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Environmental Engineering Estimation for Consequences of PWR Accident and Determination of the Evacuation Critical Areas Using Computer Codes Analysis

N. M. Sirag, E.F. Salem, Asmaa K. Abdien

Abstract— **Although Severe Accidents (SA) in nuclear power plants (NPPs) are unlikely events, occurrence with low probability (such as 10-5 per reactor per year), but causing significant damage to the reactor core, with core meltdown and serious consequences into the environment in case of radioactive products release. The mathematical models consider useful tools to predict the impacts of accidents consequences process. For site evaluation and environmental impact assessment for nuclear power plant models are needed to predict consequences of a hypothetical accident and evaluate the suitable protection or mitigation actions for emergency plan. In this work RASCAL (Radiological Assessment System for Consequence Analysis) Version 4.2 code was used for making dose projections for atmospheric releases during radiological emergencies. This hazard is location-specific since it is associated with the radiation dosage that is a function of distance from radiation source. In order to map the radiation hazard, Geographic Information Systems (GIS) is used. Accident consequence, RASCAL code output result, inter as an input to GIS codes to determine evacuation area and routes. The total amount radioactive released to atmosphere calculated using RASCAL code was about 1.5E+07 Ci and the maximum size of the PAZ was assessed at approximately a radius of 3 km from the NPPs. The maximum size of the UPZ zone, with generic criteria 100 mSv was about 5 Km. The maximum evacuation and sheltering zones are up to 8 Km and 16 Km respectively. Using GIS, we determined the time required for escape and release arrival time if effective signs were installed. With effectively installed, the average required evacuation time was 36.88 minutes; without such signs in case the target area, the average time was 47.10 minutes. For a quick evacuation, activation network analyst directly within the emergency room**

INTRODUCTION

A severe accident is exceeding in severity the Design Basis Accidents, which are those against which plant safety systems are designed [1]. Sever accidents have a very low probability $<10^{-6}$ (very unlikely to occur), but may have significant consequences resulting from nuclear fuel degradation, needed emergency response. For pressurized water reactors (PWR), the likelihood of creep failure of steam generator tubes for some severe accidents at high pressure of the reactor coolant is not negligible, with the possible consequence of a containment bypass [2]. In (PWR), a steam generator tube rupture is a containment bypass event that could lead to significant releases of radioactive material. Preventive design features should be installed in steam generators to reduce the frequency of such events to a very low value. The design of the plant should allow isolation of the containment bypass due to the damaged steam generator to be achieved before the authorized limits on radioactive discharges to the environment are reached [3]. Containment bypass events arise when a fault sequence allows primary coolant and any accompanying fission products to escape to the outside atmosphere without being processed by containment systems for the management of energy, radionuclides and combustible gases [4]. Sever accidents in (NPPs) research started originally in the seventies with initial risk assessment studies and later on with experimental programs, development of numerical simulation codes. For severe accidents, specialized codes are used to model the wide range of physical phenomena that occur, such as melting of the core and fission product behaviour [5]. The codes are used as a tool to determine accident management strategies and for probabilistic safety assessment (PSA). Analysis starts with selection accident sequences, without operator intervention, and lead to core damage. Computer codes can be used to assess these actions by evaluating the dose consequences. RASCAL code which stands for Radiological Assessment System for Consequence Analysis, is the software developed and used by the U. S. Nuclear Regulatory Commission (NRC), Emergency Operations Centre in order to estimate the projected doses in case of radiological emergencies [6]. When a nuclear accident results in the release of radioactive material into the atmosphere, urgent protective actions should be taken immediately to protect the public, particularly in the region around the accidental site. The measures to restore and maintain the safety functions under such conditions include the use of, off-site emergency measures (limitations on food consumption, taking shelter and evacuation). The lessons learned from Fukushima can be used to improve the safety of nuclear power plant operations around the world [7]. The overall objective of Emergency Preparedness and response (EPR), as defined by NUREG 0654 is "to provide dose savings (and, in some cases, immediate lifesaving) for a spectrum of accidents that could produce offsite doses in excess of Protective Action Guides (PAGs) [8]. A PAG is a dose that is projected in order to determine appropriate protective actions to include shelter, prophylactic iodide tablets, or evacuation. Emergency Planning Zones (EPZ)set the boundary for EPR. Two different EPZs were established; one known as the "plume exposure EPZs, such as precautionary action zone (PAZ), for which arrangements shall be made for taking urgent protective actions and other

