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Assessment of Radiological and Economic Consequences of a Hypothetical Accident for ET-RR-2, Egypt Utilizing COSYMA Code

F. S. Tawfik and M.M. Abdel-Aal[1]

Siting & Environmental Department, National Center for Nuclear Safety & Radiation Control, Atomic Energy Authority Cairo 11762, P.O.Box 7551,Egypt.

[1]*On leave to the following address: University of Zimbabwe, Physics Department, P O Box MP 167 Mount Pleasant. Harare, Zimbabwe.* medhat@science.uz.ac.zw

ABSTRACT

A comprehensive probabilistic study of an accident consequence assessment (ACA) for loss of coolant accident (LOCA) has accomplished to the second research reactor ET-RR-2, located at Inshas Nuclear Research Center, Cairo, Egypt. PC-COSYMA, developed with the support of European Commission, has adopted to assess the radiological and economic consequences of a proposed accident. The consequences of the accident evaluated in case of early and late effects. The effective doses and doses in different organs carried out with and without countermeasures. The force–mentioned calculations were required the following studies: the core inventory due to the hypothetical accident, the physical parameters of the source term, the hourly basis meteorological parameters for one complete year, and the population distribution around the plant. The hourly stability conditions and height of atmospheric boundary layers (ABL) of the concerned site were calculated. The results showed that, the nuclides that have short half-lives (few days) give the highest air and ground concentrations after the accident than the others. The area around the reactor requires the early and late countermeasures action after the accident especially in the downwind sectors. Economically, the costs of emergency plan are effectively high in case of applying countermeasures but countermeasures reduce the risk effects.

Key Wards: COSYMA/ Accident/ Risk effects/ countermeasures/ Radiological impact

INTRODUCTION

PC COSYMA[(1)] is a probabilistic ACA system, for use in calculating the risk posed by potential nuclear accidents involving a release to atmosphere, taking into accounting the range of conditions which may prevail at the time of accident. The code is used under agreement with the European Commission.

The code was applied to assessing the off-site radiological and economical consequences of accidental atmospheric releases of radioactive materials with countermeasures from ET-RR-2. The probabilistic assessment used to carry out the probability distributions of the different endpoints. The consequences, which termed ‘endpoints’ of the analysis, encompass the air concentration or deposition of particular nuclides, dose received by members of the population, the individual or collective risks of health effects in the exposed population, the extent and duration of countermeasures which might be imposed to reduce health effects, and the economic costs of the countermeasures and health effects.

INPUT PARAMETERS

1- Atmospheric Conditions

The atmospheric conditions are a critical factor in determine the spatial and temporal distributions of dispersed radionuclides. The collected hourly data for the whole year of 2001 in the site is used.

The distribution of wind direction and speed is considered to know the prevailing downwind direction. The WRPLOT code[2] was utilized for this purpose. The results indicate that the north direction is the prevailing wind direction , thus the south is the prevailing downwind sector. The calculated hourly basis of atmospheric stability conditions and height of ABL of the site were used[3].

2. Source Term

The amount and form of radionuclide released into the environment calculated by using a program provided with the system. This program choose those nuclides which make the largest contribution to dose from a list of calculated core inventory after a hypothetical accident[4], (assuming that the water above the core was lost) then multiplying their activity with the released fraction of LOCA accident in case of research reactors. These fractions were; 10^{-1} for Xe - Kr, 10^{-1} for I and 10^{-3} for Cs, Rb, Te, Si, Ba, Sr, La, Ru[5].

3. Population Distribution

The population distribution around ET-RR-2 was investigated, with a radius 5 km was subdivided into 5 stripes of 1 km and 16 sectors of 22.5 degree with the plant located at the center of the concentrate circles. The calculations carried out without agricultural production distributions because we have not complete sufficient information.

RESULTS AND DISCUSSIONS

The results of ACA divided into two groups. The first group is air concentration and deposition of each nuclide released at different distance considered, and results of doses at short- and long-term after the releases. The second group is health effects following an accident that split into two groups, early and late effects.

