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GSAD-IV; Analytical Software Model for Assessing the Generic Transport of Low and Intermediate Radioactive Wastes in an Aquifer

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ABSTRACT

System Analyst Group (SAG) of the Databank in nuclear/radiological regulatory authority, as an import role, has the duty to build national software codes. The present work describes a part from an integrated computer code; the generic modeling of radionuclide transport in an aquifer. This part is consider from the the generic safety assessment of low and intermediate radioactive waste disposal site. The code is preparing intentially for the praticallity of juniors from a side. From the other side, it is building to reduce the time for seniors to reach their decisions concerning a given disposal site from operators. The code is an analytical model of the dispersion-advection equations using Green's functions solutions for instantaneous release of radionuclides in an aquifer in one direction. The Code is using Oracle language under XP window platform. The code performed fulfills the target of the databank. Meanwhile, it represents for the SAG the challenge of easy learn easy use.

Keywords: *Generic Safety Assessment, Disposal Site, Aquifer, Green Functions.*

1. INTRODUCTION

By definition of the International Atomic Energy Agency (IAEA), disposal of radioactive wastes from nuclear/radiological activities is the emplacement of waste in an appropriate facility without the intention of retrieval [1]. Additionally, the safety case is the collection of scientific, technical, administrative and managerial arguments and evidence in support of the safety of a disposal facility, covering the suitability of the site and the design, construction and operation of the facility, the assessment of radiation risks and assurance of the adequacy and quality of all of the safety related work associated with the disposal facility. The safety case and supporting safety assessment shall be prepared and updated by the operator in the development, operation and post closure of a disposal facility. They shall be submitted to the regulatory body for approval [2].

Safety assessment, as an important part of the safety case, is driven by assessment of radiation hazards as presented in Figure 1 [2]. The safety assessement of the disposal site is demonstrated through the modeling of each element behavior in respect of all system in normal and accidental cases. The aim of modeling studies is to first help in understanding the characteristics of the system and its barriers component, and ultimately to assess the performance of a repository under various scenarios to support a licence application [3].

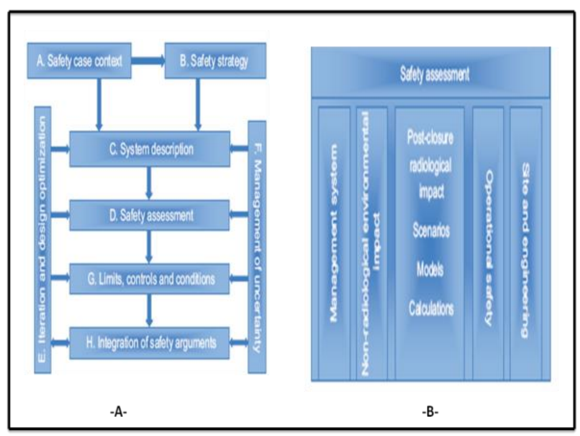


Fig. 1. Components of the Safety Case (A) and Safety Assessment (B) [2].

The System Analyst Group (SAG) in the DataBank of scientific authority has different roles to perform; analysis of data/information collected from different sectors in the authority, preparation of spreadsheets, adaptation of codes and building of computer codes required[4, 5].

Generic safety assessment for the disposal site is an useful tool to get an overall general picture about the site selected and key radionuclide that shall be consider to assess the influence of repository on human and its environment. In the present work, a national computer code is builded. GSAD is a software model for the generic (G) safety (S) assessment (A) of the low and intermediate radioactive waste disposal (D) site.

2. CODE DESCRIPTION

2.1 Scenario Considered

GSAD code treats two scenarios for the disposal of low and intermediate radioactive wastes in vault structure; 1) instantaneous release and 2) continuous release. In the first scenario, a large fracture is created on the reinforced concrete, which offers a direct pathway of rainfall flux. The containers and the part of vault basement under the flux of water are exposed to severe damage. Some containers are brooked. The radionuclides in the brooked containers are dissoluted in the water and migrated from the basement of the vault to the geosphere as an instantaneous release of activity.
The second scenario is simulates erosion of the vault cover, which increase the amount of infiltrated rain water in the vault. Some containers are loose integrity by the action of water. Surface eroded containers offer a continuous release of radionuclides that migrated from the vault to the biosphere. Figure 2 demonstrates a general draw of the two scenarios.