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N. M. Sirag, Sites and Environment Department, Egyptian Nuclear and Radiological Regulatory Authority, Cairo, Egypt

E.F. Salem, Nuclear Law and Nuclear Licenses Department, Egyptian Nuclear and Radiological Regulatory Authority, Cairo, Egypt

Asmaa K. Abdien, Quality Assurance Department, Egyptian Nuclear and Radiological Regulatory Authority, Cairo, Egypt

response actions (evacuation or shelter-in-place and prophylactic iodide tablets), before any significant release of radioactive material occurs, on the basis of conditions leading to the declaration of a general emergency, in order to avoid or to minimize severe deterministic effects. An urgent protective action planning zone (UPZ), for NPP, which arrangements shall be made to initiate urgent protective actions and other response actions, if possible before any significant release of radioactive material occurs, and after a release occurs, on the basis of monitoring and assessment of the radiological situation off the site, in order to reduce the risk of stochastic effects [9]. An extended planning distance (EPD) and an ingestion and commodities planning distance (ICPD) arrangements shall be made to conduct monitoring and assessment of the radiological situation within a day to a week or to a few weeks and protecting the public from the ingestion of food, milk and drinking water following a significant radioactive release. EPZs assist decision makers in identifying which of the recommended protective actions is appropriate for each area around the plant [10]. Now, advancements in Probabilistic Risk Assessment (PRA) tools have been made and are available to better inform Emergency planning preparedness and response modelling. The NRC uses PRA to provide various levels of risk information: system risk information (Level 1 PRA), containment risk information (Level 2PRA), and population risk information (Level 3PRA). The NRC takes its policy on the implementation of PRA in regulatory decision making [11]. The objective of a Level 3 PRA in the operations of NPPs is to estimate the risk to public health and safety. In order to map the radiation hazard, Geographic Information Systems (GIS) is used. GIS has been incorporated into many other areas of research applicable to emergency management, such as identification of evacuation routes, and infrastructure planning [12]. Since the evolution of geographic information systems (GIS) which supports various fields of study including risk assessment. GIS provides powerful tools for spatial analysis whereby their capabilities for complex and dynamic analysis are limited.

In this work the assessment hazard from radiation of accidental release, of PWR plant that poses a level of threat to public health and the environment. RASCAL Version 4.2 (Radiological Assessment System for Consequence Analysis) code was used for making dose projections for atmospheric releases during radiological emergencies. This hazard is location-specific since it is associated with the radiation dosage that is a function of distance from radiation source. Accident consequence, RASCAL code output result, inter as an input to GIS codes to determine evacuation area and routes.

RASCAL Computer Code Description

RASCAL (Radiological Assessment System for Consequence Analysis) is currently used by NRC's emergency operations centre for making dose projections for atmospheric releases during radiological emergencies [13]. This code is widely used in several recent scientific work of radiological assessment [14-15]. Containment bypass is a coolant release from the reactor coolant system to an auxiliary building or directly to the environment without passing through the containment atmosphere. For the bypass model, RASCAL first calculates the initial concentration of each radionuclide in the coolant. For the time core is uncovered source term type selection, the initial coolant concentration is the activity released from the core during the first 15-minute time step divided by the total coolant volume. The most powerful and important source term type that RASCAL 4 calculates is based on the time that the core is uncovered. For PWRs, the time the core is uncovered should be the time that the coolant drops below the top of the active fuel. At this level cladding failure will begin. For calculations using the time core is uncovered source term type, RASCAL 4 will first calculate the activity released from the fuel to either the containment atmosphere or to the coolant as appropriate for the release pathway that the user has selected [13]. The equation is:

$$A_i(k) = I_i \times AF_i(k)$$

where

I_i = the core inventory of radionuclide i
$AF_i(k)$ = the available fraction of the inventory of radionuclide i available for release from the fuel during time step k