1. Air Concentration and Deposition

The air and ground concentration of nuclides at different distances are shows in Table (1). The concentration of short-lived nuclides (iodine isotopes and LA-140) is higher than the concentration of long-lived nuclides (SR-90). Any nuclide reaches its highest concentration at its half –life time[6], this explains why the short–lived nuclides (with small half lifetime, few days or hours) have the high concentrations after the accident.

2. Countermeasures

The code considers sheltering, evacuation, iodine distribution and relocation. The results shows that the action of sheltering and evacuation automatically takes place at the downwind sectors after the accident. In the other sectors this action takes place only in the regions closed to the site.

For iodine distribution, this action takes place automatically along the distances up to 2.5 km in all sectors. Also this action based on dose level 0.02 Sv takes place in downwind sector at distance of 3.5 km. The duration time of the relocation at the distances up to 1.5 km in all sectors, except the downwind sector, is 7 days.

Nuclide	Half-life (Days)	Distance (Km)					
		0.5		1.5		2.5	
		Air Bq.s/m**3	Ground Bq/m**2	Air Bq.s/m**3	Ground Bq/m**2	Air Bq.s/m**3	Ground Bq/m**2
CE-143	1.370E+00	4.865E+08	2.373E+06	1.404E+08	5.823E+05	6.248E+07	2.237E+05
ZR-95	6.550E+01	2.540E+08	1.239E+06	7.405E+07	3.068E+05	3.321E+07	1.185E+05
ND-147	1.100E+01	2.159E+08	1.053E+06	6.288E+07	2.606E+05	2.818E+07	1.006E+05
RU-103	4.000E+01	1.720E+08	8.392E+05	5.016E+07	2.078E+05	2.249+07	8.028E+04
LA-140	1.660E+00	3.113E+10	1.519E+08	9.003E+09	3.733E+07	4.013E+09	1.436E+07
TE-132	3.250E+00	3.881E+08	1.893E+06	1.127E+08	4.671E+05	5.038E+07	1.800E+05
NB-95	3.500E+01	1.075E+08	5.244E+05	3.137E+07	1.300E+05	1.408E+07	5.024E0+4
SR-89	5.060E+01	2.290E+08	1.117E+06	6.676E+07	2.766E+05	2.994E+07	1.069E+05
SR-90	1.050E+04	1.966E+06	9.592E+03	5.735E+05	2.376E+03	2.572E+05	9.181E+02
SR-91	4.000E-01	4.877E+08	2.380E+06	1.371E+08	5.704E+05	5.988E+07	2.159E+05
CE-144	2.850E+02	6.540E+07	3.190E+05	1.907E+07	7.902E+07	8.554E+06	3.053E+04
I-132	1.000E-01	2.923E+10	3.744E+08	4.404E+09	5.619+07	1.221E+09	1.581E+07
I-133	8.750E-01	4.576E+10	5.857E+08	7.704E+09	9.768E+07	2.247E+09	2.850E+07
I-134	3.600E-02	2.118E+10	2.714E+08	2.624E+09	3.394E+07	6.775E+08	9.142E+06
I-135	2.800E-01	3.845E+10	4.922E+08	6.276E+09	7.971E+07	1.802E+09	2.299E+07
Y-91	5.900E+01	2.538E+07	1.238E+05	7.415E+06	3.071E+04	3.30E+06	1.188E+04
CE-141	3.280E+01	4.064E+08	1.983E+06	1.185E+08	4.909E+05	5.312E+07	1.896E+05
TE-129M	3.410E+01	9.941E+06	4.849E+04	2.899E+06	1.201E+04	1.300E+06	4.642E+03
BA-140	1.280E+01	5.527E+08	2.696E+06	1.610E+08	6.671E+05	7.215E+07	2.576E+05
PR-143	1.360E+01	4.744E+08	2.314E+06	1.384E+08	5.732E+05	6.206E+07	2.215E+05
RU-106	3.680E+02	3.589E+06	1.751E+04	1.047E+06	4.337E+03	4.695E+05	1.676E+03
CS -137	1.100E+04	1.977E+06	9.644E+03	5.766E+05	2.389E+03	2.586E+05	9.231E+02

