Asian Journal of Water, Environment and Pollution, Vol. 4, No. 1, pp. 125-131.

Sensitivity Analysis of the Framework for Measuring the Physiological Effects of Inappropriate Waste Disposal

C.I. Udeorji and S.A. Oke*

Department of Mechanical Engineering,
University of Lagos, Lagos, Nigeria
sa_oke@yahoo.com

Received March 26, 2005; revised and accepted May 10, 2006

Absract: Today waste disposal presents a significant problem and an environmental challenge to communities and governments. Consequently there is a growing environmental awareness among governments and consumers of the consequences of unfriendly environments on future generations. As a result there is a huge investment of human intelligence and capital resources in the management and control of waste problems. In recent times researchers have called for papers outlining both the physiological and psychological effects of waste disposal. This work attempts to address this problem by considering the sensitivity analysis of the physiological effects of inappropriately disposed wastes. Improperly disposed wastes have strong influences on human beings. It reveals itself in the form of physical reactions of the human beings to his environment. This research hopefully stimulates further studies in an area that is attracting empirical investigations.

Key words: Psychology, waste disposal, environment, physical consequences.

Introduction

An important area of industrial engineering practice and research is safety, health, and environment (SHE). A large number of studies have therefore been documented in this area both in the local and international literature (Walls and Palmer, 2000). However, of increasing research interest and practical significance today to the industrial engineering community is the achievement of an environmentally friendly community (Schaffer and Malia, 1994). In this paper, we present a test of sensitivity, which conceptualises the health problem from the standpoint of the physiological effects that inappropriate waste disposal would have on the health conditions of inhabitants in a community (Attrill et al., 2003).

Based on the mathematical expectation theory in statistical analysis, a formulation comprising the probability that a disease type would affect a particular human body system was made. Considerations were given to the number of components of the human body system on which this framework is based. The sensitivity analysis was tested to determine the degree of responsiveness of the model to changes in the parameters. The sensitivity analysis carried out here is perhaps one of the first initiatives in this area.

*Corresponding Author

The Sensitivity Test of the Model

For the sensitivity analysis of the process, we have to reduce the number of the human body systems components that is or are affected by the diseases gradually. Then, we will be able to identify or understand what the cumulative physiological probability matrix of a man will be at each alteration or variation. Having known the human body systems and the components of each of the systems that are affected by the diseases that are affected physiologically, in an environment of inappropriate waste disposal, we can vary the components, by gradually reducing them, so as to know the effect it will have on the end result, which is the physiological probability matrix.

Now, recall that:

$$E = \sum_{i=1}^{6}\sum_{j=1}^{6} a_{ij}P_{ij} = \sum_{i,j=1}^{6} P_{ij}$$

where E represents the expectation of an event, P_{ij} is the cumulative physiological probability matrix, and others are as defined earlier. But before this analysis can proceed, there are some reasonable assumptions that will be made.

Assumptions

In a probability matrix form all the values of the elements in a row, when added, must be unity.

1. The probability values are assigned on the basis of how much a system is affected by a particular disease. When a particular disease does not affect a system, a zero value is assigned as the probability value.
2. The present state of the human body system is independent of the past state, and that does not affect the analysis on a system.
3. The Markovian properties for a stochastic process are applied in the analysis.

Hence, carrying out the analysis we have the condition, state 1:

$$E = \begin{bmatrix} 2 & 1 & 1 & 1 & 1 & 2 \\ 4 & 4 & 2 & 4 & 1 & 4 \\ 4 & 2 & 1 & 2 & 2 & 3 \\ 3 & 4 & 1 & 5 & 8 & 4 \\ 3 & 1 & 1 & 3 & 2 & 2 \\ 6 & 6 & 5 & 6 & 1 & 6 \end{bmatrix}$$

$$\begin{bmatrix} 0.25 & 0.125 & 0.125 & 0.125 & 0.125 & 0.25 \\ 0.21 & 0.21 & 0.11 & 0.21 & 0.1 & 0.21 \\ 0.29 & 0.14 & 0.07 & 0.14 & 0.14 & 0.21 \\ 0.12 & 0.16 & 0.04 & 0.2 & 0.32 & 0.16 \\ 0.5 & 0.08 & 0.08 & 0.5 & 0.17 & 0.17 \\ 0.2 & 0.2 & 0.17 & 0.2 & 0.03 & 0.2 \end{bmatrix}$$