Scenarios Description

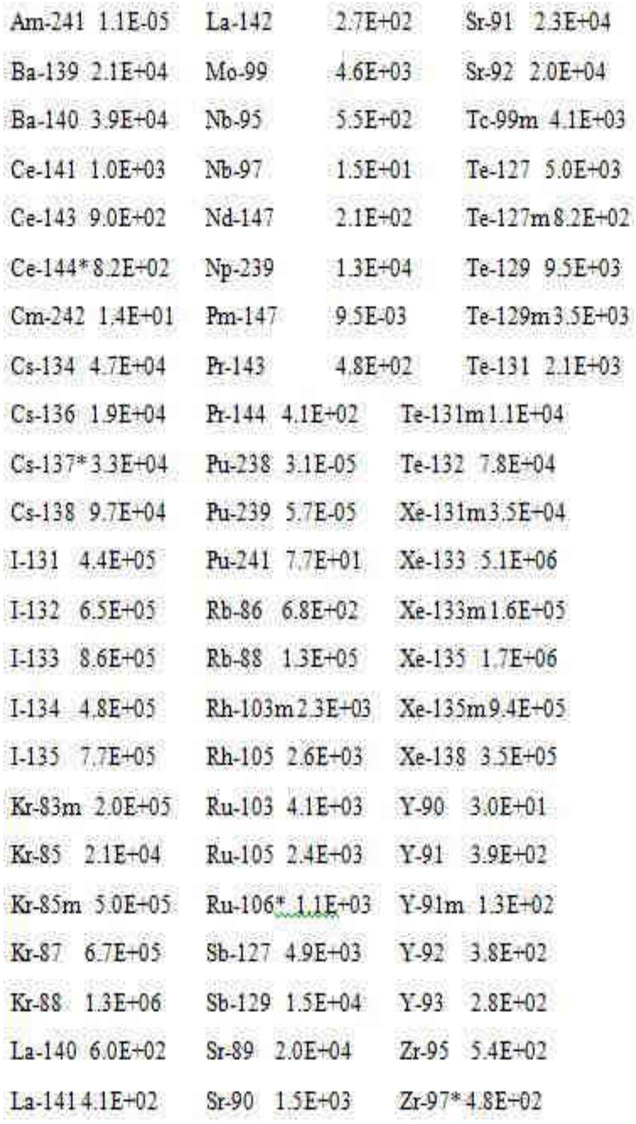
A postulated nuclear power plant pressurized water reactor (PWR) 1200 MW thermal nuclear parameters of VVER had been operating at full power. The reactor tripped due to a containment bypass flow rate, with large dry containment. The reactor scrammed at 12:00 Am time and the core was uncovered 12:15, and not recovered, significant release of radionuclides was occurred. The accident is classified as general emergency accident. The TEDE dose was calculated to nuclide leakage from bypass containment. The site of the meteorological data and the population distribution data for the Eldabaa city were used for this study. The meteorological data for the proposed site is north western coast of the Mediterranean Sea in Egypt which is a coastal area lie at Latitude 30° 56′58″N and longitude 28° 26′41″ E. The winds from the north and west accounted for more than 90 % of the wind directions. In this paper a representative rainy day was selected for winter season with wind speed 10 m/s, there and the wind direction is 285°.

Source Term:

To assess the source terms, we choose "time core is uncovered" option in RASCAL to quantify it. Containment bypass with 18 m height is used as a release pathway in the calculations. Table. 1. represented the source term for the postulated accident, is the type and quantity of radioactive materials (fission products and transuranic elements) released from the core of the reactor, into the containment atmosphere and then within the containment into the surrounding environment. A reactor shutdown occurs and simultaneously the core become totally uncovered by loss of coolant and remains uncovered, at the beginning of the accident. The duration of 10 hours was assumed for radioactive material release although it may continue many hours after initiation of severe accident [16]. The total amount radioactive released to atmosphere was about 1.5E+07 Ci

Table.1. source term for PWR sever accident

Nuclide	Ci	Nuclide	Ci	Nuclide	Ci



Am-241	1.1E-05	La-142	2.7E+02	Sr-91	2.3E+04
Ba-139	2.1E+04	Mo-99	4.6E+03	Sr-92	2.0E+04
Ba-140	3.9E+04	Nb-95	5.5E+02	Tc-99m	4.1E+03
Ce-141	1.0E+03	Nb-97	1.5E+01	Te-127	5.0E+03
Ce-143	9.0E+02	Nd-147	2.1E+02	Te-127m	8.2E+02
Ce-144*	8.2E+02	Np-239	1.3E+04	Te-129	9.5E+03
Cm-242	1.4E+01	Pm-147	9.5E-03	Te-129m	3.5E+03
Cs-134	4.7E+04	Pr-143	4.8E+02	Te-131	2.1E+03
Cs-136	1.9E+04	Pr-144	4.1E+02	Te-131m	1.1E+04
Cs-137*	3.3E+04	Pu-238	3.1E-05	Te-132	7.8E+04
Cs-138	9.7E+04	Pu-239	5.7E-05	Xe-131m	3.5E+04
I-131	4.4E+05	Pu-241	7.7E+01	Xe-133	5.1E+06
I-132	6.5E+05	Rb-86	6.8E+02	Xe-133m	1.6E+05
I-133	8.6E+05	Rb-88	1.3E+05	Xe-135	1.7E+06
I-134	4.8E+05	Rh-103m	2.3E+03	Xe-135m	9.4E+05
I-135	7.7E+05	Rh-105	2.6E+03	Xe-138	3.5E+05
Kr-83m	2.0E+05	Ru-103	4.1E+03	Y-90	3.0E+01
Kr-85	2.1E+04	Ru-105	2.4E+03	Y-91	3.9E+02
Kr-85m	5.0E+05	Ru-106*	1.1E+03	Y-91m	1.3E+02
Kr-87	6.7E+05	Sb-127	4.9E+03	Y-92	3.8E+02
Kr-88	1.3E+06	Sb-129	1.5E+04	Y-93	2.8E+02
La-140	6.0E+02	Sr-89	2.0E+04	Zr-95	5.4E+02
La-141	4.1E+02	Sr-90	1.5E+03	Zr-97*	4.8E+02

