CHAPTER 1

INTRODUCTION

1.1 General Statement

Water being one of the most important natural resources is not only a valuable and inexpensive resource of the world in general but to entire life forms in particular. For sustaining socioeconomic growth, standard of living or environment maintenance it is one of the most essential components. Thus, not only the prosperity of a nation but the ease of the whole world depends on the capitalization of it. Most of the anthropogenic activities including habitation or agricultural or industrial activities, etc. depend on the utilization of water in one form or the other. Water acts as a medium for both biochemical and chemical reactions taking place on the surface of the earth. It forms the external and internal medium for all organisms. On an average an adult human body consists of nearly 60% of water by body weight therefore, it acts as a source of maintaining the physiology of the human body as well as the existence of life on the planet earth. Consequently, playing a critical role for proper functioning of each and every cell or organ of the human body. Even though the Great Civilization from the historical era was also around the major rivers due to its importance in every aspect of life. On earth, the activity and location of the human population depends entirely on the availability of water for proper functioning of day to day life. Being a medium for metabolic functioning of life on earth, it not only helps in regulating temperature of the body but also helps in transporting oxygen, nutrients and wastes to the body cells and tissues. In short, it can be said that water acts as a major constituent of social and economic infrastructure of life. In developing nations, there is absence of both appropriate quality and quantity of water thus making it an indispensable issue in rural as well as in urban areas for providing safe and sufficient water supply to the local population. Hence, it becomes evident to incomparably protect, assess and monitor water which flows in rivers, streams, lakes and reservoirs. Although the surface of our planet is nearly covered with 71% water and the oceans hold about 96.5% of all Earth's water. Of this less than 3% is fresh water. Out of this available 3% about 75% is found in the form of glaciers and icebergs, 24% constitute ground water and the remaining 1% of it is in the form of fresh water occurring as rivers, lakes, reservoirs and ponds suitable for human consumption (Dugan1972).

The Earth's fresh water present in form of Ground Water, Swamp water, Rivers and Lakes would be approximately 2551000 mi^3 or 10633450 km^3 (usgs.gov) of this much of it is present in form of deep groundwater which is unavailable to human beings.

If surface water is taken into account then the volume of water present in form of lakes is about 42320 mi^3 or 176400 km^3 of which the amount of water present in form of fresh water is 21830 mi^3 or 91000 km^3 while the saline water amounts to 20490 mi^3 or 85400 km^3. However, rivers account for 509 mi^3 or 2120 km^3 of water capacity. (Shiklomanov 1993).

While taking into consideration the Indian Scenario of fresh water, it was found that India being a residence of about 16% of the total world's population and having a land area of less than 2.5% utilizes approximately 4% of world's water resources. The fresh water reserves in India accounts for about 1869 trillion litres out of which only an estimated 1,122 trillion litres can be exploited due to the geographical limitation and dispersal effects. Apart from this, India has a rich network of rivers containing about 1953 km^3 of average annual flow per year (Kumar et al 2005).

Moving on to the State level, the State of Madhya Pradesh encompasses drainage areas of 5 major river basins having an estimated surface flow of 8.15 mn hectare metres out of which 5.68 mn hectare metres is usable by the state and the remaining 2.47 mn hectare metres is left for use of neighbouring states. However, it can only utilize 56.8 km^3 of surface water annually due to geographical restrictions. 30% of it is stored in ponds and lakes while 70% is found in reservoirs. (Khanna et al 2005). Out of this, a very small percentage of water is stored in Inland water bodies and a huge amount of it is either returned to the seas and oceans via rivers or absorbed by soil and stored in the form of ground water. (Pan IIT 2010).

Due to the accelerating water pollution and its direct effect on human and ecological health, the estimation of quality of water along with its quantity has become an important issue of consideration in acquaintance with the use of water resources (Zamani et al 2012). Taking into consideration, the study area i.e. the Govind Ballabh Pant reservoir, is having a capacity of 10625 cubic million meters at the FRL (Full Reservoir Level) of 268m above mean sea level with an estimated annual rate of inflow of around 6301 cubic million meters. (Sharma et al 2012).