Converting to physiological probability matrix, we have:

$$E = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.2 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 7.28 & 3.6 & 2.41 & 7.16 & 4 & 4.76 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.38 \\ 6.63 & 4.95 & 3.1 & 5.61 & 4.32 & 6.14 \end{bmatrix}$$

Physiological probability matrix for state 1,

$$P_{ij} = \begin{bmatrix} 0.24 & 0.15 & 0.1 & 0.2 & 0.12 & 0.19 \\ 0.21 & 0.16 & 0.1 & 0.19 & 0.14 & 0.2 \\ 0.24 & 0.14 & 0.1 & 0.2 & 0.13 & 0.19 \\ 0.25 & 0.12 & 0.08 & 0.25 & 0.14 & 0.16 \\ 0.23 & 0.14 & 0.09 & 0.21 & 0.15 & 0.09 \\ 0.22 & 0.16 & 0.1 & 0.18 & 0.14 & 0.2 \end{bmatrix}$$

The above physiological probability matrix is obtained by adding all the elements in each row and dividing each element in the row by the obtained aggregate value. This analysis can be explained further by using a mathematical expression for row 1 which is $\sum_{j=1}^{6} E_{ij}$ and the probability values are:

$$\left(\frac{E_{11}}{\sum_{j=1}^{6} E_{ij}} \quad \frac{E_{12}}{\sum_{j=1}^{6} E_{ij}} \quad \frac{E_{13}}{\sum_{j=1}^{6} E_{ij}} \quad \frac{E_{14}}{\sum_{j=1}^{6} E_{ij}} \quad \frac{E_{15}}{\sum_{j=1}^{6} E_{ij}} \quad \frac{E_{16}}{\sum_{j=1}^{6} E_{ij}} \right) \tag{1}$$

$$\sum_{j=1}^{6} E_{ij} = E_{11} + E_{12} + E_{13} + E_{14} + E_{15} + E_{16} \tag{2}$$

$= 2.02 + 1.24 + 0.89 + 1.7 + 1.4 + 1.65 = 14.996$

Row 1 thus becomes

$$\left(\frac{2.02}{8.54} \quad \frac{1.24}{8.54} \quad \frac{0.89}{8.54} \quad \frac{1.7}{8.54} \quad \frac{1.04}{8.54} \quad \frac{1.65}{8.54} \right)$$

The same approach is used in getting the other elements of the physiological probability matrix. Now, we carry out the sensitivity by reducing the positive value of components in the matrix a_{ij} by 1. This gives a matrix of the form shown below.

$$E_1 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 1 \\ 3 & 3 & 1 & 3 & 0 & 3 \\ 3 & 1 & 0 & 1 & 1 & 2 \\ 2 & 3 & 0 & 4 & 7 & 3 \\ 2 & 0 & 0 & 2 & 1 & 1 \\ 5 & 5 & 4 & 5 & 0 & 5 \end{bmatrix}$$

$$\begin{bmatrix} 0.25 & 0.21 & 0.125 & 0.125 & 0.125 & 0.25 \\ 0.21 & 0.21 & 0.11 & 0.21 & 0.1 & 0.21 \\ 0.29 & 0.14 & 0.07 & 0.14 & 0.14 & 0.21 \\ 0.12 & 0.16 & 0.04 & 0.2 & 0.32 & 0.16 \\ 0.5 & 0.08 & 0.08 & 0.5 & 0.17 & 0.17 \\ 0.2 & 0.2 & 0.17 & 0.2 & 0.03 & 0.2 \end{bmatrix}$$