Notes:

• Nuclides with * in name include implicit daughters.

GIS computer cod description:

Dose Assessment results in Accident using RASCAL code, can be integrated to Geographic information Systems (GIS), where the analyzed outcomes from model can be allow to determine the number of people to be evacuated, and mitigation activities post emergency. Geographic information Systems (GIS) supply the chance to cover information for databases that offer the type of knowledge needed for evacuation designing prolong to explore a number of the opportunity's accessible exploitation GIS and the way they may be accustomed to supplement emergency management plans ready by protection and Emergency Management teams, to supply Engineering Proposal for Risk Management in Case of Nuclear Emergency by using Meteorological Data in Phases of evacuation. The diagram below shows the generic evacuation phase sequence for a mass evacuation, including the shelter in place option and voluntary evacuees:

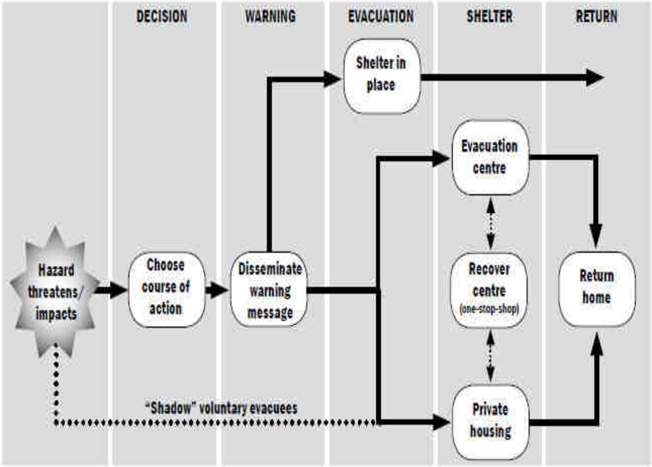


Figure (1) The generic evacuation phase sequences diagram

Decision

The decision phase constitutes the period when intelligence from the field is measured and a choice is made whether to order an evacuation or advise people to shelter in place [17-22].

Warning

This phase occurs when notifications are issued to the public advising them of the situation and what action they should take.

Evacuation

This phrase describes the actual physical evacuation of occupants from an area.

Shelter

The 'shelter' phase incorporates:

- the registration process
- accommodating evacuees
- the assessing and provision of welfare and recovery requirements.

Return

The return phase involves:

- an assessment of the evacuated area
- issuing an all-clear, and coordinating the physical return of evacuees.

Steps of Analytical Study (Network Analysis)

Defaults to spot the analysis of iodine station points at intervals of 100m,500m,1000m, end up associate analytical study of the road network (network analyst) Steps:

1. The primary step to the resolve button on the Network Analyst. A route feature appears within the map show and therefore the Network Analyst window below the Routes class. Analyst toolbar.
2. To the Directions panel opens, Click the Directions in the toolbar button within the Network Analyst.
3. On the correct column of the Directions panel, click one on each of the links named Map. During this section, you will add a barrier on the route to represent a roadblock, associated you may notice AN alternate route to your destination.
4. Inside the Network Analyst window below purpose Barrier, click Restriction.

5. To induce a replacement route is computed, Click Network Analyst to solve on.

The route analysis layer is prevailed in memory.

Result and discussion:

Figure 2 represent total effective dose equivalent (TEDE) for the postulated scenario after 2 and 10 hours from the start of release. Dose at red sectors exceed than >50mSv. The plume for the distance 4.8 and 8 km arrived quickly, whereas release rate started with the beginning of the accident. Sheltering in place or evacuation of the public will be for dose 10 to 50 mSv.

