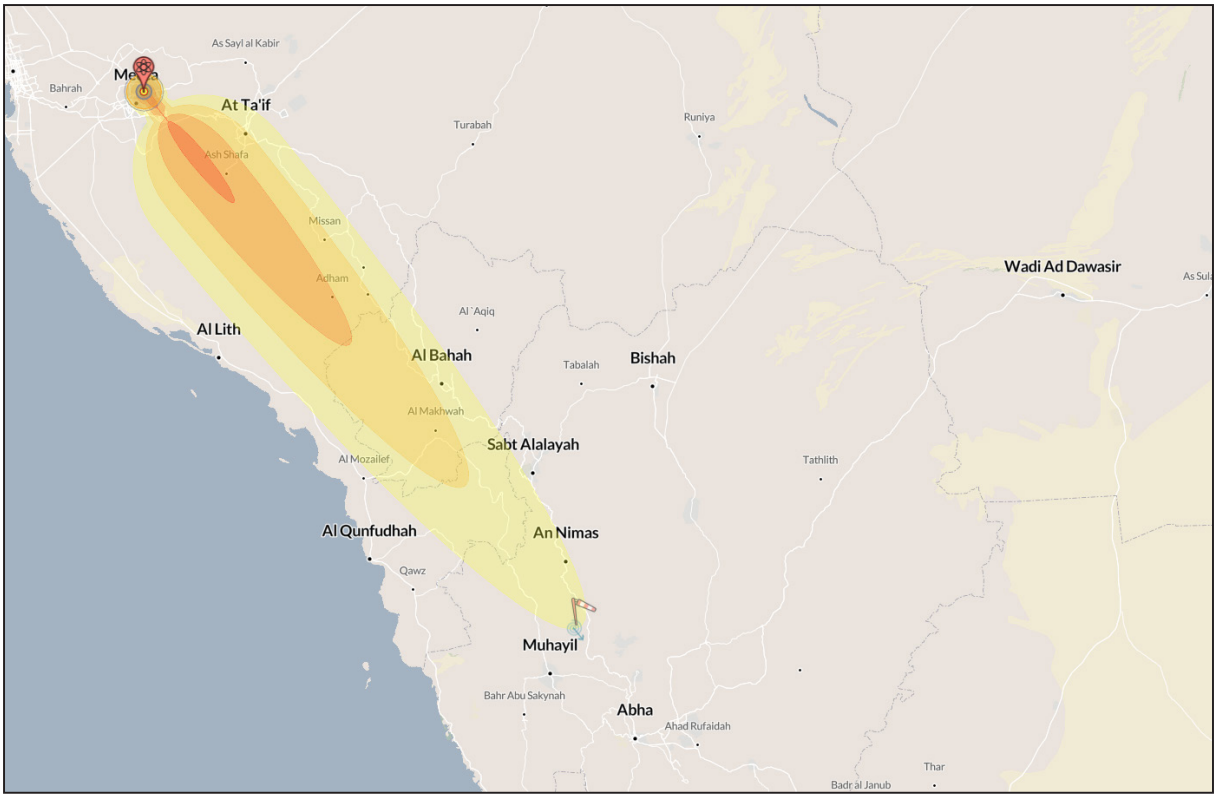
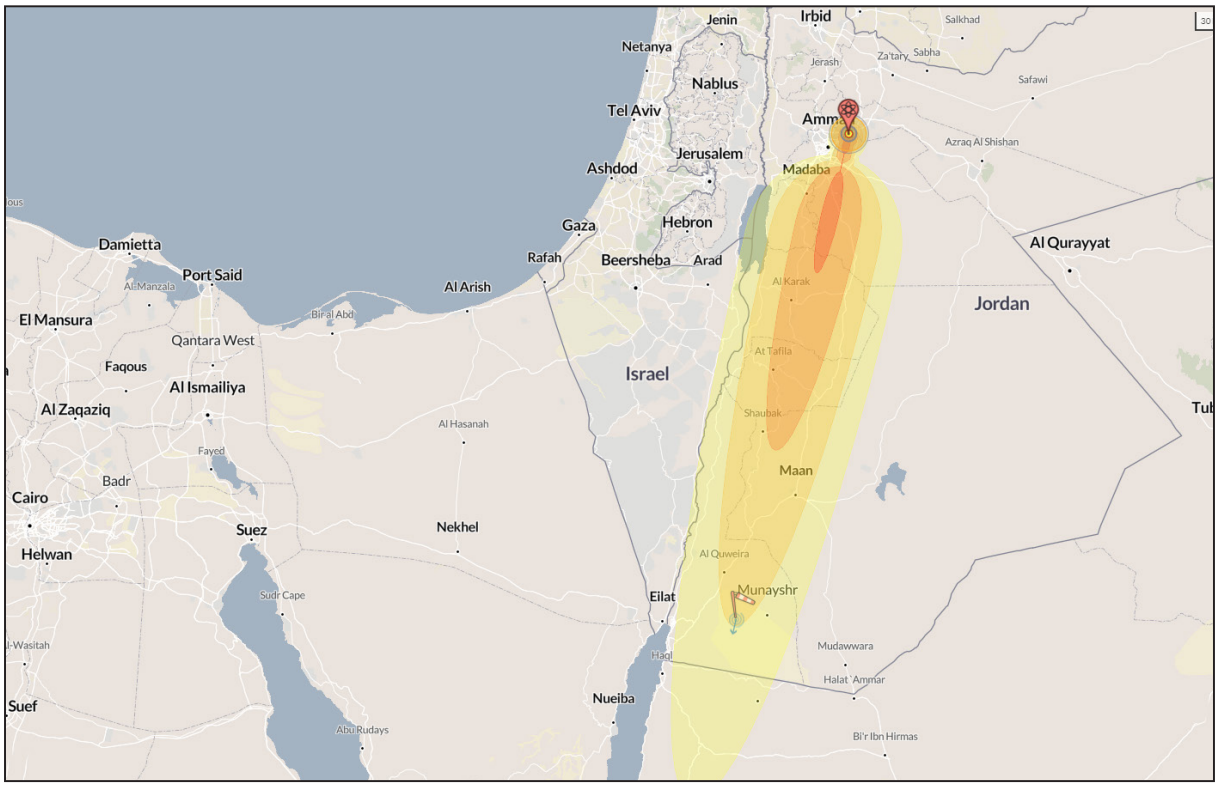