Nuclide	Half-life (Days)	Distance (Km)			
		3.5		4.5	
		Air Bq.s/m**3	Ground Bq/m**2	Air Bq.s/m**3	Ground Bq/m**2
CE-143	1.370E+00	3.957E+07	1.215E+05	2.428E+07	6.855E+04
ZR-95	6.550E+01	2.127E+07	6.486E+04	1.311E+07	3.665E+04
ND-147	1.100E+01	1.802E+07	5.500E+04	1.110E+07	3.108E+04
RU-103	4.000E+01	1.440E+07	4.392E+04	8.876E+06	2.482E+04
LA-140	1.660E+00	2.547E+09	7.808E+06	1.564E+09	4.407E+06
TE-132	3.250E+00	3.212E+07	9.820E+04	1.976E+07	5.547E+04
NB-95	3.500E+01	9.023E+06	2.750E+04	5.564E+06	1.554E+04
SR-89	5.060E+01	1.917E+07	5.847E+04	1.182E+07	3.304E+04
SR-90	1.050E+04	1.648E+05	5.024E+02	1.016E+05	2.839E+02
SR-91	4.000E-01	3.685E+07	1.1519E+05	2.236E+07	6.478E+04
CE-144	2.850E+02	5.480E+06	1.671E+04	3.378E+06	9.443E+06
I-132	1.000E-01	5.134E+08	6.919E+06	2.525E+08	3.653E+06
I-133	8.750E-01	1.000E+09	1.286E+07	4.848E+08	6.569E+06
I-134	3.600E-02	2.662E+08	3.900E+06	1.344E+08	2.147E+06
I-135	2.800E-01	7.7877E+08	1.026E+07	3.828E+08	5.288E+06
Y-91	5.900E+01	2.137E+06	6.508E+03	1.318E+06	3.679E+03
CE-141	3.280E+01	3.401E+07	1.037E+05	2.096E+07	5.863E+04
TE-129M	3.410E+01	8.331E+05	2.540E+03	5.136E+05	1.436E+03
BA-140	1.280E+01	4.616E+07	1.409E+05	2.844E+07	7.960E+04
PR-143	1.360E+01	3.975E+07	1.212E+05	2.451E+07	6.850E+04
RU-106	3.680E+02	3.007E+05	9.170E+02	1.854E+05	5.183E+02
CS –137	1.100E+04	1.657E+05	5.051E+02	1.021E+05	2.855E+02

Table (1): - The nuclides concentration in air and ground

3. Short and Long-tem Individual Doses

The significance of countermeasure is shows in Fig. (1), where the short individual dose value without countermeasure is higher than their values with countermeasure. The difference appears close to the reactor. The effective short and long individual doses for both cases at 1.5 km from the reactor (Population Zone) are shows in Fig. (2), taking into account the contribution of different nuclides. Both short and long individual dose without countermeasures is higher than in countermeasures. For example, the contribution of iodine isotopes the dose decreases for countermeasures according to the distribution of stable tablets of iodine after the accident.

Calculations of mean short-term individual dose for different organs at different distances revealed that skin and thyroid have received highest dose values than the other organs in both cases. Nevertheless, the dose values of different organs taking into consideration the countermeasures get lower.

