MATHEMATICAL MODELING, TECHNOLOGY, AND THE SOLUTION OF ENVIRONMENTAL PROBLEM (HAZARDOUS WASTE DISPOSAL SOLUTION FOR UTTAR PRADESH)

Dr. Deepti Singh

Department of Mathematics, Mahila Vidyalaya P.G. College, Lucknow, India

ABSTRACT

Several environmental problems can be modeled using the graphing, curve-fitting, and programming technology of graphing calculators. These problems reflect real world environmental concerns and social issues that help motivate our interest in mathematical modeling. Hazardous waste generated from the industries through processes, pollution control activities reject etc. are major cause of concern. Hazardous waste if not disposed properly will be harmful for mankind flora and fauna. Their effective identification, quantification and prediction is necessary for designing, and constructing effective treatment, storage and disposal facilities. Models for the hazardous waste disposal and the world's consumption of natural resources are illustrated in the present paper using technology available in the current versions of today's mathematically powerful calculators. I have tried to give a glimpse of natural resources consumption pattern as well as prediction of hazardous waste in 2025 in Uttar Pradesh along with its possible solution.

KEYWORD: *Hazardous waste, Mathematical Modeling, Graphing Calculators, Correlation Coefficient*

CLASSIFICATION : 92F05, 62P12

INTRODUCTION

Mathematical modeling can be viewed as the process of describing phenomena in terms of mathematical equations. This paper accepts this notion and presents problems that can be applied as models and simulations of the environment. The goal here is to promote applications of calculator-based models and simulations as a tool for planning, implementing, and monitoring a sustainable future for environmental resources.

Resources are discussed from the perspective of mathematical modeling and data analysis by using the basic statistical regression features found on a calculator such as the fx-82TL or fx-350TL. The discussion involves three basic parts: (1) introduction of an environmental problem; (2) development of a mathematical representation for the problem; and (3) application of the mathematical model using the graphing calculator.

Since Environmental problems such as the ones included in this paper present real-world environmental concerns and social issues, our interest and motivation in mathematical modeling is apt to be heightened. The first problem explores trends in the world-wide consumption of natural gas. It investigates various modeling techniques by analyzing data from seven different regions of the world.

A major concern of many industries, municipal agencies and regulatory authorities, the disposal of hazardous waste into secured landfills, is the focus of the second problem. It utilizes the capabilities of the graphing calculator to investigate the best models for predicting the amount of hazardous waste produced in the future and its possible solutions.

