Hazardous Wastes and its Impact on Human Health

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Abstract. Urban sprawl, population growth, rising living standards, and industrialization has resulted in waste generation in developing countries. Many solid waste sources contribute to hazardous waste which poses many pollution problems. The purpose of this study is to understand hazardous waste and its impact on human health and to address hazardous waste issues. The results revealed that hazardous waste, when incorrectly treated, processed and disposed of, has a significant impact on public health and the environment. Air pollution, water supply depletion and the spread of human diseases are the worst effects of insufficient waste management. It makes cities untidy and dirty, affects people's health, harms flora and fauna, and hinders the economy of the countries. Some of the prevention such as hazardous waste handling, dilution, a tube-well structure using well-logging methods and other forms of geophysical monitoring designed specifically for the contaminated area, as well as the different treatment systems, could also be advised.

Keywords: Hazardous Waste; Solid Waste; Industrial Waste; Inventorization; Ground Water Contamination

1. Introduction
Hazardous waste is a waste that either poses a threat to human life, health or the environment in sufficient quantities and concentrations when it is inappropriately stored, transported, treated or disposed off. The effect of hazardous waste depends on its size, composition, physical, chemical or biological characteristics. Waste could be dangerous, for example, because it is combustible and flammable (such as many solvents used in the chemical industry), corrosive (such as battery acid), explosive or reactive (such as phosphorus) and infectious (such as hospital waste, used needles and bandages). Hazardous waste is usually a by-product of industrial operations involving heavy metals and Processes involving different oil and petrochemical categories; products such as PVC and plastics; contaminated electronic waste materials such as PCBs and DDT etc., and ultimately a volatile liquid (C4H4O), which are now recognized as highly poisonous and affect on all forms of life. Hospitals are also described as one of the potential sources of hazardous waste.

1.1 Classification of Hazardous Wastes
Hazardous waste is classified in the following categories as listed hazardous waste.

Hazardous waste features:
A waste is classified as a hazardous waste if laboratory tests show that it has one or more of the following four characteristics, La Grega et al, 2001[1]:  
Ignitability (The ability to easily ignite and thus pose a fire hazard)
Corrosively (The ability to deteriorate due to a highly acidic or alkaline nature)
Reactivity (The ability to have potentially harmful, rapid reactions like explosions)
Toxicity (The ability to release such components into water at substantial concentrations under defined conditions, i.e. leaching) Classification of hazardous waste based on its attributes, as determined by the U.S. laboratory testing, EPA.

1.2 Listed Hazardous Wastes
A hazardous waste listed is that which appears in the list of specific hazardous wastes compiled by the government authorities because it is known or suspected to provide hazardous characteristics. MoEF, GoI [2] suggested a total of 18 categories of hazardous waste as identified by the Ministry of the Environment and Forests of India (MoEF), and 11 types of hazardous wastes, banned for import by (MoEF).

1.3 Sources of Generation of Hazardous Wastes
Hazardous waste is generated from a wide range of industrial, agricultural, commercial and household activities. Manufacturers of many everyday products, manufacturers of specialized items, produce them through service and retail businesses, laboratories in schools, hospitals, car repair shops, government facilities and households. The generator can either handle the waste on-site or transport it off-site for processing, disposal, or recycling after a waste is produced, usually to a commercial hazardous waste facility. Waste generation is usually related to production and technology. Following observations were typically made through a comprehensive study on the generation of hazardous waste, U.S. Code of Federal Regulations, 1985 [3]: The manufacture of paint generates 4 to 6 percent of the total production as hazardous waste by weight, steel production generates 15 to 25 pounds of electrical furnace dust per ton of steel produced; and the manufacture of printing ink generates 1% overall weight processing as hazardous waste.

1.4 Groundwater Contamination by Hazardous Wastes
Contamination of groundwater may result from spillage of hazardous chemicals, leakage from underground tanks containing hazardous substances, disposal of toxic waste, discharges of domestic and industrial wastewaster, and leachate from landfill. The ground water is usually polluted by one or more of the following pollutants transferred from their sources to the aquifers:

1.4.1 Wastewater: Across developing countries, domestic and industrial waste water is a major source of pollution of groundwater and surface water.

1.4.2 Pesticides: The flooded water from agricultural fields carries chemicals and pesticides are responsible for water contamination. Due to accumulation of contaminants in the soil, this water is vulnerable to contamination.