Source: Nukemap

Scenario 2

Nuclear Leaks

(Malfunction, Cyber-Attacks, and Environmental Threats)

The evolving landscape of global security has amplified concerns over the safety of nuclear facilities, extending beyond conventional operational risks to include digital threats and environmental vulnerabilities. Nuclear safety, by definition, encompasses the entire life cycle of nuclear installations, from reactor design and fuel management to plant decommissioning and emergency preparedness. However, failures in any part of this safety regime can result in catastrophic consequences.

Nuclear leaks, whether from core meltdowns or compromised containment systems, can lead to the release of highly radioactive materials into the air, soil, and water. These incidents can render vast areas uninhabitable and pose long-term health risks to populations, both within and beyond the borders of the affected country. The environmental implications are particularly severe, with radioactive isotopes contaminating food and water supplies, disrupting ecosystems, and persisting in the environment for decades. Core meltdowns, as seen in historical disasters like Chernobyl and Fukushima, occur when the heat inside a nuclear reactor becomes uncontrollable, causing fuel rods to melt. These leaks are not merely local events; depending on wind patterns, water flows, and soil permeability, their consequences can be transboundary, triggering international crises, refugee flows, and geopolitical tensions.

In the modern era, **cyber threats** have emerged as a critical dimension of nuclear vulnerability. While nuclear safety protocols traditionally focus on physical infrastructure, digital systems now form the backbone of control, communication, and early warning mechanisms for both civilian and military nuclear operations. According to nuclear and technology experts, these systems, including those used for command and control of nuclear weapons, are increasingly susceptible to cyberattacks. The integration of digital components as part of nuclear modernization programs, particularly in the U.S. and other nuclear-armed states, has inadvertently introduced "mission critical cyber vulnerabilities." As noted by the U.S. Government Accountability Office, nearly all weapons systems under development are exposed to potential digital exploitation.

The risks posed by such cyber intrusions are not abstract. A successful cyberattack could result in unauthorized access to nuclear arsenals, the disabling of early-warning systems, or even the triggering of a nuclear launch. Unlike conventional cyberattacks targeting financial or commercial systems, the consequences here are existential. The historical record already contains numerous close calls, instances in which accidents or

miscommunications nearly resulted in catastrophic escalation. In the age of increasingly sophisticated cyber capabilities, the likelihood of a cyber-nuclear incident grows more plausible, threatening to unravel the delicate balance of nuclear deterrence that has prevailed since 1945.

Compounding these threats is the climate crisis, which introduces a new layer of complexity to nuclear safety. As highlighted by the European Commission's Joint Research Centre (JRC) PESETA IV Report, rising global temperatures and more frequent heatwaves are expected to place immense pressure on the cooling systems of nuclear reactors. Water, essential for reactor cooling, may become less available in drought-prone regions, raising the risk of overheating and potential accidents. A projected increase of 3°C above pre-industrial levels could significantly diminish nuclear power production, particularly in regions already facing water scarcity. This not only undermines energy security but also increases the risk of environmental contamination through compromised cooling systems.