Figure 3, 4represent maximum TEDE and thyroid committed dose equivalent (Thyroid CDE), after 2hours, 5 hours and 10 hours from the start of release with distances from release point. For Early-Phase PAGs: TEDE - 10 mSv, Thyroid (iodine) CDE - 50 mSv. It is clear that TEDE greeter than 10 mSv extends up to 11 Km after two hours from the starting of release increase up to 16 Km after 5 hours and exceeding to 24 Km after 10 hours. For Thyroid CDE ≥ 50 mSv extends up to 8 Km , 16 Km and 24 Km after 2 hours , 5 hours and 10 hours respectively. Consequently, the avertable doses decrease with the increase of distance far away from the release point. In the present study, a dose criterion for the acute exposure to the whole body (bone marrow) of 1 Gy (1 Sv) was applied, according to the IAEA’s 1996 Basic Safety Standards (BSS) [23]. Using the results shown in Figures 2 and 3 exceeding a dose criterion of 1 Sv, the maximum size of the PAZ was assessed at approximately a radius of 3 km. The maximum size of the UPZ zone, with generic criteria 100 mSv was about 5 Km.

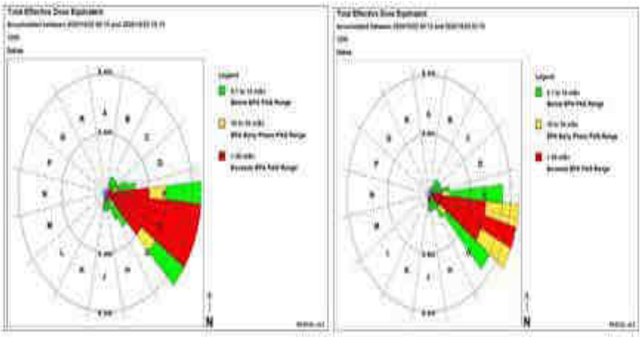


Fig. 2. Total effective dose after 2 and 10 hours from the start of release

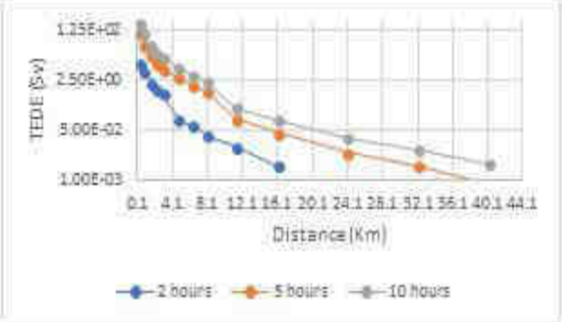


Figure .3 Maximum TEDE with the distances from the release point

The maximum evacuation and sheltering zones are up to 8 Km and 16 Km respectively. Whereas the area with radius 3 Km should be evacuated at the early phase before release at the sector F (110°). Knowing that the population in the radius 4 Km and 10 Km about 9800 and 65000 people respectively. Potassium iodide (KI) admission for dose threshold 50 mSv received on thyroid child by exposure to iodine.

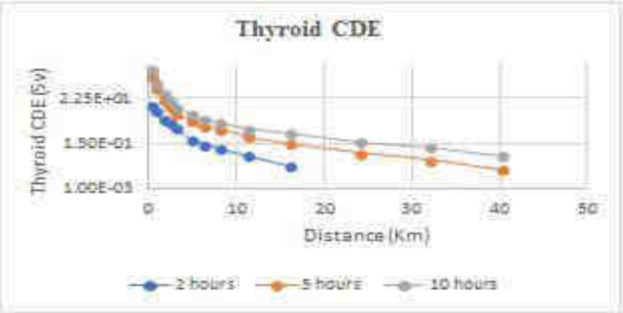


Figure. 4 thyroid CDE for 2, 5 and 10 hours from release

From figures 5 and 6, it is clear that I-13I and Cs- 137 maximum release rates to the environment after 2 hours from the start of release is about 3.46×10^{11} Bq/15min/ m^3 and 2.4 × 10^6 Bq/m^2, respectively, which increases as accident progresses and attains to 3.25×10^{12} Bq/15min/m^3 and 2.83 × 10^7 Bq/m^2 after 10 hours. The behaviour of I-131 and Cs-137 release rate is concerning the accident progression through different phases of reactor core failure. The release fractions of iodine or cesium groups resulting in acute exposure in the early phase of the accident, and the time before release related to the implementation of the protective action at PAZ and UPZ zones.

