# Chapter: 2

## Literature review

**2.1 General**

Groundwater is the most important natural resource and essential for life, it makes 65% of the human body and plays a vital role in various sectors of the economy such as agriculture, livestock production, forestry, industrial activities, hydropower generation, fisheries and other creative activities. Therefore assessment of groundwater quality is very important for threats arising from leachate percolation and for the design of sustainable techniques to mitigate them. Groundwater contamination from the MSW landfill studies generally comprise of following points.

1. The scientific understanding of physical, chemical, and biological processes that controlling the leachate percolation in the subsurface environment.
2. The periodical assessment of the different quality parameters of leachate and groundwater around the MSW landfill site.
3. The development of groundwater flow and transport models to predict leachate contaminant movement if they are introduced.
4. The mitigation methods to control and prevent the introduction of contaminants in the subsurface environment and to determine the methodology for the safe disposal of municipal solid wastes.

In view of the objective of the research, literature review was carried out together with information on various relevant aspects of this study.

Presence of $Cl^-$, $NO_3^-$ and $NH_4^+$in leachate sample can be used as a tracerin relation to leachate percolation[46]. As there is no natural or other possible reason for high concentration of these pollutants, the quality of the groundwater was found to improve with the increase in depth and distance of the location of the well from the landfill site.Tatsi and Zouboulis (2002) [47]concludedthat during the wet season, low-strength leachate was generated, while during the dry season, reduced percolation and enhanced evaporation increase the leachate strength.

Kumar and Alappat (2003) [48]quantifies the landfill leachate pollution in terms of Leachate Pollution Index (LPI), a value higher than 7.5 considered as a polluting leachate. LPI is useful to monitor the leachate trends over the lifetime of the landfill site and thus useful to take necessary decisions.

Sunil Kumar and Ramanathan (2008) [49] studied theBhalaswa MSW landfill and found that leachate hasa high concentration of chlorides, as well asCOD. The study was undertaken to determine the concentrations of principal contaminants in the groundwater over a period of time due to the discharge of such contaminants from landfill leachates to the underlying groundwater. The observed concentration of chlorides was found in the groundwater within 75m of the radius of landfillwhich wasobserved to be consonance with the simulated concentration of chloride in groundwater considering one-dimensional transport model, with a finite mass of contaminant source.

Mor et al(2005) [12]discussed that the moderately high concentration of EC, TDS, $Cl^{-}$, $SO_4^{-2}$, $NO_3^{-}$, $Na^{+}$ and $Fe^{3+}$deteriorates in groundwater near MSWGazipurlandfill for drinking and other domestic purposes. Further, the presence of $Cl^{-}$, $NO_3^{-}$, $NH_4^{+}$, Phenol, and COD can be used as a tracerin relation to leachate migration. The groundwater samples were also found to be bacteriological unsafe and leachate has a significant impact on groundwater quality near the area of Gazipur landfill site.

The high value of LPI of these landfill sites indicated that the leachate needed proper treatment before discharging it to land.

Tiwary et al (2005)[50]studied shows that the soil lying in the vicinity of mine waste dump has the highest concentration of $Cr^{+6}$.  The groundwater flow and mass transport models were constructed with the help of geo-hydrological and geophysical informationusing Visual MODFLOW software. Contaminant migration and path lines for 20 years have been predicted in two layers model of groundwater. This research gave an understanding of the reasonable migration of contaminant in groundwater because of leaching from the overburden dump of chromite mineral.

D. Kumar and Alappat (2005) [52];Aziz et al (2010)[53];Awaz (2015)[54]; Manimekalai and Vijayalakshmi (2012)[55] used LPI as a tool to assess the leachate pollution potential from MSW landfill sites especially at the places where there is a high threat of leachate percolation and contamination of groundwater.

Lee et al (2006) [56]studied thatheavy metals such as As, Cd, Cu, Cr andPbwere leached out from uncontrolled MSW landfill and contaminates the groundwater which causes a major threat to human health. These heavy metals are non-biodegradable hence causes a long-term impact on the environment.