Accordingly, these challenges underscore a shift in nuclear risks. Leakage, cyberattacks, and climate-related disruptions each represent distinct but interrelated threats that demand integrated policy responses.

Sub-Scenario 2:

Population Exposure from Nuclear Reactor Containment Breach

This analysis evaluates the population exposure levels in four Arab cities located near nuclear power plants—El Dabaa (Egypt), Duwahin (Saudi Arabia), Qasr Amra (Jordan), and Barakah (UAE)—under a containment breach scenario. The scenario assumes no evacuation, no access to hardened shelters, and steady wind speed at 24 km/h.

Methodology

The study employs a zone-based population exposure model, guided by IAEA standards and post-Chernobyl assessments. Fallout zones are delineated by concentric distances from the nuclear reactor, classified as follows:

Severe Contamination (within a 5 km radius, covering approximately 78.5 km^2), High Contamination (10 km radius, ~314.2 km^2), Moderate Contamination (30 km radius, ~2,827 km^2), and Light Fallout (50 km radius, ~7,854 km^2).

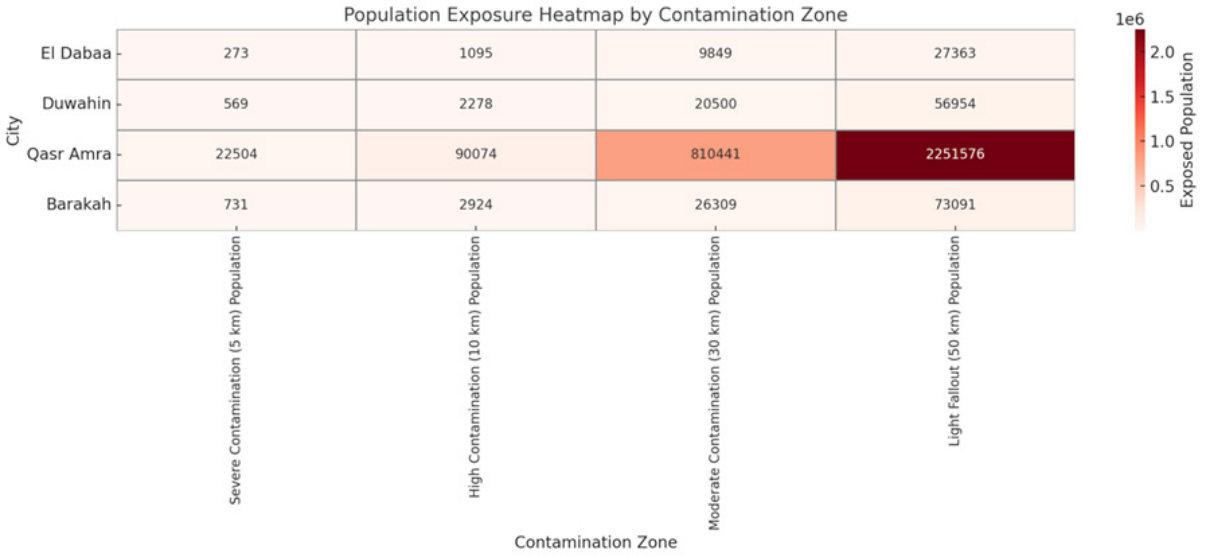
Population exposure within each zone is estimated using the formula: "Exposed Population = Population Density × Zone Area." Population density is derived by dividing the total population of the administrative area by its land area. The fallout distribution is assumed to be symmetrical around the reactor site.

Reactor City Overview

City	Country	Region	Area (km^2)	Population
El Dabaa	Egypt	Matrouh Governorate	166,563	580,304 (Nov 2023)
Duwahin	Saudi Arabia	Eastern Province	710,000	5,148,598 (2022)
Qasr Amra	Jordan	Zarqa Governorate	4,761	1,364,878 (2015)
Barakah	UAE	Al Dhafra Region	35,890	334,001 (2016)

Results by City

City	Density (/km^2)	5 km Zone	10 km Zone	30 km Zone	50 km Zone
El Dabaa	3.48	273	1,095	9,849	27,363
Duwahin	7.25	569	2,278	20,500	56,954
Qasr Amra	286.68	22,504	90,074	810,441	2,251,576
Barakah	9.31	731	2,924	26,309	73,091



The results highlight notable differences in exposure risk across the cities studied. Qasr Amra in Jordan emerges as the most vulnerable site, with its high population density placing over 2.25 million people at potential risk within a 50-kilometer fallout zone. While Duwahin in Saudi Arabia has a high total population, its lower population density reduces the overall exposure risk. In contrast, Barakah in the UAE and El Dabaa in Egypt exhibit lower levels of potential exposure due to the sparse population distribution surrounding these sites. These findings emphasize the critical importance of locating nuclear infrastructure away from densely populated areas and underscore the need for robust emergency preparedness measures.