$$E_1 = \begin{bmatrix} 0.45 & 0.41 & 0.3 & 0.33 & 0.16 & 0.45 \\ 2.63 & 2.48 & 1.41 & 2.35 & 1.87 & 2.67 \\ 1.98 & 1.48 & 0.95 & 1.69 & 1.03 & 1.69 \\ 5.71 & 2.85 & 1.81 & 5.78 & 3.11 & 3.56 \\ 1.44 & 1.02 & 0.58 & 1.35 & 1.09 & 1.19 \\ 5.06 & 4.46 & 2.51 & 4.24 & 3.44 & 4.94 \end{bmatrix} \text{State 2}$$

Using the explained method of converting matrix into probability matrix used for state 1, we can do the same for state 2. Hence, we have

$$P_{ij} = \begin{bmatrix} 0.21 & 0.2 & 0.14 & 0.16 & 0.08 & 0.2 \\ 0.2 & 0.18 & 0.11 & 0.18 & 0.14 & 0.2 \\ 0.22 & 0.17 & 0.11 & 0.19 & 0.12 & 0.19 \\ 0.25 & 0.13 & 0.08 & 0.25 & 0.14 & 0.16 \\ 0.22 & 0.15 & 0.09 & 0.2 & 0.16 & 0.18 \\ 0.21 & 0.18 & 0.1 & 0.17 & 0.14 & 0.2 \end{bmatrix}$$

which is Physiological probability matrix for state 2.

The matrixes E and E_1 give the expectation values of each of the systems being affected by different diseases. Comparing the two matrices of E and E_1, it is evident that at the reduction of the components of each body systems affected by the different diseases; the elements of the new matrix (E_1) is seen to have reduced in their values from their initial values. This means that the expectation value of each element of the matrix, the expectation value of a particular system of the body being affected by a particular disease is reduced as the components of the body systems affected by the disease are reduced.

Reducing the positive values of components in matrix a_{ij} the second time by 1, we have:

$$E_2 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 2 & 2 & 0 & 2 & 0 & 2 \\ 2 & 0 & 0 & 0 & 0 & 2 \\ 1 & 2 & 0 & 3 & 6 & 2 \\ 1 & 0 & 0 & 1 & 0 & 0 \\ 4 & 4 & 3 & 4 & 0 & 4 \end{bmatrix}$$

$$\begin{bmatrix} 0.25 & 0.21 & 0.125 & 0.125 & 0.125 & 0.25 \\ 0.21 & 0.21 & 0.11 & 0.21 & 0.1 & 0.21 \\ 0.29 & 0.14 & 0.07 & 0.14 & 0.14 & 0.21 \\ 0.12 & 0.16 & 0.04 & 0.2 & 0.32 & 0.16 \\ 0.5 & 0.08 & 0.08 & 0.5 & 0.17 & 0.17 \\ 0.2 & 0.2 & 0.17 & 0.2 & 0.03 & 0.2 \end{bmatrix}$$

$$E_2 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1.56 & 1.56 & 0.89 & 1.47 & 1.15 & 1.64 \\ 0.9 & 0.82 & 0.59 & 0.65 & 0.31 & 0.9 \\ 4.43 & 1.99 & 1.29 & 4.55 & 2.37 & 2.57 \\ 0.37 & 0.37 & 0.17 & 0.33 & 0.45 & 0.41 \\ 3.99 & 2.54 & 1.99 & 3.36 & 2.72 & 3.91 \end{bmatrix} \quad \text{State 3}$$