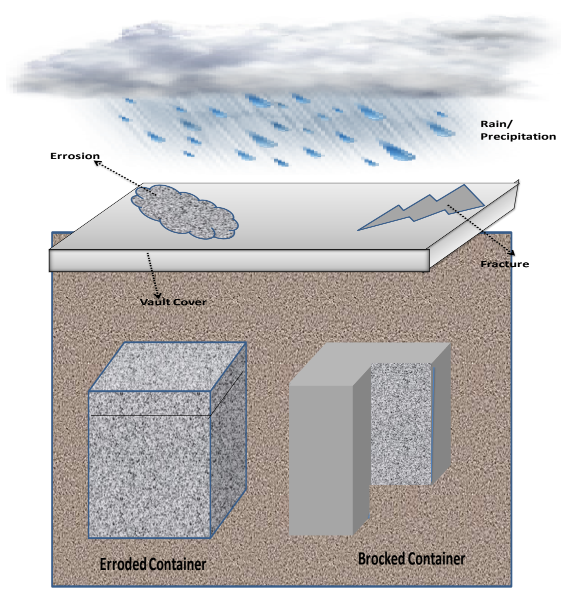


Fig. 2. A Simple Draw of the Infiltration Pathway for the two Scenarios Considered.

The code in both scenarios is composed of different parts as shown in Figure 3. Figure 3 describs the whole path of radionuclides from the vault to the geosphere and the biosphere within various driven source; water and air. Each part will study and build separately and finally connected as a whole one scenario for both cases. In the present work, part IV, considers the instantaneous transport of radionuclides in the aquifer.

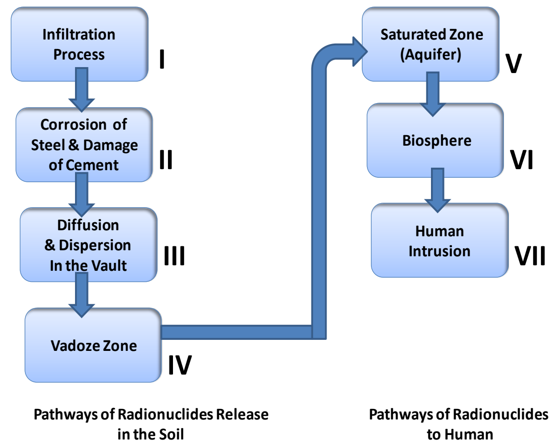


Fig. 3. Different Parts Considered in the GSAD Code

2.2 Assumptions Undertaken

1- Instantaneous release of activity one dimension in the aquifer.
2- Chemical reaction and solubility limit of radionuclides are neglected.
3- Decay Chain is neglected.
4- Homogeneous isotropic media in which the gradient is constant.
5- Failure is occurred after the institutional control time (t=100 years).
6- The site is dH above the mean level and dX up gradient from a river.
7- The aquifer is infinite lateral extent.

2.3 Code Structure

In general, GSAD-IV is a main computer code program with one subroutine for the calculation of error function. It is developed to simulate the radionuclide transport from waste disposal site to an aquifer within different mechanisms (dispersion, advection and sorption). The subroutine in the code is for the calculation of the error function values. The error function calculational subrotine is transferred from fortran language [6] to oracle language. The output of the code gives the concentration of radionuclides migrated in the aquifer as a function of time and distance.

The code starts by selecting; mode of migration, case option and level of conservatism. The input variables and parameters file is friendly use interface. The variables are fed by the user such as; activity, x, y and z directions, hydraulic conductivity, width and depth. The parameters, according to the level of conservatism selected by the user, can be given by the user. In case of ungiven data of parameters, the code will consider the values from the internal library of the stored data. Therefore from the start window, the user shall select the level of conservatism of the data from three options exist; conservative (100% conservatism), moderate (50% conservatism) and extrimisty level (0% conservatism). The conservative level for value of parameters reflects the pessimistic case and it will be a good option in the fact of higher number of unknown parameters and/or intermediate level of radioactive wastes. On the other hand, the extrimisty is the optimistic case and it can be suitable for good site and/or short half-life radionuclides. The output file is always printed with the input file considered with mentioning the source of the input data if it is given or stored data fom the library. Figure 4 presented flowchart of the code.