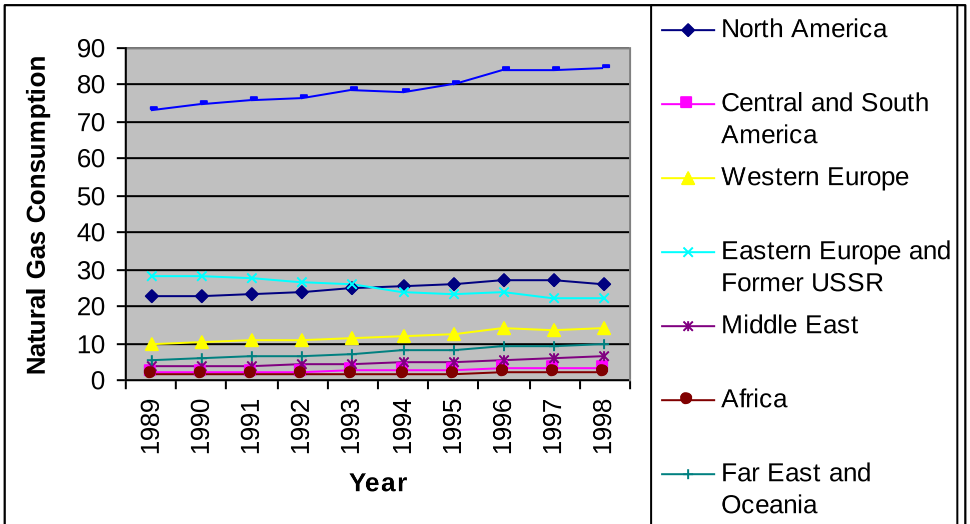
PROBLEM 1

One of the most critical environmental problems facing humanity today is the depletion of natural resources. The trends in natural gas consumption present interesting insights into the characteristics of exponential growth and raise questions about the future availability of these resources. An analysis of resource depletion data provides an opportunity to find a function which best fits the data. This analysis allows for the creation of symbolic, tabular, and graphical models that clarify past activities and justify making conjectures about the future. The consumption of natural gas in various regions of the world for the years 1989-1998 is detailed in Table 1. These data allow us to explore relationships about regional trends in the consumption of natural gas.

Table 1: World Natural Gas Consumption 1989 – 1998 in (10^9 Cubic Feet)

S.N.	Region	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	North America	22.77	22.73	23.10	23.83	24.69	25.35	26.18	26.87	26.92	26.29
2	Central and South America	2.31	2.21	2.35	2.37	2.55	2.70	2.86	3.06	3.24	3.41
3	Western Europe	9.86	10.12	11.06	11.10	11.46	11.69	12.57	13.92	13.75	14.24
4	Eastern Europe and Former USSR	28.09	28.42	27.74	26.30	26.23	24.11	23.21	23.60	22.34	22.21
5	Middle East	3.75	3.77	3.77	4.20	4.47	4.75	4.96	5.52	6.13	6.54
6	Africa	1.50	1.52	1.69	1.66	1.71	1.79	1.88	1.95	1.95	2.02
7	Far East and Oceania	5.64	6.02	6.31	6.77	7.29	7.95	8.36	9.09	9.45	9.67
8	World Total	73.43	74.78	76.02	76.23	78.40	78.34	80.01	84.01	83.77	84.40

World Natural Gas Consumption in (10^9 Cubic Feet) 1989–1998
A Graphical Representation



This tabular model spotlights the relatively consistent decline in consumption in Eastern Europe and the former USSR, while the total world consumption, after a temporary slowdown, continues to grow.
For example, an analysis of the consumption data for the Middle East using the regression models on a graphing calculator shows that the linear ($Y = a + bX$) and exponential ($Y = a\ e^{bx}$) models produce correlation coefficients of 0.97. The logarithmic ($Y = a + b\ln X$) and power regression ($Y = a\ X^b$) models each result in correlations of 0.98. In addition, the linear, logarithmic, exponential, and power regression models for the data analysis of the World Total of natural gas consumption result in correlations of 0.98. Environmental resource data such as these provide many worthwhile modeling explorations for us, and may motivate us to investigate the use of natural resources in our own countries.

PROBLEM 2

Hazardous Waste has been defined in many ways. However, one popular way of defining it is- Any waste that exhibits the characteristics of ignitability (flash point less than 60o C or non liquid of spontaneous and sustained combustion or ignitable compressed gas), conductivity (pH less than 2 or greater than 12.5), reactivity (unstable waste can cause explosion or react violently with water or generate toxic gases, vapor with water), toxicity and/or listed in schedule I & II of Hazardous Waste Rules, 1989 and new Hazardous Waste (Management, Handling & Trans Boundary Movement) Rules, 2008(amended in 2009) framed under Environment Protection Act, 1986 of Govt. of India, is termed as Hazardous Waste and is to be taken care of accordingly, so that it does not leach into ground water or seeps to surface or carried away into surface water or migrates to atmosphere by combustion.