Using the same mathematical analysis of equations 1 and 2 used for state 1 for the above expectation matrix of state 3, we shall get the physiological probability matrix. This is as shown below:

$$P_{ij} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0.19 & 0.19 & 0.11 & 0.18 & 0.14 & 0.2 \\ 0.22 & 0.2 & 0.14 & 0.16 & 0.07 & 0.22 \\ 0.26 & 0.12 & 0.08 & 0.26 & 0.14 & 0.15 \\ 0.18 & 0.18 & 0.08 & 0.16 & 0.21 & 0.2 \\ 0.2 & 0.18 & 0.1 & 0.17 & 0.14 & 0.2 \end{bmatrix}$$

A comparison of E and E_2 matrixes shows that there is a further decrease in the elements of matrix of E_2 at further reduction of components of a_{ij}. For a further reduction in positive elements of matrix a_{ij}, we have:

$$E_3 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 2 & 5 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 3 & 3 & 2 & 3 & 0 & 3 \end{bmatrix}$$

$$\begin{bmatrix} 0.25 & 0.125 & 0.125 & 0.125 & 0.125 & 0.25 \\ 0.21 & 0.21 & 0.11 & 0.21 & 0.1 & 0.21 \\ 0.29 & 0.14 & 0.07 & 0.14 & 0.14 & 0.21 \\ 0.12 & 0.16 & 0.04 & 0.2 & 0.32 & 0.16 \\ 0.5 & 0.08 & 0.08 & 0.5 & 0.17 & 0.17 \\ 0.2 & 0.2 & 0.17 & 0.2 & 0.03 & 0.2 \end{bmatrix}$$

$$E_3 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0.78 & 0.7 & 0.45 & 0.74 & 0.58 & 0.82 \\ 0.45 & 0.33 & 0.3 & 0.33 & 0.16 & 0.45 \\ 3.15 & 1.1 & 0.76 & 3.31 & 1.62 & 1.58 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 2.92 & 2.37 & 1.48 & 2.49 & 2.01 & 1.95 \end{bmatrix} \quad \text{State 4}$$

The physiological probability matrix can thus be calculated by the approach explained above. Hence we have:

$$P_{ij} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0.19 & 0.17 & 0.11 & 0.18 & 0.14 & 0.2 \\ 0.22 & 0.16 & 0.15 & 0.16 & 0.08 & 0.22 \\ 0.27 & 0.1 & 0.07 & 0.29 & 0.14 & 0.14 \\ 0 & 0.375 & 0 & 0.125 & 0.375 & 0.125 \\ 0.22 & 0.18 & 0.11 & 0.19 & 0.15 & 0.14 \end{bmatrix}$$

The elements of the matrix E_3 show that there are decreases in the values of the elements as a result of the reduction in the positive values of the matrix a_{ij} the third time. For a fourth time reduction in the positive elements of matrix a_{ij}, we have:

$$E_4 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 2 & 2 & 1 & 2 & 0 & 2 \end{bmatrix}$$

$$\begin{bmatrix} 0.25 & 0.125 & 0.125 & 0.125 & 0.125 & 0.25 \\ 0.21 & 0.21 & 0.11 & 0.21 & 0.1 & 0.21 \\ 0.29 & 0.14 & 0.07 & 0.14 & 0.14 & 0.21 \\ 0.12 & 0.16 & 0.04 & 0.2 & 0.32 & 0.16 \\ 0.5 & 0.08 & 0.08 & 0.5 & 0.17 & 0.17 \\ 0.2 & 0.2 & 0.17 & 0.2 & 0.03 & 0.2 \end{bmatrix}$$

$$E_4 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 2.12 & 0.24 & 0.36 & 2.2 & 1 & 0.84 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1.85 & 1.53 & 0.96 & 1.61 & 1.29 & 1.85 \end{bmatrix} \text{ State 5}$$

We can thus get the physiological probability matrix using equations 1 and 2 approach.

$$P_{ij} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0.31 & 0.04 & 0.05 & 0.33 & 0.15 & 0.12 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0.2 & 0.17 & 0.11 & 0.18 & 0.14 & 0.2 \end{bmatrix}$$