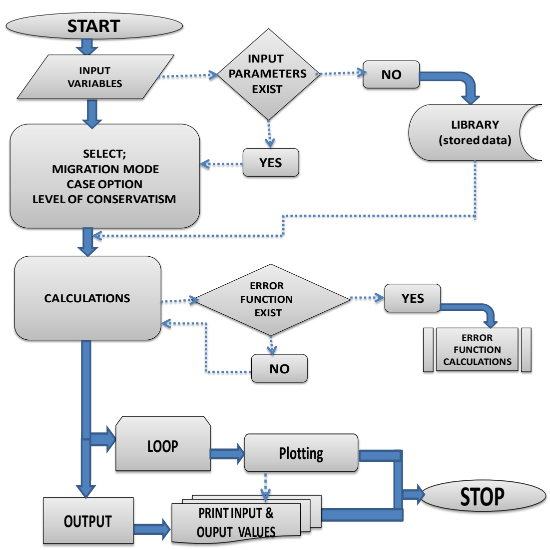


Fig. 4. Flowchart of GSAD-IV Process.

2.4 Theoretical Code Calculations

The code calculations are considered the analytical solutions of Green functions method that provides a general way to solve inhomogeneous differential equations of the form [7-8];

$$c_i = \frac{1}{n_e R_d} X(x,t) Y(y,t) Z(z,t)$$

Where;

Ci is the concentration at any point in space for an instantaneous one curie release,

n_e is the effective porosity of the medium, dimensionless

R_d is the retardation coefficient, dimensionless and equal

$$R_d = 1 + \frac{\rho_b}{n_e} K_d .$$

ρ_b is the density of the soil L^3/M

K_d is the distribution coefficient of radionuclide within the aquifer M/L^3

X, ***Y***, *Z* are the Green's functions in the x, y, *z* coordinate directions, respectively.

The Green Function equation has been developed for a variety of boundary and source configurations as presented in Table 1 [7].

Table 1: Solutions of Green Function for Different Boundaries and Source Condition

$$c_i = \frac{1}{n_e R_d} X(x,t) Y(y,t) Z(z,t) ,$$

*****For an aquifer of finite depth**		$X_1 = \frac{1}{\sqrt{4\pi D_x t/R_d}} \exp\left[-\frac{(x-Ut/R_d)^2}{4D_x t/R_d} - \lambda t\right] ,$
Point Source	$c_i = \frac{1}{n_e R_d} X_1 Y_1 Z_1 ,$	$Y_1 = \frac{1}{\sqrt{4\pi D_y t/R_d}} \exp\left(-\frac{y^2}{4D_y t/R_d}\right)$
Vertical Line Source	$c_i = \frac{1}{n_e R_d} X_1 Y_1 Z_2 ,$	$Z_1 = \frac{1}{b}\left\{1 + 2\sum_{m=1}^{\infty} \exp\left(-\frac{m^2\pi^2 D_z t}{b^2 R_d}\right) \cos m\pi \frac{z_s}{b} \cos m\pi \frac{z}{b}\right\}$
Horizontal Line Source	$c_i = \frac{1}{n_e R_d} X_1 Y_2 Z_1 ,$	$X_2 = \frac{1}{2\ell}\left\{\mathrm{erf}\frac{\left(x+\frac{\ell}{2}\right) - \frac{ut}{R_d}}{\sqrt{4D_x t/R_d}} - \mathrm{erf}\frac{\left(x-\frac{\ell}{2}\right) - \frac{ut}{R_d}}{\sqrt{4D_x t/R_d}}\right\} \exp(-\lambda t) .$
Vertical Area Source	$c_i = \frac{1}{n_e R_d} X_1 Y_2 Z_2 ;$	$Y_2 = \frac{1}{2w}\left\{\mathrm{erf}\frac{(w/2+y)}{\sqrt{4D_y t/R_d}} + \mathrm{erf}\frac{(w/2-y)}{\sqrt{4D_y t/R_d}}\right\}$
Horizontal Area Source	$c_i = \frac{1}{n_e R_d} X_2 Y_2 Z_2 ,$	$Z_2 = \frac{1}{b}$
*****For an aquifer of infinite depth**		$Z_3 = \frac{1}{\sqrt{4\pi D_z t/R_d}}\left\{\exp\left(-\frac{(z-z_s)^2}{4D_z t/R_d}\right) + \exp\left(-\frac{(z+z_s)^2}{4D_z t/R_d}\right)\right\}$
Point Source	$c_i = \frac{1}{n_e R_d} X_1 Y_1 Z_3 ,$	
Horizontal Line Source	$c_i = \frac{1}{n_e R_d} X_1 Y_2 Z_3$	