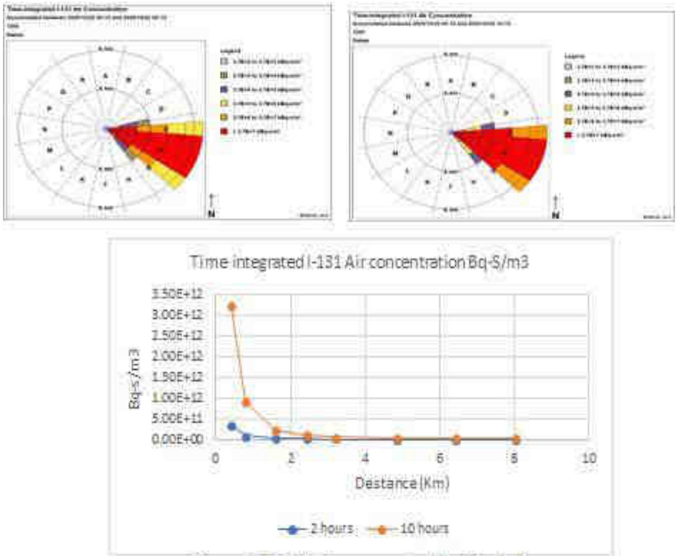


Figure 5. I-131 Air concentration Bq-s/m^3

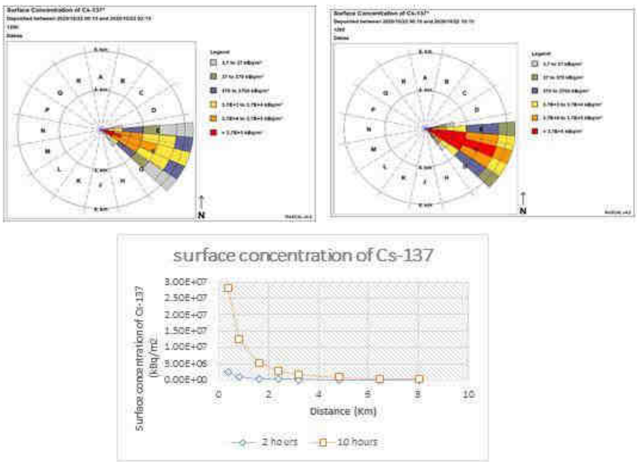


Fig.6. surface concentration deposited of Cs- 137 after 2 and 10 hours from start of release

The study considers the contaminated areas from which individuals are resettled just in case of an accident. Space |target| topographic point| place| spot of this study is the “Restricted Area” (the space within a twenty-km radius of the facility station) and also the “Deliberate Evacuation Area” (the area within which the annual additive dose may exceed 20 mSv) Figure 7. By the event and introduction of technologies as geographic info systems (GIS) emergency management primarily includes four phases, particularly readiness, mitigation, response, and recovery.

The area was selected considered would suffer severe damage following a major event, we identified difficulties in the provision of escape routes. Using GIS, we determined the time required for escape and release arrival time if effective signs were installed; we undertook such analysis using the metrology data in the target area. With effectively installed, the average required evacuation time was 36.88 minutes; without such signs in case the target area, the average time was 47.10 minutes.