For a fifth time reduction in the remaining positive elements of matrix a_{ij}, we have:

$$E_5 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 0.25 & 0.125 & 0.125 & 0.125 & 0.125 & 0.25 \\ 0.21 & 0.21 & 0.11 & 0.21 & 0.1 & 0.21 \\ 0.29 & 0.14 & 0.07 & 0.14 & 0.14 & 0.21 \\ 0.12 & 0.16 & 0.04 & 0.2 & 0.32 & 0.16 \\ 0.5 & 0.08 & 0.08 & 0.5 & 0.17 & 0.17 \\ 0.2 & 0.2 & 0.17 & 0.2 & 0.03 & 0.2 \end{bmatrix}$$

$$E_5 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1.5 & 0.24 & 0.24 & 1.5 & 0.51 & 0.51 \\ 0.78 & 0.7 & 0.45 & 0.74 & 0.58 & 0.82 \\ 1.85 & 1.53 & 0.96 & 1.61 & 1.29 & 1.85 \end{bmatrix} \text{ State 6}$$

We can thus proceed to calculating the physiological probability matrix, and this is shown below:

$$P_{ij} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0.33 & 0.05 & 0.05 & 0.33 & 0.11 & 0.11 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0.19 & 0.17 & 0.11 & 0.18 & 0.14 & 0.2 \end{bmatrix}$$

A further reduction in the remaining positive values of elements of matrix a_{ij}, the sixth time we have:

$$E_6 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 0.25 & 0.125 & 0.125 & 0.125 & 0.125 & 0.25 \\ 0.21 & 0.21 & 0.11 & 0.21 & 0.1 & 0.21 \\ 0.29 & 0.14 & 0.07 & 0.14 & 0.14 & 0.21 \\ 0.12 & 0.16 & 0.04 & 0.2 & 0.32 & 0.16 \\ 0.5 & 0.08 & 0.08 & 0.5 & 0.17 & 0.17 \\ 0.2 & 0.2 & 0.17 & 0.2 & 0.03 & 0.2 \end{bmatrix}$$

$$E_6 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0.16 & 0.16 & 1 & 0.34 & 0.34 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \text{ State 7}$$

The physiological probability matrix thus become:

$$P_{ij} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0.33 & 0.05 & 0.05 & 0.33 & 0.11 & 0.11 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

which is physiological probability matrix for state 7.

Differences in the Expectation Values of Matrix Elements

The differences in the expectation values of the elements of the matrix as a result of the reduction in the human body systems components that are affected by the diseases are computed for different levels of reduction. For 1st reduction, the difference in expectation values of elements of the matrix is found by the analysis below:

$$E - E_1 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.2 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 7.28 & 3.6 & 2.41 & 7.16 & 4 & 4.76 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 6.63 & 4.95 & 3.1 & 5.61 & 4.32 & 6.14 \end{bmatrix}$$

$$\begin{bmatrix} 0.45 & 0.41 & 0.3 & 0.33 & 0.16 & 0.45 \\ 2.63 & 2.48 & 1.41 & 2.35 & 1.87 & 2.67 \\ 1.98 & 1.48 & 0.05 & 1.69 & 1.03 & 1.69 \\ 5.71 & 2.85 & 1.81 & 5.75 & 3.11 & 3.56 \\ 1.44 & 1.02 & 0.58 & 1.35 & 1.09 & 1.19 \\ 5.06 & 4.46 & 2.51 & 4.24 & 3.44 & 4.94 \end{bmatrix}$$

$$\Delta E_1 = \begin{bmatrix} 1.57 & 0.83 & 0.59 & 1.37 & 0.88 & 1.2 \\ 1.57 & 0.66 & 0.59 & 1.37 & 0.88 & 1.2 \\ 1.57 & 0.66 & 0.59 & 1.37 & 0.88 & 1.2 \\ 1.57 & 0.75 & 0.6 & 1.41 & 0.89 & 1.2 \\ 1.57 & 0.75 & 0.6 & 1.38 & 0.89 & 1.2 \\ 1.57 & 0.49 & 0.59 & 1.37 & 0.88 & 1.2 \end{bmatrix}$$

The above matrix represented by ΔE_1 shows the reduction in the expectation values of each system being affected by different diseases. This automatically reduces the physiological effect on a man at the end of the day. Now, the percentage reduction for each element of the matrix of ΔE_1 can be computed. This is done by applying the mathematical expression shown below for each element of the matrix represented by ΔE_1.