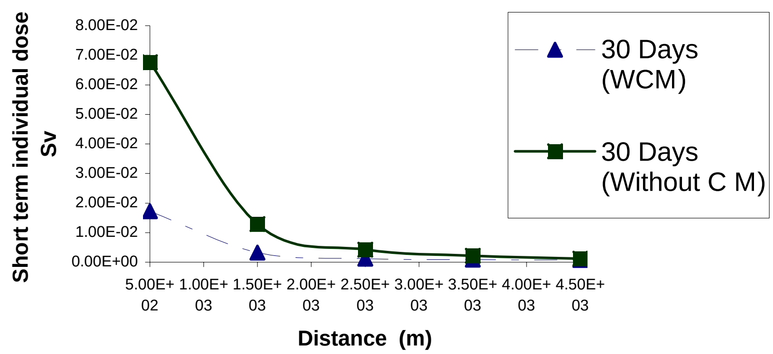
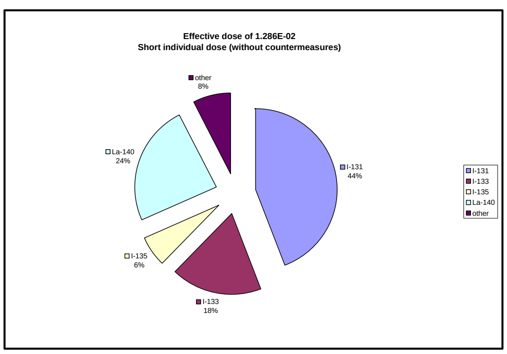
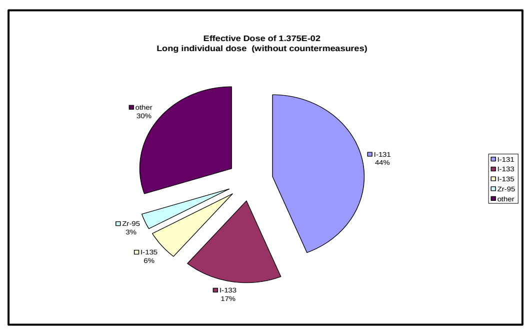
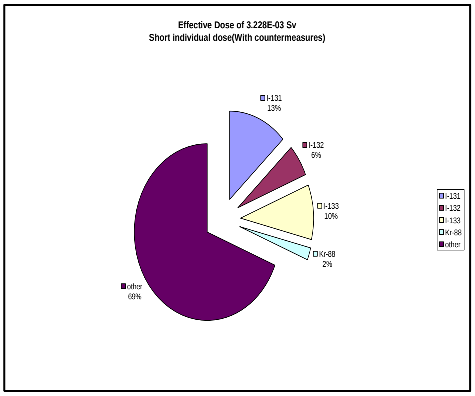


Fig. (1): The relation between the short-term individual dose and distance







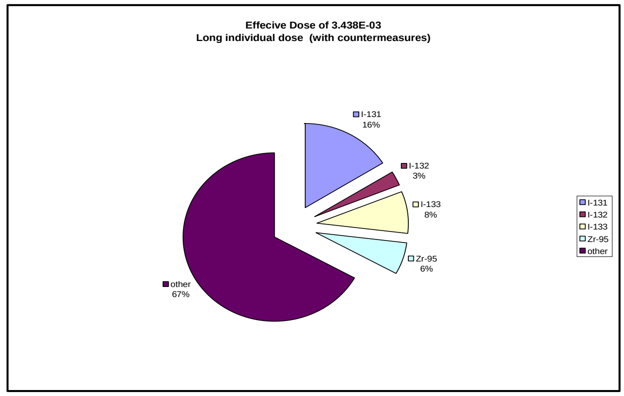


Fig. (2) : Short and long individual doses at 1.5 km for different contribution of nuclides

4. Collective Doses

The results of effective long term collective doses with countermeasures and the contribution of dose from different pathways shows that the inhalation is the most important pathway than exposure to cloud and ground. The CCDFs (complementally cumulative distribution frequency) of collective dose in the exposed population is about 1.0 for collective dose values from (0.01-30) Sv, and then it reduced until reached 0.04 for dose value of 300 Sv.

5. Late Health Effects

The CCDFs for numbers of late health effects in the population in both incidence and mortality are shows in Fig. (3,4) respectively. The numbers is greatest in the absence of countermeasures for the same probabilistic values. Countermeasures reduce mortality number in the population.