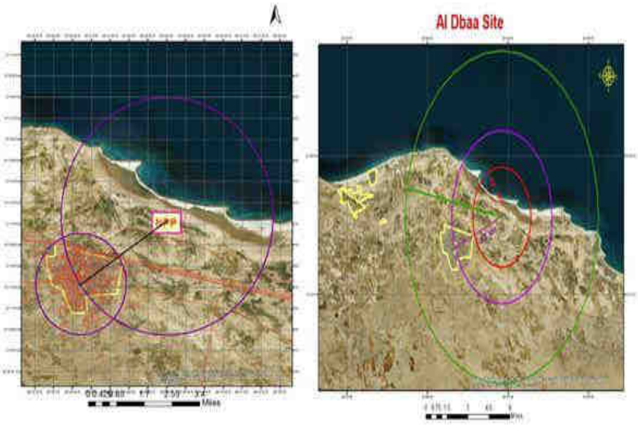


Figure 7 Maps showing the Al-Dbaa site

Altogether mentioned phases, GIS be used according the result of emergency management actions are a unit supported the analysis of knowledge. A fundamental quantity of knowledge, that is employed in emergency management, has special characteristics shown on maps. Also, once some information is mapped and knowledge is coupled with the map, recall digestion makes altogether phases of emergency management have a robust tool for creating the acceptable recall. In finding these functions, GIS can facilitate their work and lift public safety before, throughout, and once disasters. The future set of steps shows the due to export the Routes sublayer to a feature class. Just, simply designed the analysis to hunt out four facilities at intervals a three-minute cut-off; however, only two facilities are at intervals the cut-off. Forward associate accident among the north-west direction. Throughout this case, we tend to start to ponder evacuating the high-density zone (point 1) Figure (8) network analyst the high-density zone to the ingest, and easiest way to realize the initial evacuation route, while Figure.8 shown at constant time reversing the wind direction to scale back the danger point 2, or from points 3 to 4. Figure.9 – a shows automobile points are famous to convey the voter's doses of iodine and straightforward access to the foremost roads equipped for quick evacuation. By report and attribute table points Figure 9 – b has been calculating identified to give the citizens doses of iodine and easy access to the main roads.

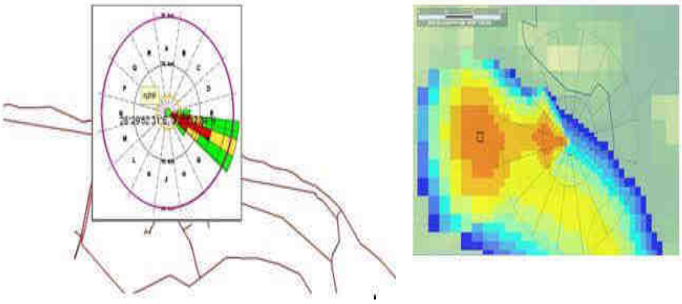


Figure 8 Network analyst reversing the wind direction to reduce the danger the high-density zone

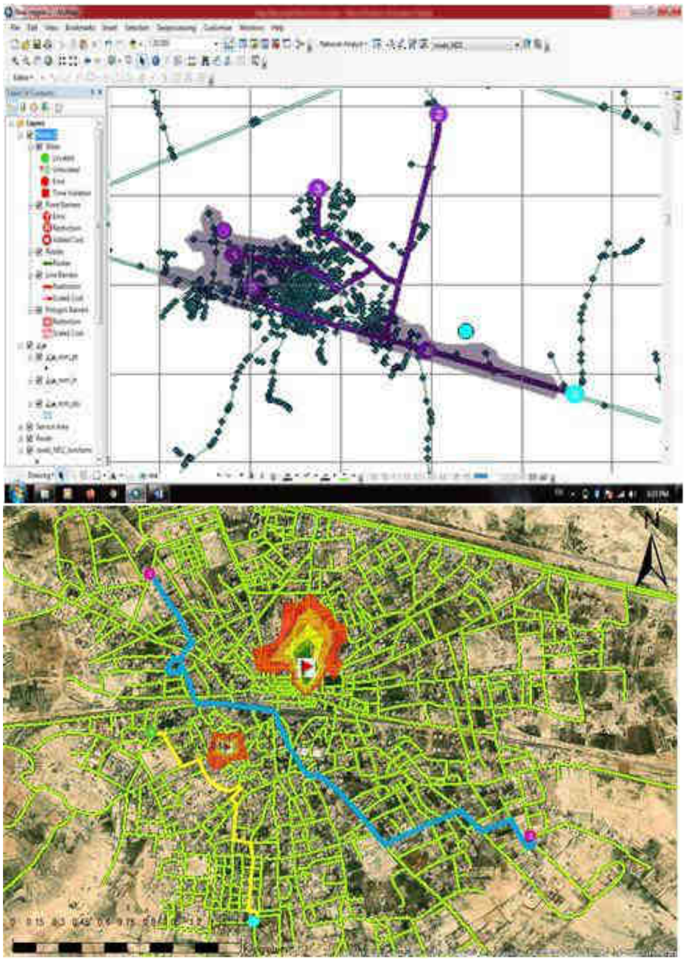
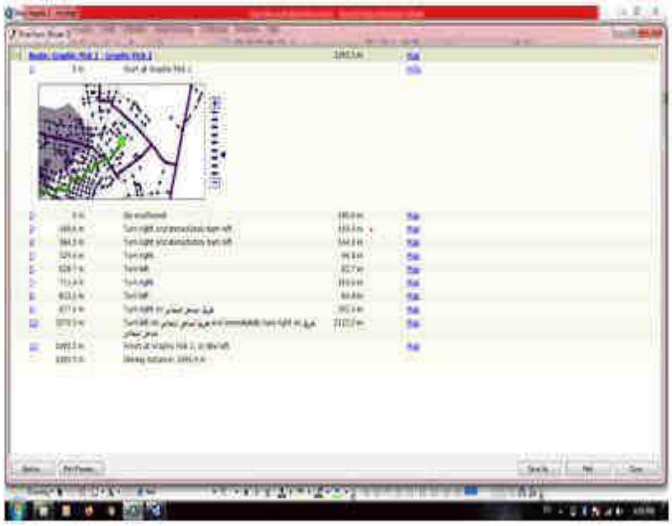
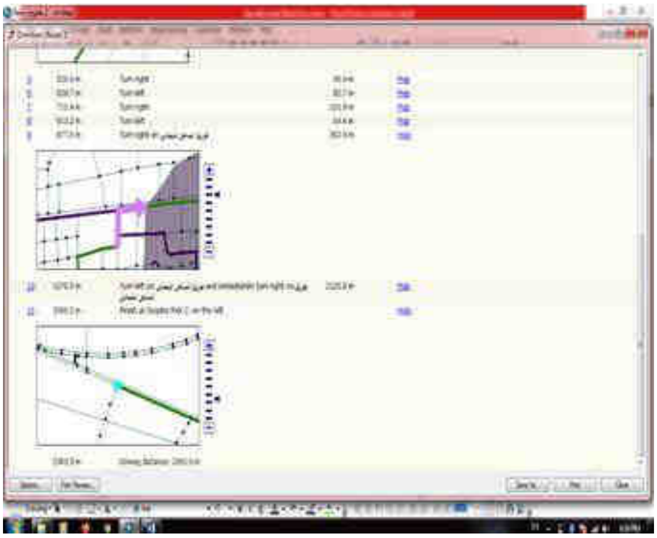