1.4.3 Petrochemicals: Petrochemicals from underground oil storage facilities contaminate groundwater.

1.4.4 Chlorinated solvents: Metal finishing and plastic effluent, membrane cleaning, electronic equipment and aircraft manufacturing are often discharged and contaminate groundwater.
1.4.5 **Heavy metals**: pollutants like, (lead, mercury, iron, copper, manganese, cadmium, arsenic, nickel, aluminum, gold, and beryllium etc.) are extracted from waste and tailings mining, landfills, and hazardous waste landfills.

1.4.6 **Synthetic organics**: Many of the 100,000 chemical compounds commonly used are present and accumulated in the food chain in the aquatic environment. The most dangerous components to the atmosphere and human health are POPs (Persistent Organic Pollutants). Some chemicals can accumulate in fish and cause severe human health problems. Groundwater is also contaminated due to large-scale use of pesticides in agriculture, which leads to contamination. Other organic pollutants in groundwater such as carbon tetrachloride (CTC), trichloroethane (TCA) and trichloroethylene (TCE) are also responsible for ground water contamination.

1.4.7 **Landfill leachate**: Leachate is produced in landfills by the interaction of garbage, water and gravity. When the content of the waste water, Water moves slowly down the garbage under gravity until it reaches the bottom. The water, which passes through the garbage under gravity, is called the leachate. A contaminant released on the ground surface, such as leachate, first migrates vertically down (i.e. z-direction) and reaches the groundwater table. After reaching the groundwater, the contaminant is mixed with the groundwater forming a "groundwater plume" that begins to migrate in the aquifer (i.e. groundwater body) As usually shown in the horizontal plane (i.e. x and y directions) Fig. 1 Connor et al. 1997, [4]

![Figure 1](image)

**Figure 1.** Idealized schematic of soil leachate migration

Modeling the transfer of a contaminant from ground surface sources, as shown in ‘Figure 1’, consists of two sets of models being developed:

The first model for the transport of contaminants from the surface to the groundwater table vertically downwards. Connor et al. 1997 [4]; Ganguly et al. March 1998 [5] and December 1998 [6]; Mieszkowski 2003 [7]. This model is used to estimate the concentration of steady-state contaminants reaching the aquifer (i.e. groundwater exposure concentration).

Second model for transport of contaminant through aquifer in horizontal plane (De Josselin de Jong 1958 [8]; Ogata and Banks 1961 [9]; Sayre 1968 [10]; Baetsle 1969 [11]; Domenico 1987 [12];
Runkel 1996 [13]; Hossain and Yonge 1997 [14]. Using the groundwater exposure concentration (calculated using the first model) as a reference term, this model is used to estimate the strength of contaminant at any point in the aquifer horizontal plane.

2. Hazardous Waste Impact on Human Health

Inadequate storage, handling, processing, treatment and disposal of hazardous waste may affect human health and the environment by releasing contaminants into groundwater, soil, and atmosphere. The population may be adversely affected if toxic waste is absorbed through contaminated water supplies and polluted air and soil pollution can migrate or be transported through infiltration and may eventually enter the human food chain either directly or indirectly by agriculture. Exposure to hazardous waste can cause a number of health issues, including: skin irritation, impairment and disease, breathing problems, cancer, hormonal disruption, disruption of the nervous system, liver damage, mental retardation, weight loss, etc., depending on the type of waste to which it is exposed.

Lead: This affects the central nervous system of humans. It is a toxin caused by ingestion and is mildly annoying. Common air pollutant due to substandard fuel used in the automobile industry, which is now eliminated by the use of unleaded petrol; and the atmosphere near to industrial facilities where steps are not taken. When exposed to heat or flame, it is flammable in the form of dust. Lead may cause irreversible behavioral changes in young children, babies, and pregnant women, neurological damage and other problems. Exposure at significant levels can cause mental retardation, coma, seizures, and death.

Cadmium: Inhalation and other pathways are toxic to humans. It can be joined to the food chain by absorption, intraperitoneal, subcutaneous, intramuscular or intravenous pathways. Excess exposure can increase the risk of lung cancer.