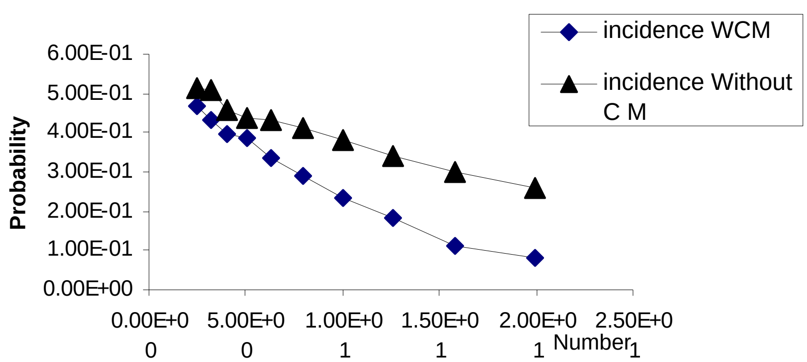


Fig. (3): The probability of number of late health effect (incidence)

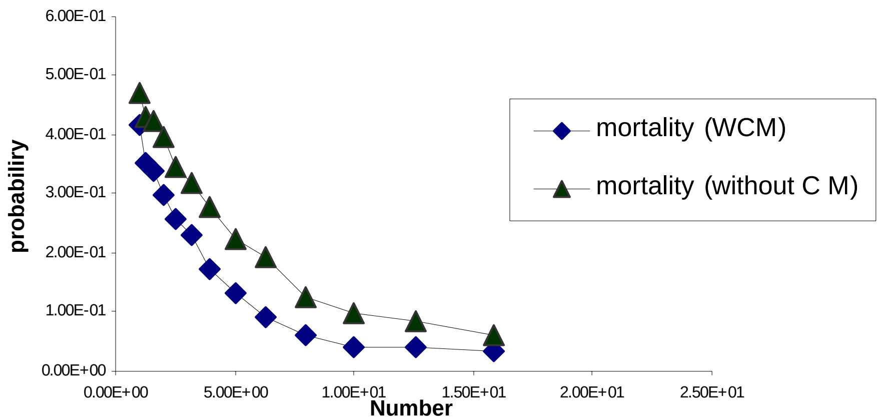


Fig. (4):The probability of number of late health effect (mortality)

6. Risk of Health Effects

The CCDFs for long-term individual risk at 0.5 km and 1.5 km are shows in Fig. (5). The probability at 0.5 km is higher than at 1.5 km for the same value of individual risk, where 0.5 km is the first distance located inside the working area around the plant, this value can be taken for operators, while the 1.5 km for public.

