Groundwater Contamination By E-Waste And Its Remedial Measure - A Literature Review

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Abstract

The very precious resource of Earth, the groundwater is being contaminated and polluted day by day. E-Waste is one of the major cause for this problem related to ground water. E-wastes are produced mainly due to discarded electronic gadgets like PCs, tablets, hard drives, printers, monitors, batteries, mobile phones, television, etc. The use of these electronic gadgets is increasing enormously day by day around the globe. Lack of awareness about the proper disposal of these e-wastes cause serious health and environmental issue in developing countries like India and to some extent in developed countries. Discarded computers, mobile phones and other electronic equipment that are considered as e-waste contain hazardous toxic metals like chromium, lead, mercury, iron, zinc, copper, cadmium etc. These e–wastes are dumped in the landfills near the industries where large area of land is available. As most of the industries are located near the water sources, the toxic e-wastes are percolated inside the water hence make the water contaminated inside the deep aquifers. This water is not safe for drinking and other purposes. The quantity of pollutants is more near to the landfill sites and reduces as the distance between the landfill site and aquifer increases. In the present work, a literature survey of groundwater pollution by e-waste and its remedial measure to reduce groundwater contamination is being done.

Keywords: E-waste, groundwater contamination, leachate, percolation

1. Introduction

The groundwater, one of the world’s most valuable natural resource, used by human being is in danger and is considered as one of the major issue in today’s scenario. At present, global population is about 7.7 billion (September 2019). The growth and development of major part of this population are based on Information and Communication Technology (ICT) and electrical and electronic equipment (EEE). The unintended and uncontrolled use of these lead to the tsunami of electrical and electronic waste: e-waste. E-wastes encompasses wide range of electrical and electronic gadgets such as PCs, tablets, hard drives, printers, monitors, batteries, mobile phones, television, etc which contains hazardous heavy metals (like Chromium (Cr), Lead (Pb), Zinc(Zn), Copper(Cu), etc). These hazardous materials present in the e-waste can infiltrate from the landfill sites into groundwater. This obnoxious liquid is known as ‘leachate’[1]. This leachate waste, which is highly toxic in nature starts percolating through the porous soil and finally mixes with the groundwater and pollutes the water. Areas near landfill sites have higher possibility of groundwater contamination because the leachate production is higher in the nearby sites. From a recent study [2] on groundwater contamination in Gazipur, Delhi location, it is found that the leachate generated...
from e-wastes is the major cause of groundwater contamination. Several other cities in the country and outside the country are also facing the same problem. This contamination can be minimized by using various techniques so that the leachate does not percolate into the aquifers. In the present review article, literature survey of groundwater pollution by e-waste is being done in Indian and global scenario and its remedial measures to reduce groundwater contamination is discussed in detail.

2. Survey on groundwater pollution in different regions by e-wastes:

Unscientific design and indiscriminate disposal of waste and carelessness about the lifespan of landfill lead India under threat of pollution of environment and risk of health. According to a recent report, published by Parliamentary Standing Committee on Science & Technology, Environment and Forests in section 8.2 [2] the Gazipur landfill, India’s tallest rubbish mountain is now 65 meters tall having only a difference of 8 meters from the height of national monument Qutub Minar (72.5 meters). In Delhi region, at present the operative landfill sites are at Gazipur, Okhla and Bhalswa [3]. Mor et al. have studied the concentration of various heavy metals and other physio-chemical factors in groundwater and leachate sample collected from Gazipur landfill sites and its adjacent areas. The analysis of the effect of depth and distance from landfilled sites made the conclusion that groundwater should be avoided from the wells near to the landfill sites. In its unavoidable circumstances, water should be collected and used only after proper analysis of water sample drawn from deeper drilling.

The leachate and groundwater sample from the landfill sites Vendipalayam, Semur and Vairapalayam in Erode city of Tamil Nadu was studied by R. Nagarajan et al.[4]. To study the contamination in groundwater, they have collected the samples from 43 wells in the city. The area has moderate dry weather except monsoon seasons. It usually experiences heavy rains during rainy seasons because of which water level varies with respect to ground level. Based on their analysis, they found moderately high concentration of heavy metals in groundwater which force them to conclude that leachate percolation has a huge impact on the quality of groundwater.