Prior to 1989 the Hazardous Waste was normally mixed with Municipal Waste, thus the very purpose of installing the Effluent Treatment Plant(E.T.P.) and the Air Pollution Control System (APCS) was defeated because the sludge thus collected from E.T.P. and hazardous dust collected through APCS did get the way into surface water or ground water or soil and polluted them. In the state of U.P., Kanpur is the eye opening example where hazardous waste generated from tanneries, lead smelters, dyers, and basic chrome sulphate manufacturing was being thrown in open for a long time thereby polluting the soil and ground water to a large extent. Since the imposition of Hazardous Waste Rules, 1989 and new Hazardous Waste (Management, Handling & Trans Boundary Movement) Rules, 2008(amended in 2009), the disposal methods and management of hazardous waste have improved and today the industries are not allowed to throw their hazardous waste as before. At present, hazardous waste is being safely stored or incinerated within the premise which is to be sent to Treatment Storage Disposal Facility (TSDF) finally. However, one needs to be still more vigilant for these operations. As of now, ultimate disposal methods are recycling the waste, incinerating the waste or putting in a secured land fill site.

In terms of final disposal of hazardous waste, U.P. now has three TSDFs in operation at – (i) Kumbhi, Kanpur Dehat on 7 hectares of land (ii) Banthar, Unnao & (iii) Kumbhi, Kanpur Dehat on 3 hectares of land with respective operational capacity at present, of 100000 MT, 18000 m3 (27000 MT) & 50000 MT with the scope of expansion at these sites. 10 hectares of land was provided by the State Board on lease for establishing the TSDF at Kumbhi, Kanpur Dehat. Besides these three operational COMMON TSDF/SLF, 3 captive TSDF/SLF have been set up by individual industries.

At present, 20 no. of incinerator for captive use and one common incinerator for specific type of hazardous waste i.e. oily sludge & paint sludge etc. exist in the State.

TABLE 2: STATUS OF HAZARDOUS WASTE GENERATED IN UTTAR PRADESH (SOURCE UPPCB)

S. N.	YEAR	IDENTIFIED INDUSTRIES	RECYCLABLE WASTE (LAC TON/Yr)	INCINERABLE WASTE (LAC TON/Yr)	LANDFILABLE WASTE (LAC TON/Yr)	TOTAL WASTE (LAC TON/Yr)
1	2006	1685	0.39	0.04	0.40	0.82
2	2007	1915	1.28	0.15	0.44	1.88
3	2008	2043	1.18	0.15	0.36	1.70
4	2009	2100	1.12	0.15	0.38	1.65
5	2010	2114	1.61	0.16	0.35	2.11

These data can be entered into a graphing calculator to investigate the efficacy of various models. As with the data on natural gas consumption, several regression models produce correlation coefficients that are quite close to 1. The Logarithmic model produces the best correlation, and is possible to compare the year 2025 prediction with this model to those of the other models. Table 3 displays various models, their associated correlation coefficients, and their predictions for the amount of garbage produced per day in 2025.

Table 3: Predictive Models for 2025 Hazardous waste generation in the state of Uttar Pradesh

Model	Correlation Coefficient	Predicted Thousand Tons Per year in 2025
Linear	.76	562.7
Logarithmic	.76	561.1
Exponential	.75	3099.0
Power	.75	3063.0