Discussion

The analysis presented in this paper reveals a rapidly evolving and increasingly perilous nuclear threat landscape in the Middle East, shaped by global geopolitical shifts, regional rivalries, and expanding civilian nuclear programs. The findings underscore an urgent need for robust safeguards, strengthened regional cooperation, and sustained international engagement to address the dual risks posed by nuclear warfare and civilian nuclear disasters.

Intensifying Nuclear Vulnerability in MENA's Strategic Hubs

The selection of Egypt, the United Arab Emirates, Saudi Arabia, and Jordan as case studies highlights that the region's most geopolitically significant and economically interconnected states are simultaneously the most vulnerable to nuclear threats. This vulnerability is exacerbated by the presence of major nuclear facilities—such as the Barakah Nuclear Power Plant in the UAE and the El-Dabaa project in Egypt—situated near critical infrastructure and densely populated urban centres. While these nuclear programs advance national development and energy diversification goals, they also introduce new vectors of risk that adversaries could exploit to inflict disproportionate harm.

Urban Centres as High-Value and Amplifying Targets

The city-level assessment demonstrates that major urban hubs—Dubai, Abu Dhabi, Cairo, Alexandria, among others—are not only vital to their national economies but also serve as critical nodes in global trade, finance, and logistics. These cities' dense populations and concentration of critical infrastructure make them prime targets in any nuclear conflict or nuclear-related incident. The catastrophic human losses projected in these scenarios would extend far beyond immediate blast zones, triggering cascading disruptions to global supply chains, financial markets, and regional stability.

- **Dubai and Abu Dhabi**: As global business and logistics hubs, an attack here would cause mass casualties and paralyze international trade and investment, with economic shockwaves reverberating worldwide.
- **Cairo and Alexandria**: The incapacitation of these cities would destabilize Egypt's political system, disrupt the operation of the Suez Canal—a vital maritime chokepoint—and threaten the security of the broader region.

Two primary threat scenarios were examined:

1. **Nuclear Warfare**: Though still remote, the possibility of nuclear conflict is no longer unthinkable given the current geopolitical climate. The scale of potential casualties and infrastructure destruction in populous and economically vital cities would have profound humanitarian and geopolitical consequences.
2. **Nuclear/Radioactive Leaks**: The risk of accidental or deliberate release of radioactive materials from civilian nuclear facilities remains a grave concern. Despite international safeguards and the "gold standard" non-proliferation approach of the UAE, the proximity of nuclear plants to urban centres and critical infrastructure means that even an unlikely incident could cause significant casualties, long-term health effects, and massive displacement. The strategic locations of these plants, particularly near the Suez Canal, further amplify the potential for a nuclear incident to escalate into a global crisis.

Human loss remains the primary metric guiding the vulnerability assessment, and the projected fatalities and casualties are staggering. Cities with the highest population densities and critical infrastructure concentrations are the most vulnerable, validating their selection as case studies. Moreover, seniors and other vulnerable groups would bear a disproportionate burden in any nuclear scenario, suffering not only from immediate casualties but also from long-term health consequences due to radiation exposure and disrupted health care services.

Urban centres act as force multipliers: their interconnectedness with regional and global systems means that the impact of a nuclear event would be exponentially greater than the immediate blast or contamination zone. Economic, political, and humanitarian consequences would cascade across borders, magnifying the global stakes of regional nuclear risks.

Conclusion

The resurgence of nuclear threats in the post-Cold War era, fuelled by heightened geopolitical tensions, eroding arms control regimes, and regional instability, poses profound and multidimensional risks to the Middle East. This paper has shown that nuclear dangers in the region are no longer hypothetical or confined to military strategy; they now encompass a broader spectrum of threats, including civilian nuclear disasters and their devastating humanitarian, consequences.

By focusing on Egypt, the UAE, Saudi Arabia, and Jordan, the analysis reveals that the most strategically important states in the region are also among the most vulnerable. Their urban centres, infrastructure density, and regional significance make them high-value targets in both nuclear warfare and nuclear disaster scenarios. The dual nature of the threat, demands urgent attention to nuclear safety, non-proliferation, and conflict de-escalation mechanisms. Ultimately, the findings call for a recalibration of national and regional security priorities. Governments in the Middle East must enhance their resilience through transparent nuclear governance, improved emergency preparedness, and stronger international cooperation. At the same time, the international community must revitalize efforts to contain nuclear proliferation and rebuild trust in disarmament frameworks. Without decisive action, the region risks becoming not just a theatre for geopolitical confrontation, but a potential ground for nuclear catastrophe, one whose consequences would echo far beyond its borders.

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