Due to increase in urbanization, industrialization and other anthropogenic activities, there are emergence of ample complications arising due to these activities. These activities are causing serious catastrophe to the environment. The impact of anthropogenic activities on water bodies has been so extensive that they have lost their self-purification capacity to a large extent (Sood et al 2008). Amongst these anthropogenic manoeuvres, industrial activities have an important role. In this regard, coal mines act as a major genesis of pollution. Though coal is regarded as a primary source of energy since it provides about 27% of global primary energy need and generates about 36% of the world's electricity and in India, the share of coal for the generation of electricity is about 62.3% (Tiwari, 2001). At the end of 2018, the world's total production of coal was about 1054782 million tonnes (BP Statistical Review of World Energy 2019) including anthracite, bituminous, sub-bituminous and lignite variety of coal. The total coal production in India is about 730.35 million tonnes during April-March 2018-19 (Coal statistics 2018-19) constituting as one of the five major coal producing nations of the world. Out of the total produced coal, approximately 7% and 93% of it is generated by underground and opencast mining respectively. Currently, 493 coal mines are being operated in India out of which 210 are underground, 252 are open cast and 31 are mixed. (IBM Report 58^{th} edition 2019). In 2019, Jharkhand was the largest coal producing state followed by Odisha, Chhattisgarh and Madhya Pradesh. The State of Madhya Pradesh produces about 28.79 billion tonnes of coal accounting for more than 13% of the total coal produced in the country. Coal mining is mainly confined to the Public Sector which contributed 95% to the national production (IBM report 2019). The state is mainly dominated by the presence of Gondwana coal which is mainly characterized by dominance of non-coking coal. (Indian Coal and Lignite Resources 2019). Being part of the state of Madhya Pradesh and Uttar Pradesh, the Singrauli Coalfield is spread over 2202 km^2 comprising two basins, viz. Moher Sub-basin and Singrauli Main basin. In this, all the coal mining operations present in Northern Coalfield Limited (NCL) is mainly operated by presence of 10 opencast coal mines. The mines of NCL approximately produced 101.50 million tonnes in 2018-19 thereby comprising approximately 14% of the total coal produced in India (www.nclcil.in).

Due to its low cost and abundance, coal remains an important energy source particularly for electricity generation (Freese, 2003). Being one of the core industries it is having a huge contribution in the economic development of a country like India but at the same time it is deteriorating the environmental condition of the country (Tiwari, 2001). In India, coal mining dates back to 1774. The first commercial coal mining started from Raniganj coalfield on the western bank of Damodar River in West Bengal. After the 1970's the environmental issues arising from activities of coal mining have become an important area of concern. The large amount of coal extricated from mining activities not only causes widespread landscape wrecking but it also participates in energy generation for which a huge quantity of coal is required for industrial expansion in the country indeed. As per environmental point of view coal mining is a major habitat transforming activity which has a number of adverse environmental consequences namely soil erosion, acid mine drainage and increased sediment load as a result of abandoned and unreclaimed mined land (Park et al, 1987). The magnitude of mining for the utilisation of the mineral resources and fossil fuels is continuously increasing owing to the development activities and the population demand (Wong, 2003, Sheoran et al 2008). Therefore, it can be seen that the effects of mine wastes can be multiple such as soil erosion, air and water pollution, toxicity, geoenvironmental disasters, loss of biodiversity and ultimately loss of economic wealth (Singh et al 2014). Due to the presence of coal mining activities there is substantial alteration in the topography of the area to an appreciable expanse culminating into the deterioration of the stable ecosystem. For the attainment of increasing demands of coal there may occur an increase in destabilization of the ecosystems in the area pertaining to mining activities which may be at the expense of sustainable development. In order to sustain the coal extraction process in accompaniment with the decreasing vandalization of the surrounding ecosystem, continuous monitoring and remediation strategy are required in order to ace the economic development of the country without posing considerable damage to the environmental balance of the concerned study area.

An increased concern for environmental evocation in concurrence with landscape restoration strategy for maintaining the balance in exploitation of resources and continuing the refurbishment of the ecosystem should be rendered (Ghose 1989). In order to augment the environmental degradation along with coal exploration in the study area various strategies of assessment of surface water body in combination with monitoring changes in land use land cover of the area over a long period of time in addition with the estimation of volume of the reservoir over a time span of 20 years has been conducted in this study. Apart from this, the remediation strategy include the treatment of effluent water with the help of sandstone filtration system in amalgamation with use of aquatic macrophytes as a part of phytoremediation for the revival of effluent water for use in industrial or agricultural utilization for minimising the generation of wastewater.