USA, one of the leading country of the world in per capita production of e-waste, is considered to be rich and developed country with consumerist culture. This culture not only crossing environmental sustainability but also creating hazardous effect on health of human being. According to a global e-waste statistics by Baldé et al.[5], the total e-waste generation by America was 11.3 Mt in 2016. The top three countries in America in producing e-waste are USA, Brazil and Mexico. But as USA refuse to ratify 1989 Basel Convention on international trading of Hazardous Wastes, they export most of their hazardous e-waste to many Asian and African countries. But United States is not free from danger of groundwater contamination. 1200 sites in US have been identified in the national priority list for the treatment of contaminated water [6]. Approximately 63% of the sites were found to be contaminated by heavy metals (like cadmium, copper, lead, mercury, nickel, zinc) leading to a major problem for groundwater and food supplement. These heavy metals are considered to be the most hazardous pollutants by US Environmental Protection Agency (EPA).
According to the global statistics [5], in 2016 Canada produced total e-waste by an amount of 724 kt. Approximately 140 kt of e-waste are disposed in Canadian landfills each year [7]. In spite of this huge amount of e-waste production, Canada does not have national legislation in effect on e-waste management. But in some provinces of Canada, few non-profit organizations are there who have taken initiative to collect e-waste and recycle it.

World’s largest manufacturer and consumer of electronic products, China is making e-waste as the fastest growing waste with an annual growth rate of 13–15 per cent [8] that can be increased by a factor between 1.5 and 7 by 2020. The percolation of leachate from this huge amount of e-waste to the groundwater can be a major environmental concern. In assessing the groundwater quality near landfills by Z.Han et al. [9], 96 kinds of groundwater pollutants including 12 inorganic salts, 5 metal ions, 15 heavy metals, 2 bacteriological pollutants, and 62 xenobiotic organic compounds were detected. These pollutants may leak from the landfill and contaminate the groundwater by making it of “very bad” quality. They also observed that the groundwater contamination mainly detectible within a range of 1000 m of a landfill and most of severe contamination arises within 200 m; which again indicates that the groundwater near the landfill sites should be avoided as much as possible.

The growing role of Information Communication Technology (ICT) has transformed Africa as a heaven of e-waste overlooking the Basel Convention that was intended to reduce the movements of hazardous waste from developed to developing countries. Up to 75% of the imported electronics are junk and irreparable and they are dumped in the landfill in uncontrolled way [10] which lead to the degradation of groundwater quality. V Nevondo et al. [11] have shown that in the surrounding areas of the Thohoyandou landfill site, South Africa, the groundwater is highly contaminated by mercury which can have harmful effects on human health and surrounding environment. Agbogbloshie, a slum in Ghana, is considered as the largest dumpsite of the planet [12]. The groundwater sample from landfill site at Kumasi, Ghana [13,14] shows high levels of lead, iron, cadmium, and chromium (above the acceptable limits of the World Health Organization) and the high levels of heavy metals found in the Oti community suggested a significant pollution of water by leachate percolation from the landfill site. The quality of groundwater sample improves with increase in the distance of the borehole and well from the landfill site. In Africa, only very few countries like Uganda and Rwanda have formal official government policy documents that is specific to e-waste management. Their legal and infrastructural framework may have the potentials for reuse, recycle, and reduce e-waste, which result in economic and environmental benefits. According to the same report, the amount of e-waste is still quite moderate [5].

3. Parameters used for estimation of groundwater quality:

The ground water is used for domestic and other purposes like irrigation, industry etc. So its contamination is a major health and environment issue. The factors to estimate the quality and suitability of groundwater pollution, different physico-chemical parameters are used such as pH, electrical conductivity, total dissolved solids, total hardness, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride [15]. These are then compared with the permissible
The pH value indicates the acidic or basic nature of water. If pH is less than 7, the water is considered to be acidic and with pH is greater than 7, the water is considered to be basic. As per the guideline of WHO and BIS on drinking water quality the pH value should be in between 6.5 to 8.5.

Electrical conductivity (EC) is a measurement of saltiness in groundwater sample. Higher EC value indicate that the groundwater is enriched with salt. The acceptable limit of EC in drinking water is 1500 micro-siemens per centimeter (µS/cm).