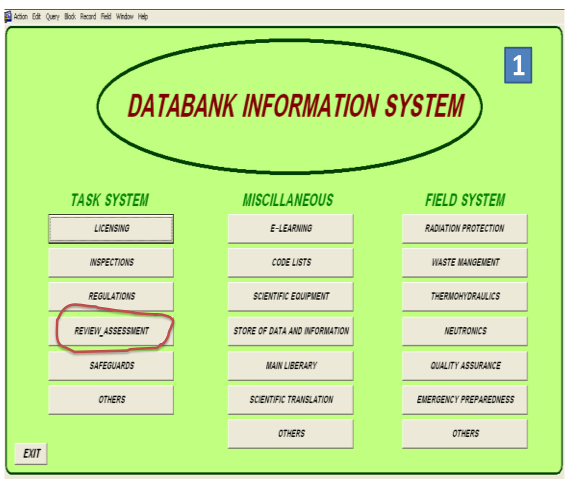
According to Table 1, the user shall select the condition according to his assumptions after completing the input data. After process, the output sheet is printed. The sheet printed is listed the output data and the input data (noted if it is given or from internal library) and for what level are selected in case of stored data. Also, the code can executes loops for plotting the variation of concentration with the time and/or the distance.

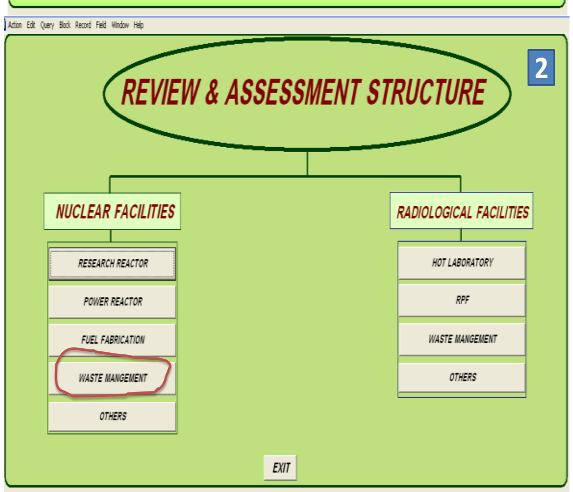
Any comment can be added to the output file (as an option). The comments send by the juniors is to explain their interruptation/opinion about the results to the seniors.

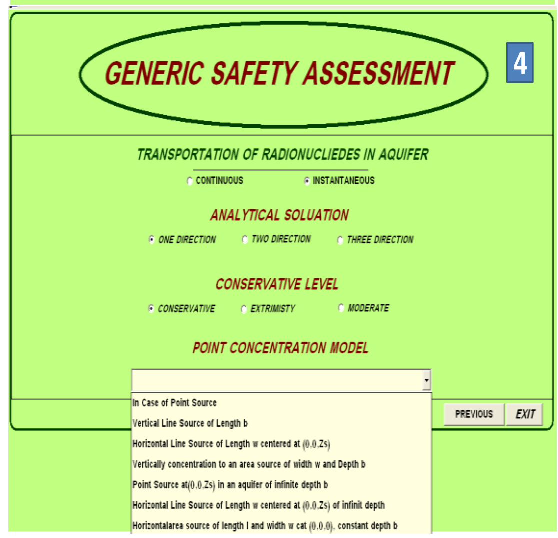
3. DEMONSTRATION OF CODE LOCATION IN THE INFORMATION SYSTEM

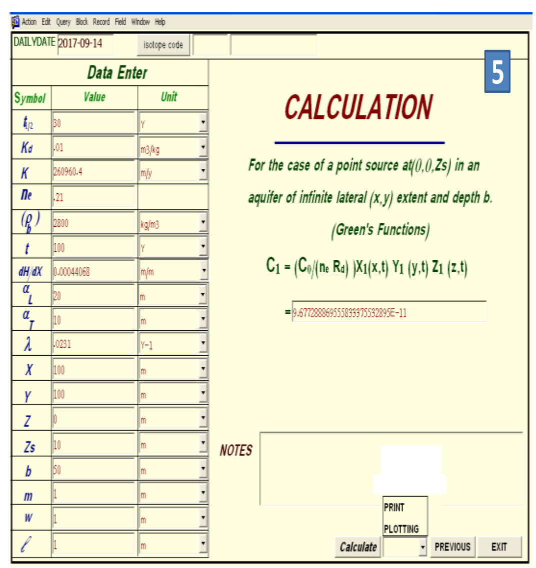
The location and presentation of the code in the information systems is an important issue. It should be found within a simple path to reach. Additionally, the sequence of the code should be clear to juniors users. Figure 5, from 1 to 6, represents the consecutives windows required to reach and execute the code.