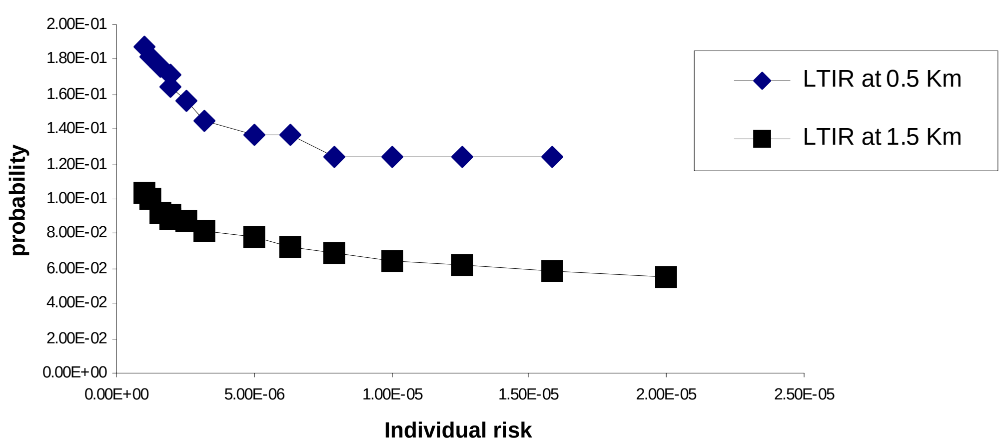
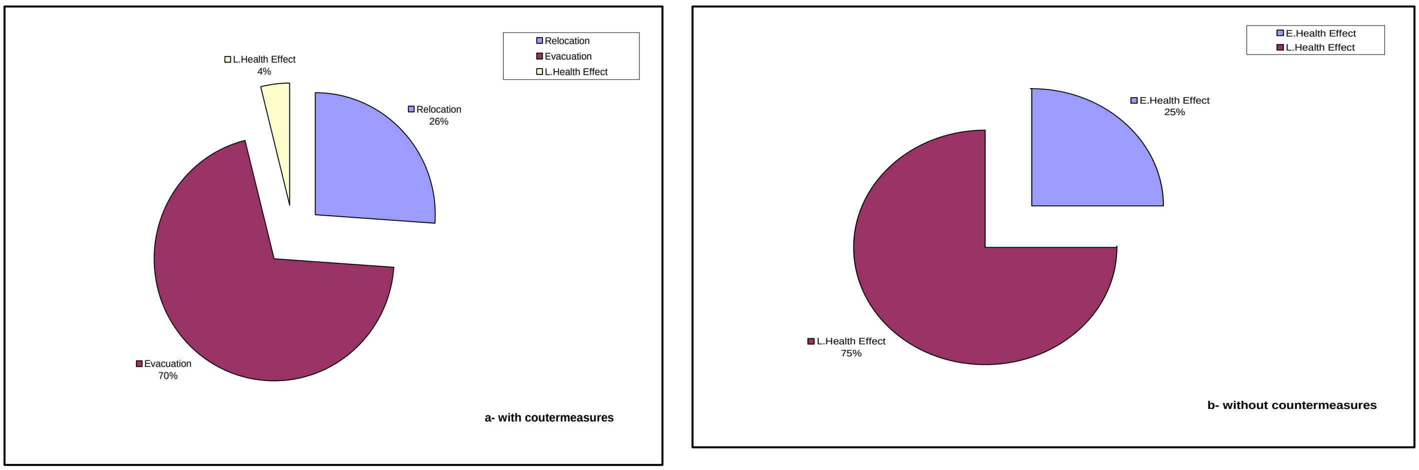


Fig. (5): Ccfds of long-term individual risk

7. Economic Costs

This is the first attempts to figure out the estimation of economic costs of nuclear research reactor accident. This should help us to evaluate the costs of potential nuclear power plants accident. The overall costs and the costs of countermeasures for early and late health effects are shows in Fig. (6). The cost of countermeasures is higher than the cost without countermeasures, but most of these costs for countermeasures. Without countermeasures, all costs for late and early health effects. Therefore, countermeasures are increasing the costs but reduce the accident consequence.



(a)Total cost = 7.248E+05 LE

Total cost = 1.375E+07 LE)b(

Fig. (6): Total economic cost

CONCLUSIONS

PC COSYMA code has been adapted for probabilistic ACA of a hypothetical LOCA accident in ET-RR-2. The results showed that: (1) the short-lived nuclide gives highest air and ground concentration than the nuclides, which have, long half-life at the same distances. (2) The short individual dose with countermeasures gives the highest effective dose, which decreased with increasing the distances. For different organs, the skin and thyroid received the highest dose values than the other organs. (3) The short individual dose values without countermeasures, gives higher dose values than with countermeasures. (4) The CCDFs for short and long-term observed that it is higher in case of long term than in case of short- term_at same values of dose. (5) The CCDFs for collective doses gives probabilistic value of 0.04 for dose equal 300 man Sv was. (6) Due to taking into consideration the countermeasures, the early health effects are very small and the late health effects are more important in case of_mortality and incidence. (7) The late individual risk was important than the early near the_plant and decrease with the distance. (8) The economic cost is high with countermeasures but the countermeasures reduce the health and risk effects.

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