Many inorganic or organic minerals, metals, salts, ions can be dissolve in groundwater. The total mass of these dissolved constituents is denoted as total dissolved solids (TDS). The dissolved solid will produce ions in groundwater. So higher TDS indicate more ions in groundwater, which will make the water as saline. Low TDS water is safe to drink. WHO and BIS desirable limit of TDS is 600 mg/l and 500 mg/l and permissible limit is up to 1000 mg/l and 2000 mg/l respectively.

Water hardness is the measure of the capacity of water to react with soap. Metallic ions like calcium, magnesium etc. are the principle source of hardness of groundwater. According to both WHO and BIS desirable limit of hardness is 200 mg/l and permissible limit of hardness is 500 mg/l and 600 mg/l respectively.

Calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride are measured in groundwater sample is compared with the permissible limit set by WHO and BIS.

### 4. Remedial techniques:

Groundwater contamination has become an important issue worldwide as it has severe effect on the aquatic ecosystem, plants, human beings, and environment. Therefore, protection of groundwater resources is one of the major challenge in 21st century. In the following section, we will discuss on some remedial techniques that can help in minimizing groundwater pollution. The remediation technologies for groundwater contamination are broadly categorized into three stages [18]. In the first stage the pollution sources are identified, then in the second stage diffusion of pollutants are being controlled, and lastly in the third stage, repair the contaminated site. The remediation technique can be in-situ repair method and ex-situ repair method. In the remediation process, either the pollutants are removed or it is converted into harmless product. In situ remediation technique has several physical and chemical methods [19] like pump and treat technique, nano treatment technique, soil vapor extraction treatment technique, thermal treatment technique, permeable reactive barriers (PRBs) technique, bioremediation treatment etc. Being low cost and less construction time, barrier technology are widely accepted technology. The barrier technology are categorized into three classes: cover barrier technology, vertical barrier technology and horizontal barrier technology [18]. When the contaminated groundwater flows through the reactive barrier, they may form insoluble precipitates and leave the solution. Vertical barriers can also used to reduce the movement of contaminated water through the deep aquifers. Slurry walls
are commonly used for this purpose, as they are least expensive. Horizontal barriers are under development and are potentially useful in controlling downward movement of metal contaminants because they act as underlying liners. Lining is a process, which is done to prevent the percolation of heavy metals through landfill sites into the deep aquifers. In this process, the landfill site is lined by using synthetic material or clay liner. The liner should be strong, permeable, and flexible and possess high tensile strength. In addition, it should be black in color to resist UV light. Apart from physical techniques, some chemical techniques also come into practice. Chemical technique can be executed ex situ or in situ. In the process of in situ chemical treatment, the chemical agents should be carefully selected so that there is no additional contamination in the landfill area under treatment. Chemical processes involved are reduction, neutralization, and oxidation, which mainly reduce the mobility and toxicity of metal pollutants by converting them into inactive state.

The threat of groundwater quality in different parts of India has led the government to think about the effective remediation process seriously. On 4th October, 2019, the Bhopal Municipal Corporation (BMC) and the Central Pollution Control Board (CPCB) jointly have signed a MoU to set the country’s first e-waste clinic at Bhopal, Madhya Pradesh [20]. The clinic will work on segregating, processing, and disposal of waste from household and commercial units. For this purpose, e-wastes would be collected door to door or could be deposited to the clinic directly in exchange of fee. The success of this three-month pilot project can give future India with more e-clinics that could be helpful for the remediation process of groundwater contamination.

5. Conclusion:

In 21st century, daily advancement of technology pushes mankind to the daily generation of huge amount of e-waste. These e-wastes produce hazardous heavy metals which when dumped into landfills can seepage to the groundwater. Characteristics of the leachate depend on the composition of waste and the amount of water present in the waste. The major components of the e-waste found were used mobile phones, laptops, computers and household electrical gadgets that contains significant amount of toxic substances. This high amount of toxicity in groundwater is making it worst for drinking, irrigation and other purposes. Groundwater contamination is a serious issue, not only in Indian perspective but also in global perspective. That is why many countries along with India also is focusing on e-waste management. It is suggested by many groups that the quality of groundwater improves at increasing depths and distance from the landfill sites.

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