From the first window, the user will select review and assessment icon from the task system, then the waste management facility under consideration. From the waste management, user select the generic safety case of disposal. The code, in start, required four selections; scenario type (instaneous or continuous), number of dimensions (one, two, or three), level of conservatism, and source configuration.









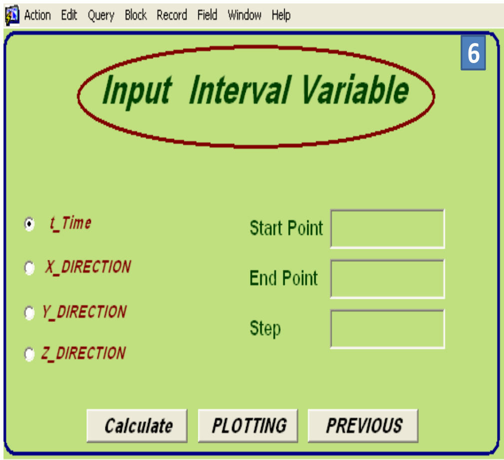


Fig. 5 (1-6). Cosecutive Windows for the Execution of the Code.

After, the user feedthe input data; calulate icon is executing the code. The sixth window is used for plotting the variation of concentration with time and sistance.

4. CODE VALIDATION; CASE STUDY

A case study is considered for the validation. A concrete vault disposal design is assumed for low- and intermediate level radioactive wastes covered with thick layers of soil. In the concrete vault disposal facility, multiple barriers are used; clay, sand, cement and reinforced concrete. It is expected that radionuclide migration can be reduced by natural barriers and through the engineered multi- barriers of impermeable materials. The institutional control is assumed to be 100 years. The vault considers in the study is shown in Figure 2.

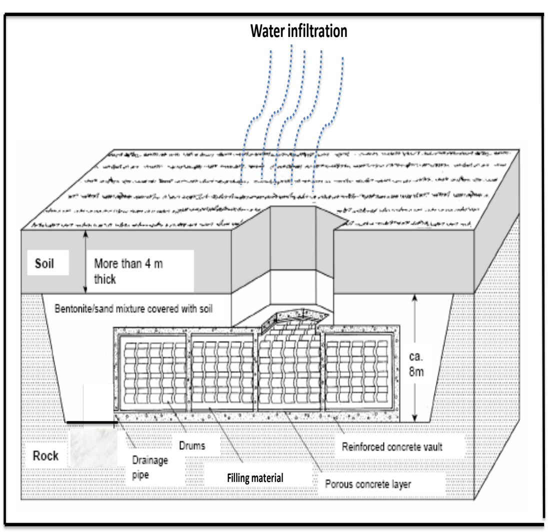


Fig. 2. Concrete Vault Considered in the Calculation of the Computer Code [9].

After 100 years, the multi layers loose their integrity and let rain water infiltrates during 20 years through the multi-layers of soil to a large fracture of the reinforced cover. This fracture is resulted from the corrosion of the steel. The corrosion, also, reach some containers and the basement of the vault. Instantaneously, four containers release 100 Ci of Cesium-137 from the vault to the nearest aquifer. The water in the aquifer is contaminated by the radioactive waste.

The destination of contaminated water is reached a well used by a family in a farmer. Drink water, vegetation and animals are used the contaminated water.

Meanwhile, the disposal site looses the security measures (security agents and labels) and leave unsafe area. An intruder is excavated the site to build a home. The workers will be exposed to different types of doses.

The whole scenario is considered part by part separately undertaken the same assumptions as demonstrated in Figure 3. The present work is studied the migration of radionuclides in the aquifer (Part IV). This part is hand calculated using excel spreading and the results are compared by the results after the excecution of the code using same input data.

5. CONCLUSIONS

GSAD IV is a part of computer code designed for simulating the migration of radionuclide in an aquifer. The code used Oracle language, which succeed to be a computational language in addition to its usage as data base language. The code reaches the goals of the databank management system by its friendly user interface. In other words, very simple code to understand and learn by Juniors. Additionally, it save time by its fast execution.

This work is an alliance of efforts between the SAG and scientific employees. Despite the efforts of SAG to faced different challenges to reach best configuration of the code, it is important to note that scientific employees have to explain in a good manner their problem, conditions, check point, trick points and goals to offer a good full image for SAG to implement the code. Other recommendation should be considered that the SAG shall be selected from the same scientific community to well use their scientific capabilities of common scales as the user (computer and regulatory sciences) to perform their works in optimum forms.

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