Chromium: It occurs in two ways, i.e. chromium trivalent and hexavalent. Hexavalent chromium at higher doses is the cause of digestive tract cancer, cutaneous and nasal mucosal ulcers, and dermatitis. Many chromate salts, including calcium chromate, are carcinogenic when inhaled. Lung cancer has been identified in chrome industry workers.

Zinc: It is painful to the skin and affects the respiratory system. The problem arises from the pre-inhalation degradation of zinc fumes or the impurities like cadmium, antimony, arsenic, and lead are present.

Arsenic: Skin and gastrointestinal effects have been reported and is toxic to subcutaneous, intramuscular and intraperitoneal pathways. It is a carcinogen. Arsenic contamination in water can also cause damage to the liver and nervous system, vascular diseases, and skin cancer.

Mercury: White liquid mercury used in thermometers contains strong neurotoxin that can trigger severely brain damage and moderate tremor in the fetus and emotional disturbance in adults. When mercury and tin, converted to organic forms such as methylmercury and methyltin, these are more harmful to health and the environment.

Polychlorinated biphenyls (PCBs): It is toxic if ingestion, inhalation, or contact with the skin. A suspected human cancer is having an effect on the skin and liver. Common overdose symptoms include nausea, vomiting, weight loss, jaundice, abdominal pain, and edema.

Pesticides: Among pesticides, Organophosphates and carbonates cause severe nervous system damage and cancer. Many pesticides contain toxic substances that surpass the recommended levels and produce chlorides that trigger reproductive and endocrine damage.

Petrochemicals: Benzene and other petrochemicals can cause cancer even at low levels of exposure.
Waste oil: If oil is spilled out in the open, in sewers or landfills, it can spread to surface or sub surface aquifers. It is found that one gallon of oil contaminates one million gallons of water, rendering this non-potable. Marine species may be adversely affected even if they are exposed to oil concentrations as low as 1 mg/L. Because waste oil contains various hazardous contaminants, burning of oil increases air pollution as toxic gasses are poured into the atmosphere, affecting the ecological balance.

2.1 Health Risk Assessment Model
The general equation developed by U.S. EPA (1989 and 1991) [15,16] to estimates of chronic daily intake (CDI) for contaminants under ingestion have been considered. The equation for CDI is as follows:

\[ CDI = \frac{CW \times IR \times EF \times ED}{AT \times BW} \]

where

\[ CDI = \text{Chronic Daily Intake (mg/kg-day)} \]
\[ CW = \text{Concentration of contaminant in Groundwater (mg/L)} \]
\[ IR = \text{Ingestion Rate (average = 2 L/day for adult)} \]
\[ EF = \text{Exposure Frequency (350 days/year)} \]
\[ ED = \text{Exposure Duration (average = 70 years)} \]
\[ BW = \text{Body Weight (average 70 kg for adult)} \]
\[ AT = \text{Averaging Time (ED \times 365 days/year)} \]

The ELCR can be calculated by multiplying the CDI with a slope factor (SF) as follows:

\[ ELCR = CDI \times SF \]

Where,

\[ ELCR = \text{Excess Lifetime Cancer Risk} \]
\[ SF = \text{Slope Factor, the value of which depends on the type of carcinogenic contaminant (1/ mg/kg-day)} \]

Using the value of \( ELCR \), the number of people predicted to develop cancer as a result of contaminant exposure can be calculated as follows:

\[ P_c = ELCR \times P \]

Where,

\[ P_c = \text{Number of people expected to develop cancer from exposure to the contaminant of concern during their lifetime} \]
\[ P = \text{total number of persons exposed to the contaminant of concern} \]

The Excel-sheet program for the groundwater quality forecasting and health risk assessment consist of a mixture of models as outlined:

2.2 Utility of the Developed Integrated System
A typical example has been considered in order to illustrate the usefulness of the integrated computerized system developed in the current work on groundwater quality prediction and health risk assessment. In this example, consideration has been given to groundwater contamination and the health risk associated with this contamination. The cause of contamination has been identified as the
transport of a carcinogenic contaminant to groundwater from a hazardous waste disposal site. The input variables, the unified computer program produced in the Excel-sheet and the output results are described as follows:

2.2.1. Input Parameters

The typically considered input parameters for running the developed program are shown in Table 1. (Integrated Computer Program Developed in Excel-Sheet).

2.2.2. Output Results

The values of contaminant concentration in groundwater and the related health risk expected using the established software are presented, taking into account different sets of, and values.