Tsanis (2006)[57]simulated the leachate contamination of an aquifer from a landfill site using groundwater flow and transport modelling. Simulations result infers that without remedial action the pollutants in the leachate plume would persist above the acceptable limit for a longer period of time.

Esakku et al (2007) [58] discussedthat the smaller dumping sites are posing higher pollution potential in terms of leachate characteristics. The paper also discussed the site-specific variation in leachate quality and evaluated the LPI in monsoon and dry seasons.

Slack et al (2007)[59] concluded that the heavy metals and organic pollutants were found to transport into the layer under the landfill site over a 20,000 year time. Arsenic and chromium content were observed above to European Union and US-EPA drinking water standards at the unsaturated aquifer.

Alslaibi et al (2011) [60]observed an incensement of the main indicator parameters such as nitrate ($NO_3^-$) chloride ($Cl^-$), chemical oxygen demand (COD) and electrical conductivity (EC) in the downstream side at the dumping sites.

Azim et al (2011) [61]discussed the risk of pollution of surrounding low landarea that is highparticularly during the wet season around the landfill site, untreated grab leachate samples show high concentration of TDS (734 mg/l ), COD (1631 mg/l ), $NH_4^+$ (1253mg/l ), $HCO_3^-$(27962 mg/l) and certain heavy metals such as Ni (1.0 mg/l ) and Cr (0.74 mg/l ) and have very high potential for contaminating ground and surface water.

Rejani et al (2008)[62] carried out simulation modeling for efficient groundwater management in Balasore coastal basin, India with an intent to develop a two-dimensional groundwater flow and transport model using visual MODFLOW software for analyzing the aquifer response tovarious pumping strategies. Modeling result suggested salient management strategies for long-term sustainability of vital groundwater resources.

Umar et al (2010) [53]concluded that the leachate pollution index (LPI) provides an overall pollution potential of a MSWlandfill site. The parameters required to calculate LPI from a landfill site are discussed in terms of their variations over time, and their significance has been highlighted in the context of LPI.

Mohan and Gandhimathi (2009) [63] studied the characterization of the municipal solid waste and the effect of the leachate on groundwater from the MSW dumping site in Perungudi, Chennai. They were estimated the presence of pH, total hardness, electrical conductivity, total dissolved solids, major cations such as $Ca^{2+}$, $Mg^{2+}$, $Na^+$, and $K^+$, major anions such as $NO_3^-$, $Cl^-$ and $SO_4^{2-}$ and heavy metals such as Pb, Cu, Mn, Cd, Cr and Zn. The physico-chemical analysis results revealed that all leachate samples and water samples have a high concentration of heavy metals, especially lead. It was observed that the groundwater is not good for drinking purpose as most of the physical and chemical parameters exceed the permissible limits of drinking water quality.

**Table 2.1** Some groundwater pollutants and their harmful effects on human health.

| Pollutants | Diseases | References |
|---|---|---|
| Arsenic | Skin lesions, blackfoot disease, peripheral neuropathy, encephalopathy, hepatomegaly, cirrhosis, altered heme-metabolism, anaemia, skin cancer, hyperpigmentationand keratosis. | [64], [65],[66], [67] |
| Lead | Causes a number of diseases ranging from anaemia to nervous system degeneration, renal effects and hearing impairments, Inhibition of synthesis of hemoglobin, affects central & peripheral nervous system. | [68], [67] |
| Cadmium | Kidney damage, lung insufficiency, cancer, painful bone disease. | [69], [70] |
| Nickel | genetic toxicity and carcinogenicity, the disturbance of respiratory system and asthma, birth defects, vomiting and damage to deoxyribonucleic acid (DNA) at high concentrations. | [71], [72] |
| Zinc (Zn) | Fainting, nausea and stomach disorder. | [72] |
| Copper | Idiopathic Copper Toxicities (ICT), rare disorders of copper metabolism with established and putative genetic causes respectively. Acute and chronic health effects including gastro-intestinal diseases and liver damage. | [73],[74] |
| Al | Neurotoxic agent in human with renal impairments. | [75] |
| $NO_3^-$ | Severe intoxication and methemoglobinemia (blue baby syndrome) or even death among infants. | [76],[77] |
| TDS | Decreases palatability and causes gastrointestinal irritation in the consumers. It has also a laxative effect, especially upon transits. But, the prolonged intake of water with the higher TDS can cause kidney stones, which are widely reported in different parts of the country. | [78] |
| Hardness | Urolithiasis, anencephaly, prenatal mortality, some type of cancer, and cardiovascular disorders, the unpleasant | [79],[80] |