Hazardous Waste generation in (Thousand MT) 2006–2025
A Graphical Representation

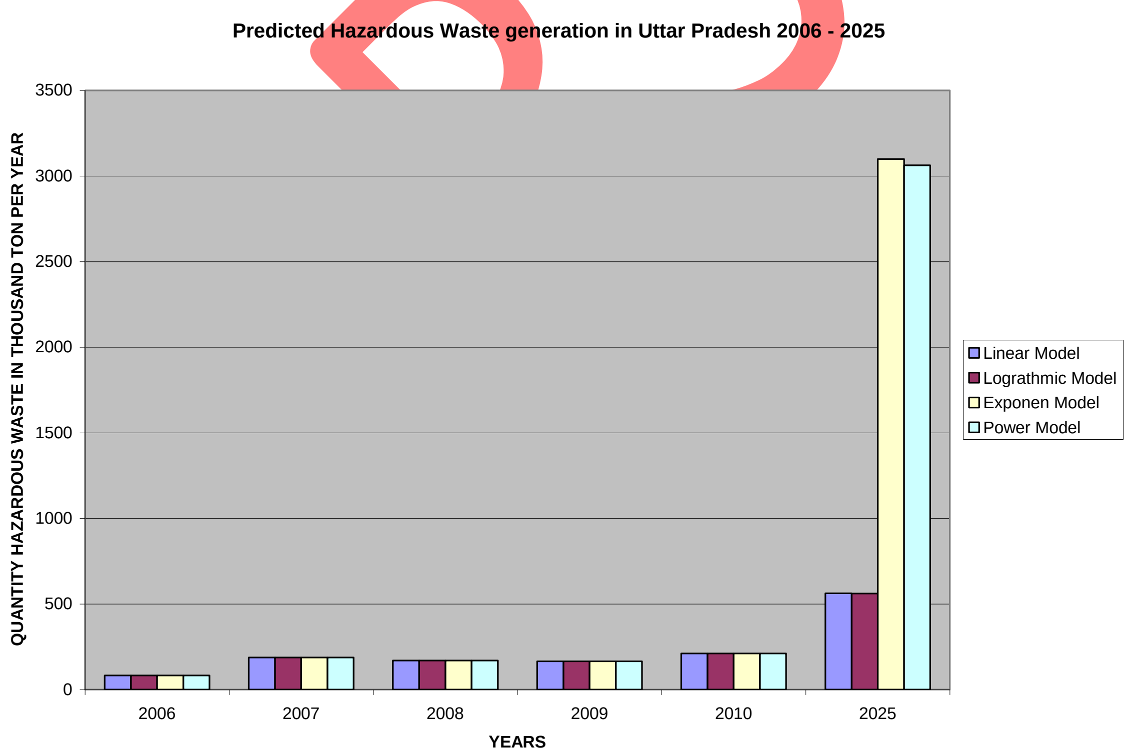


Table 3 shows that the predictions produced by the four models provide a good demonstration of the considerable differences that can result from using models with almost similar correlation coefficients in predicting future environmental situations. One motivation in utilizing these modeling problems is to provide realistic opportunities to connect mathematics to significant environmental and social problems while incorporating recent advances in technology. Problems such as these serve to demonstrate that mathematical models can be developed in a variety of forms: graphs, tables, charts, equations, and programs. While we understand the limits of using these functions to model data, and that models may not always fit the data well, we also learn that just observing data patterns may not give all the information needed to mathematically model and solve environmental problems. The depletion, recycling, and controlled management of resources are critical environmental issues facing the world today. By integrating data analysis and mathematical modeling techniques with the capabilities of graphing calculators, it is hoped that a deeper understanding of environmental problems and their impact on society will result.

As per the survey and findings it has been observed that of the total hazardous waste generated, approximate 76.3% waste is recyclable hazardous waste which can be easily recycled / reprocessed by recycling / reprocessing industries like oil, non ferrous, lead reprocessors / recycles , 7.58 % waste is incenerable in nature & can be incinerated. Then only 16.58% waste needs to be disposed through secured land fill. So proper segregation of waste as per their nature and proper utilization of segregated waste will not only reduce the land requirement for secured landfill, but will also bring revenue for the industries. This can be further explained as follows:

Suppose in year 2010 the hazardous waste generation is 2.11 lac ton/annum and in 2025 it will be 5.61 lac ton/annum. So in 15 years total hazardous waste generated will be 6562000 ton. Taking average hazardous waste density as 1.3 ton/m3 and height of secured landfill as 8 meters, the area required will be 63.09 hectare if all the generated hazardous waste is disposed in secured landfill. If we segregate the hazardous waste into recyclable waste, incenerable waste and other, then we can sell approximate 481423.65 to recyclers, 47826.88 ton could be incenerated and only 104613.42 ton hazardous waste needs to be disposed through secured landfill. The area required in this case will be only 1.0 hectares. So this will considerably reduce land requirement and will also bring revenue to industries by sale of recyclable waste.

Generation of hazardous waste can be further reduced by adoption of cleaner technology, waste minimization and process modification in industries.

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