### Table 1: Input parameters typically selected

| Input parameter                                                 | Description/notation | Typical value |
|-----------------------------------------------------------------|-----------------------|---------------|
| Contaminant of concern                                         | Trichloroethylene (a carcinogen) | --- |
| Thickness of single soil layer overlying the aquifer            | $e$                   | 0.5 m         |
| Soil’s longitudinal dispersivity coefficient                    | $\alpha$              | $0.1 \times e$|
| Infiltration rate through the soil layers overlying the aquifer | $I$                   | $10-10 \times e$|
| Porosity of the soil overlying the aquifer                     | $n$                   | 0.50          |
| Contaminant free-solution diffusion coefficient                 | $D_0$                 | 10-9 m2/s     |
| Tortuosity of the soil overlying the aquifer                   | $\tau$                | 0.3           |
| Concentration of contaminant at the source (i.e. at the base of the landfill) | $C_s$                 | 1100 mg/L     |
| Permeability of the aquifer                                    | $K$                   | 10-3 m/s      |
| Hydraulic gradient                                              | $i$                   | 0.01          |
| Retardation factor                                              | $R$                   | 2             |
| First-order decay coefficient for the contaminant               | $\lambda$             | 0             |
| Thickness of mixing layer, measured below water table           | $H$                   | 30 m          |
| Length of the site (e.g. a landfill) in the direction of groundwater flow | $L$                   | 50 m          |
| Distance down gradient of source                                | $x$                   | 10-1000 m     |
| Distance from centerline of source                             | $y$                   | 0-10 m        |
| Time                                                            | $t$                   | 1-10 year     |
| Longitudinal groundwater dispersivity                           | $\alpha_x$ (Eq. 2.6) | $0.1 \times x$|
| Transverse groundwater dispersivity                             | $\alpha_y$ (Eq. 2.7) | $0.33 \times \alpha_x$ |
| Vertical groundwater dispersivity                                | $\alpha_z$ (Eq. 2.8) | $0.06 \times \alpha_x$ |
| Source width                                                    | $Y$                   | 25 m          |
| Source depth (= thickness of mixing layer, $H$)                 | $Z$                   | 30 m          |
| Ingestion Rate                                                  | $IR$                  | 2 L/day       |
| Exposure Frequency                                              | $EF$                  | 350 d/y       |
| Exposure Duration                                               | $ED$                  | 70 years      |
| Body Weight                                                     | $BW$                  | 70 kg         |
| Averaging Time                                                  | $AT$                  | $ED \times 365$ d/y |
| Slope factor for the contaminant                                 | $SF$                  | 0.011 l/mg/(kg-d) |
| Total number of persons exposed to the contaminant              | $P$                   | 106           |
3. Results and Discussion

Following observations have been made:

- At a constant transverse distance, $y$, values of $C$ and $P_c$ are decreasing with increase in longitudinal distance, $x$, from the source, as shown in ‘Figure 2’.
- $C$ and $P_c$ are found to be approaching towards a steady-state (i.e. invariant with time) with increase in $t$ value. The steady-state condition has been found to be typically reached at $t = 1.6$ years, as shown in ‘Figure 2’.
- The plot of $x$ and $y$ versus $C$, as shown in Fig. 3, shows that the pollutants concentration is increasing with increase in $y$ and after approaching to a peak value the concentration is decreasing with increase in $y$. It is also evident from ‘Figure 3’ that the contaminant concentration is approaching to be invariant with transverse distance $y$ as longitudinal distance $x$ increases.
- The health risk is found to be increasing with time.

4. Conclusions

Environment and Forest Ministry has established Specific treatment and disposal options include physical / chemical treatment, landfill, biological treatment, incineration, reuse and recovery and solidification, etc. A systematic literature review and survey was conducted on the generation of hazardous waste in various Indian states and its effects on human health. The patterns and estimation of groundwater contamination have been shown since examining the amount and its effects on human health. It is therefore recommended that The agency concerned should concentrate more on establishing effective methods for waste reduction, reuse, storage, and proper disposal. Considering that previous findings and hypotheses were based on the present results, it is recommended that this study is further extended by local environmental researchers by incorporating economic and environmental aspects. In addition, A mathematical model that uses linear regression behavior in conjunction with the Geographic Information System (GIS) may improve predictions for hazardous waste generation.
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