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|---|---|---|
| | taste may get increased due to the long-termuse of very high hard water. | |
| Sulfate | Diarrhoea, catharsis, dehydration, and gastrointestinal irritations. | [78] |
| Chloride | Physiological disorders, hypertension, the risk of stroke, left ventricular hypertrophy, osteoporosis, renal stones and asthma | [78], [81] |

Brindha et al (2011) [83]carried out the study with the objective of understanding the spatial and temporal variation of uranium concentration in groundwater level in a uranium mineralized zone in Peddagattu and Seripalli areas of Nalgonda district, Andhra Pradesh, India. They were observed that uranium concentration in the groundwater of ranges from 0.2 ppb to 118.4 ppb. About 20.61% of the groundwater samples had uranium concentration about the standards set by USEPA (30 ppb). The comparison between groundwater level and uranium concentration in groundwater shows that the uranium concentration increases with rising in the groundwater table.

Raju (2012) [66]concluded that the groundwater is contaminatedup to the large extent due to leachates of the MSW landfilland is not suitable for drinking and domestic purposes.Sixty-eight groundwater samples have been collected and analysed for major ions, iron and arsenic contaminations.The preliminary survey reports indicate that part of the rural and urban population of Varanasi environs are drinking arsenic contaminated water, mostly from hand tube wells (<70 m). It was found that 14% & 5% of the samples are exceeding the permissible limit prescribed by the WHO, 1993(10 μg/l) and BIS, 2003 (50 μg/l) respectively.

Rafizul and Alamgir (2012)[84] concluded that some groundwater quality parameters like hardness, total alkalinity, chloride, and COD appears to be proportional to one another in a scattered way around the MSW landfill site.

Afolayan et al (2012) [85] described that leachate of different landfills varies in parameters concentration with time. Most of the parameters reduced in quantity, toxicity and concentration with respect to time and type of landfill either operational and open or old and closed.

Suman et al (2012) [12]used correlation analysis method to estimation the degree of relationship among the selected leachate variables parameters. Correlation analysis is to measure the intensity of association between two variables parameter. They were concluded such relationship is probably leading to cognitive the basic association between the variables parameters.

Bhalla et al (2013) [26] study indicates that with the passage of time and with seasonal variation mainly during rainy season, values of various parameters increases due to infiltration of waste constituents with rainwater which is degraded with time. Thus, seasonal variations and the age have a significant effect on leachate composition.

Srinivas et al (2013)[80] carried out a study to evaluate the major ion chemistry, the factors controlling water composition and suitability of water for both drinking and irrigation purposes in Nagercoil town, Tamilnadu. Twenty one groundwater samples were taken from open wells and bore wells in January 2012. The Study concluded that electrical conductivity is high in concentration due to presence of $Na^+$, $Cl^-$, $SO_4^{2-}$ and $HCO_3^-$ in the groundwater. It may be due to dissolution of mineral by influence of anthropogenic actions such as huge use of fertilizers and extreme agricultural practices. GISbased spatial maps shows that the study area has extremely affected groundwater quality.

Joycee and Santhi (2014)[86]analysed the physico-chemical parameters of 19 groundwater wells samples such as pH, calcium ($Ca^{2+}$), dissolved oxygen (DO), electrical conductivity (EC), magnesium ($Mg^{2+}$), total dissolved solids (TDS), turbidity, total alkalinity (TA), total hardness (TH), sodium ($Na^+$), potassium ($K^+$), sulphates ($SO_4^{2-}$), chloride ($Cl^-$). In the study to delineate the distribution of water pollutants, spatial interpolation technique through Inverse Distance Weighted (IDW) approach has been used while the spatial variation of the groundwater quality parameters was studied using spatial analyst and geostatistical analyst extensions modules of ArcGIS 10.2. The study concluded that the parameters like pH, $Ca^{2+}$, $Cl^-$, $Mg^{2+}$, $NO_3^-$, K, total hardness lie within the permissible limit and are found to be safe for drinking and other purposes according to norms prescribed by WHO and BIS.