Hence, we have:

Percentage reduction =

$$\left(\frac{\begin{matrix}\text{Initial value of} \\ \text{elements of matrix } E\end{matrix} - \begin{matrix}\text{Final value of} \\ \text{element of matrix } E_1\end{matrix}}{\text{Initial value of element of matrix } E} \right) \times 100$$

$$= \frac{\text{Value of element of matrix } \Delta E_1}{\text{Initial value of element of matrix } E} \times 100$$

Thus, the percentage reduction in elements of the expectation matrix for first reduction in positive value of element of matrix a_{ij} by 1 becomes:

$$\%\Delta E_1 = \begin{bmatrix} 77.7 & 66.9 & 66.3 & 80.6 & 84.6 & 72.7 \\ 37.4 & 21 & 29.5 & 36.8 & 32 & 31 \\ 44.2 & 30.8 & 38.3 & 44.8 & 46.1 & 41.5 \\ 21.6 & 20.8 & 24.9 & 19.7 & 22.3 & 25.2 \\ 52.2 & 42.4 & 50.8 & 50.5 & 44.9 & 50.2 \\ 23.7 & 9.9 & 19 & 24.4 & 20.4 & 19.5 \end{bmatrix}$$

For second reduction, the difference in expectation values of elements of the matrix is found by the analysis below:

$$E - E_2 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.2 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 7.28 & 3.6 & 2.41 & 7.16 & 4 & 4.76 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 6.63 & 4.95 & 3.1 & 5.61 & 4.32 & 6.14 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1.56 & 1.56 & 0.89 & 1.47 & 1.15 & 1.64 \\ 0.9 & 0.82 & 0.59 & 0.65 & 0.31 & 0.9 \\ 4.43 & 1.99 & 1.29 & 4.55 & 2.37 & 2.57 \\ 0.37 & 0.39 & 0.17 & 0.33 & 0.45 & 0.41 \\ 3.99 & 3.54 & 1.99 & 3.36 & 2.72 & 3.91 \end{bmatrix}$$

$$\Delta E_2 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 2.64 & 1.58 & 1.11 & 2.25 & 1.6 & 2.23 \\ 2.65 & 1.32 & 0.95 & 2.41 & 1.6 & 1.99 \\ 2.85 & 1.61 & 1.12 & 2.61 & 1.63 & 2.19 \\ 2.64 & 1.4 & 1.01 & 2.4 & 1.53 & 1.98 \\ 2.64 & 1.41 & 1.11 & 2.25 & 1.6 & 2.23 \end{bmatrix}$$

The mathematical expression shown below is thus applied for each element of the matrix ΔE_2 to get the percentage reduction of each element.

Percentage reduction =

$$\left(\frac{\begin{matrix}\text{Initial value of} \\ \text{elements of matrix } E\end{matrix} - \begin{matrix}\text{Final value of} \\ \text{element of matrix } E_2\end{matrix}}{\text{Initial value of element of matrix } E} \right) \times 100$$

$$\frac{\text{Value of element of matrix } \Delta E_2}{\text{Initial value of element of matrix } E} \times 100$$

Hence, the percentage reduction for each element becomes:

$$\Delta E_2\% = \begin{bmatrix} 100 & 100 & 100 & 100 & 100 & 100 \\ 62.9 & 50.3 & 55.5 & 60.5 & 58.2 & 57.6 \\ 74.6 & 61.7 & 61.7 & 78.8 & 83.8 & 68.9 \\ 39.1 & 44.7 & 46.5 & 36.5 & 40.8 & 46 \\ 87.7 & 79.1 & 85.6 & 84.9 & 77.3 & 82.8 \\ 39.8 & 28.5 & 35.8 & 40 & 37 & 36.3 \end{bmatrix}$$