Figure 9 – a Explain spatial data and grid analysis





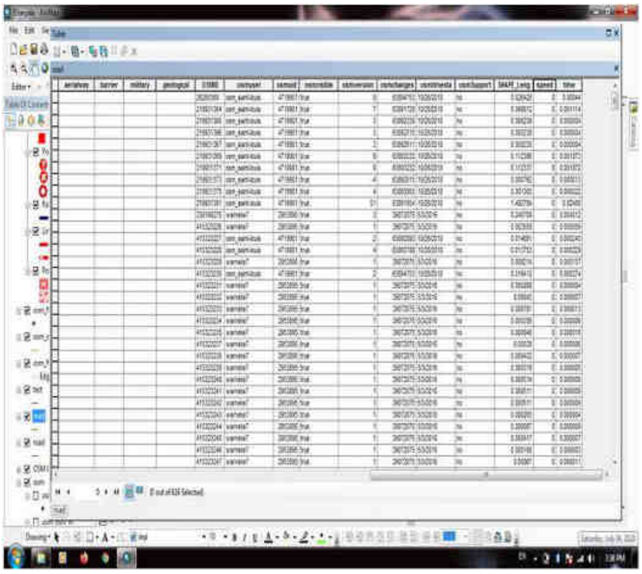


Figure 9 – b Shows report and attribute table points have been calculating identified to give the citizens doses of iodine and easy access to the main roads.

CONCLUSION:

The release consequences lead to many hazards and have significant importance to human communities living in the surroundings. In this study, the maximum TEDE at section (110°), the size of the PAZ was evaluated, to obtain technical knowledge for planning emergency response procedures for a nuclear accident. PAZ evaluated in the area with a radius 3.0 km from El-Dabba NPP should be evacuated in the early phase of an emergency. It was found that the result was similar to the IAEA's suggested PAZ of 3–5 km [24]. by integrated between Geographical information system software with Metrological Data, can be to predict and display the consequence of release hazards.

Accordingly, the maximum evacuation and sheltering zones are up to 8 Km and 16 Km respectively. Potassium iodide should be administrated before a release to about a distance of 20 km away from the nuclear power plant. The paper stressed that among different problems that will confront the utilization of special analysis, is that the accuracy of knowledge and time of processing, additionally to collective coordination within the field. The aim to use GIS Analysis presents applicable solutions for roads and time special analysis and emergency preparation, for safe evacuation. The findings of this analysis conclude that a challenge to attainable risk reduction is furnishing disaster managers, to access data and methodologies that will facilitate them in analysing, evaluating, and mapping hazard models. The requests on emergency managers and resources will change as the evacuation progresses through each phase. For that, this guideline must be covers planning considerations for each phase.

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