Vishal et al (2014) [87] predicted groundwater recharge at Delhi using numerical groundwater model using visual MODFLOW 4.3. MODFLOW model is derived from a combination of topology, soil type, land use, well location using geographic information systems (GIS). The model was calibrated and validated and then used to predict groundwater recharge. The output of the model was found to be in agreement with the earlier records. Moreover, the simulation results also show a significant decline of water table in the study area.

Kumar and Kumar (2014)[88] developed a MODFLOW model to estimate water budget of ChotuppalMandalNalgonda, Andra Pradesh with the identified boundary conditions and field observations data. They found that the computed groundwater level contours are in good agreement with the observed ones. The model results show that the simulated values are in good-fitness with the measured value that means the model is reliable and acceptable.

Atta et al (2015)[89]uses the MODFLOW 2000 to construct the groundwater flow around the MSW landfill site and calibrated as a three-layer steady-state MODFLOW model. The model revealed that the hydraulic gradient of the groundwater flow is towards the north-east side i. e. Jinjang Riverside which is located on the eastern part of the landfill. Model concluded that quick action is needed to protect JinjangRiver and Nanyang Pond which is hydraulically connected with the same aquifer so there is a chance of contamination by leaching of landfill leachate in the flow direction of the water bodies.

Abd El-Salam and Abu-Zuid (2015)[90]concluded that groundwater in the region of the MSW landfills did not have serious contamination, but parameterslike conductivity, total dissolved solids, chlorides, sulfates, Mn and Fe exceeded the WHO and EPA standard.

Anilkumaret al (2015)[91] werecollected groundwater samples from dug wells lies within 1 kilometer around the MSW dumping site in pre-monsoon and post-monsoon period for analysis of physicochemical parameters. Groundwater nearby the MSW dumping sites were observed to be more polluted in both seasons. The nitrate (88 mg/l) and total dissolved solids (726 mg/l) concentration in groundwater are in an alarming state that is not suitable for drinking purpose.

MSW management research has advanced groundwater flow and transport modeling ability to predict leachate plumes and assess helpful action plan. These models frequently highlight transport in the saturated zone and compact with point sources. Numerous models have been developed by modeling tool to precisely simulate the leachate pollution problem with fluctuating degrees of complexity.

Naveen et al (2016)[92] concluded that leachate generated from young landfills is not stabilized so it undergoes decomposition and has high risks to the groundwater of surrounding areas.

Wu and Sun (2016)[30] has been proposed an entropy-weighted fuzzy water quality index (WQI)to assess the groundwater quality in and around the industrial park, northwest China, where domestic water necessities are merely met by groundwater.

Chakraborty and Kumar (2016) [9]Rabeiy (2017)[93]calculated WQI, by using weighted arithmetic index method, which showed that the groundwater quality around the landfill came under poor category while area wise grouping exposed the magnitude of the impact of landfill leachate on groundwater.

Srivastava and Ramanathan (2018)[94]studied the movement of trace metals in groundwater around the landfill by using visual MODFLOW/MT3D.The calibration and validation of model show more than 90% models correct with 95% confidence.The contaminant transport simulated in groundwater aquifer with the high accuracy for the large area (~ 300 $km^2$). The contour lines of trace metals concentration indicated thatthe study area will be contaminatedin the near futureby its release through the landfill.

There are lots of studies were conducted on groundwater contaminant percolation from the open dumping sites by using LPI, WQI, and various mathematical models. They give a root for connectionbetween open landfill leachate and its impacts on local groundwater quality and the surrounding environment.

Groundwater flow and contaminants transportmodeling study revealed that modeling is very important to understand the groundwater system behavior and to predict the future risk from polluted water and take a decision for remediation measures. Visual MODFLOW is a well-established tool to study the groundwater flow and contaminant transport due to its user-friendly feature for the research purpose.