For third time reduction of the affected body systems components, the difference in expectation values of elements of the matrix is found by the analysis below.

$$E - E_3 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.2 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 7.28 & 3.6 & 2.41 & 7.16 & 4 & 4.76 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 6.63 & 4.95 & 3.1 & 5.61 & 4.32 & 6.14 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1.78 & 0.7 & 0.45 & 1.74 & 0.58 & 0.82 \\ 0.45 & 0.33 & 0.3 & 0.33 & 0.16 & 0.45 \\ 3.15 & 1.1 & 1.76 & 3.31 & 1.62 & 1.58 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 2.92 & 2.37 & 1.48 & 2.49 & 2.01 & 1.9 \end{bmatrix}$$

$$\Delta E_3 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 3.42 & 2.44 & 1.55 & 2.98 & 2.17 & 3.05 \\ 3.1 & 1.81 & 1.24 & 2.73 & 1.75 & 2.44 \\ 4.13 & 2.5 & 1.65 & 3.85 & 2.38 & 3.18 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 3.71 & 2.58 & 1.62 & 3.12 & 2.31 & 4.24 \end{bmatrix}$$

We then apply the equation shown below to each element of the matrix ΔE_3 to get the percentage reduction of each element.

Percentage reduction =

$$\left(\frac{\begin{matrix}\text{Initial value of} \\ \text{elements of matrix } E\end{matrix} - \begin{matrix}\text{Final value of} \\ \text{element of matrix } E_3\end{matrix}}{\text{Initial value of element of matrix } E} \right) \times 100$$

$$= \frac{\text{Value of element of matrix } \Delta E_3}{\text{Initial value of element of matrix } E} \times 100$$

Hence, the percentage reduction for each element of the matrix ΔE_3 becomes,

$$\Delta E_3\% = \begin{bmatrix} 100 & 100 & 100 & 100 & 100 & 100 \\ 81.4 & 77.7 & 77.5 & 80.1 & 78.9 & 78.8 \\ 87.3 & 84.6 & 80.5 & 89.2 & 91.6 & 84.4 \\ 56.7 & 69.4 & 68.5 & 53.8 & 59.5 & 66.8 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 56 & 52.1 & 52.3 & 55.6 & 53.5 & 69.1 \end{bmatrix}$$

For fourth time reduction of the affected body systems components, the difference in expectation values of elements of the matrix is found by the analysis below.

$$E - E_4 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.2 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 7.28 & 3.6 & 2.41 & 7.16 & 4 & 4.76 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 6.63 & 4.95 & 3.1 & 5.61 & 4.32 & 6.14 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 2.12 & 0.24 & 0.36 & 2.2 & 1 & 1.84 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1.85 & 1.53 & 0.96 & 1.61 & 1.29 & 1.85 \end{bmatrix}$$

$$\Delta E_4 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.82 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 5.16 & 3.36 & 2.05 & 4.96 & 3 & 3.92 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 4.78 & 3.42 & 2.14 & 4 & 3.03 & 4.29 \end{bmatrix}$$

We then apply the equation:

Percentage reduction =

$$\left(\frac{\begin{matrix}\text{Initial value of} \\ \text{elements of matrix } E\end{matrix} - \begin{matrix}\text{Final value of} \\ \text{element of matrix } E_4\end{matrix}}{\text{Initial value of element of matrix } E} \right) \times 100$$

$$= \frac{\text{Value of element of matrix } \Delta E_4}{\text{Initial value of element of matrix } E} \times 100$$

To each element of the matrix ΔE_4.

Hence, the percentage reduction for each element of the matrix ΔE_3 becomes,

$$\Delta E_4\% = \begin{bmatrix} 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 70.9 & 93.3 & 85.1 & 693 & 75 & 82.4 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 72.1 & 69.1 & 69.1 & 71.3 & 70.1 & 69.9 \end{bmatrix}$$

For fifth time reduction, we have

$$E - E_5 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.2 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 7.28 & 3.6 & 2.41 & 7.16 & 4 & 4.76 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 6.63 & 4.95 & 3.1 & 5.61 & 4.32 & 6.14 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1.5 & 0.24 & 0.24 & 1.5 & 0.51 & 0.51 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0.78 & 0.7 & 0.45 & 0.74 & 0.58 & 0.82 \end{bmatrix}$$

$$\Delta E_5 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.2 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 5.78 & 3.36 & 2.17 & 5.66 & 3.49 & 4.25 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 5.85 & 4.25 & 2.65 & 4.87 & 3.74 & 5.32 \end{bmatrix}$$

Applying the similar approach of analysis for percentage reduction for each element of the matrix ΔE_5, we have

$$\Delta E_5\% = \begin{bmatrix} 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 79.4 & 93.3 & 90 & 79.1 & 87.3 & 89.3 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 88.2 & 85.9 & 85.5 & 86.8 & 86.6 & 86.6 \end{bmatrix}$$

For the sixth time reduction, we have

$$E - E_6 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.2 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 7.28 & 3.6 & 2.41 & 7.16 & 4 & 4.76 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 6.63 & 4.95 & 3.1 & 5.61 & 4.32 & 6.14 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1.5 & 0.16 & 0.16 & 1 & 0.34 & 0.34 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\Delta E_6 = \begin{bmatrix} 2.02 & 1.24 & 0.89 & 1.7 & 1.04 & 1.65 \\ 4.2 & 3.14 & 2 & 3.72 & 2.75 & 3.87 \\ 3.55 & 2.14 & 1.54 & 3.06 & 1.91 & 2.89 \\ 6.28 & 3.44 & 2.25 & 6.16 & 3.66 & 4.45 \\ 3.01 & 1.77 & 1.18 & 2.73 & 1.98 & 2.39 \\ 6.63 & 4.95 & 3.1 & 5.61 & 4.32 & 6.14 \end{bmatrix}$$

Percentage reduction for each element of the matrix ΔE_6 gives

$$\Delta E_6\% = \begin{bmatrix} 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 86.3 & 95.6 & 93.4 & 86 & 91.5 & 92.9 \\ 100 & 100 & 100 & 100 & 100 & 100 \\ 100 & 100 & 100 & 100 & 100 & 100 \end{bmatrix}\%$$

Observations and Conclusions

It is observed from the sensitivity analysis of the human body systems through the reduction of the body systems components, that the expectation value of each of the diseases affecting each body system reduces subsequently. The reduction in the expectation value as shown in the matrix occurs at every reduction in each system's components affected by the disease.

Hence, we conclude that the way a particular system of the body is affected by a particular disease depends on the components of the system that is or are affected by the disease. When the system's component affected is much, the expectation value of the system being affected by the disease will be high which in turn increases greatly the physiological effect in an environment of inappropriate waste disposal. But when the system's component affected is low or none, the expectation value of the system being affected by the disease will be low or none, which in turn reduces greatly the physiological effect.

References

Attrill, P.G. and F.G.F. Gibb (2003). Partial melting and re-crystallisation of granite and their application to deep disposal of radioactive waste. *Journal mailto: F.Gibb@shef.ac.uk.*

Schaffer, D. and J. Knoxville Malia (1994). The Center for Rural Waste Management. Discussion paper, page 32.

Walls, M. and K. Palmer (2000). Upstream pollution, downstream waste disposal and the design of comprehensive environmental policies. Discussion paper 97-51-rev, http://www.off.org.

Asian Journal of Water, Environment and Pollution

Volume 3 Number 2 **July – December, 2006**

Contents