1.2 Assessment of Water Quality

The assessment of water quality of surface water present in the form of reservoir and industrial sump water is foremost because of its significance in perpetuating the ecological activities that assists in maintaining the biodiversity of the area. Since, there is continuous decline in the water quality of the area due to industrial and other anthropogenic perturbations which menace the stability of the environment and hinders the water quality of the area. These anthropogenic activities may cause eutrophication or parching of reservoirs. Therefore it is necessary to carry out continuous analysis of physico-chemical parameters in water of reservoirs and other industrial sources along with the assessment of water quality index of the area at various locations. Since, reservoirs are an important sink for various pollutants entering into it through various industrial outlets as well as through weathering of rocks, overburden etc. present in the vicinity of the reservoir. These pollutants mainly consist of various physical parameters such as pH, Total Dissolved Solids, Total Suspended Solids, Electrical Conductivity, etc. along with cations, anions and heavy metals. The excess accumulation of these parameters often lead to toxicity and ecological damage of the water body and aquatic environment associated with it. Since, many of the physicochemical parameters taken into study are non-biodegradable and susceptible to aquatic environments even at low concentrations. They are also toxic to humans even at low concentration. Therefore, the bioavailability and subsequent toxicity of such physico-parameters have been a major area of research in recent times (Singh, 2001, Klavinš et al 2000). The indiscriminate disposal of few of the parameters in water has been the major cause of pollution hence causing the worldwide concern for the last few decades (Bazrafshan et al 2015).

In this thesis an attempt, has been made to monitor the concentration of physico-chemical parameters of the water samples at various locations since very few research are done in this area. In this study, physico-chemical analysis of parameters were done during the pre and post monsoon season. Furthermore, the water quality index of these locations can be evaluated in terms of physical, ionic and heavy metals parameters. Water Quality Index can be described as the mathematical procedure implemented to assimilate numerous water quality data, thereby producing a single value as a representation of the water quality status of a particular location (Mitra 1998; Štambuk-Giljanović 1999). The calculation of the Water Quality Index was first developed in the USA by Horton in 1965. The use of Water Quality Index helps in eliminating the subjective assessments of water quality and biases of individual water quality (Hamza et al 2017). In addition to the above characteristics, it also helps in making the information simply and promptly interpretable than that of a list of numerical values which makes it a communication tool for transmitting information to water managers (Sharma et al 2010, Varnosfaderany et al 2009). Water Quality Index can also be used to differentiate the quality of water at various locations during a particular season with a certain change in the water quality of the specific sites. Though, numerous methodologies are available for the calculation of water quality index but none of the methods are designed to represent the class of pollutants (Pei-Yue et al 2010) thereby making it strenuous to elucidate the extent of entailment of various physico-chemical parameters. But due to its ability to assess the various water quality problems, Water Quality Index can be considered as an effective tool for water quality evaluations and management around the world (Ramakrishnaiah et al 2009, Tambekar et al 2008, Tundunwada et al 2007).

1.3 Application of Remote Sensing and GIS

Moreover, in addition to above objectives, in this study, application of remote sensing and GIS has also been taken into consideration. The integration of geostatistical and GIS technique helps in interpolating the results both spatially and temporally. This acts as a liable instrument for studying the water quality of a region. The spatial distribution of various physicochemical parameters and Water Quality Index manifest heterogeneity. The use of spatial analysis has greatly simplified the assessment of natural resources and environmental concerns including groundwater and surface water using ArcGIS software (Pande et al 2018). GIS software can be described as a potential tool for mapping of water quality and other parameters as well as for discovering the administration of the environmental issues and detection of variation associated with it. Satellite images have always been widely used for monitoring water quality in many water bodies (Wu et al 2009). Landsat 5, Landsat 7 and Landsat 8 provides a well calibrated continuous dataset of moderate spatial resolution with reliable geometric integrity and validate radiometric quality and they are freely available; therefore, these images are perfect for the study of natural resources (Moran et al 2001). Hence, in this thesis an attempt has been made to spatially represent the physicochemical parameters and water quality index of the study area at various sampling locations.

1.4 Role of Multivariate Statistical Techniques

Since, the evaluation of surface water quality is an intricate task that rely on use of relevant statistical techniques for its assessment. In order to assess the chemistry of surface water multivariate statistical analysis can be considered as an amicable tool for ascertaining its physicochemical parameters in various water samples at different locations. These multivariate statistical techniques are often used to point out procedures that administers the chemistry associated with water present in the area as well as for evaluating its suitability for various purposes (Kamtcheung et al 2016). These techniques are usually applied on a large number of samples for pattern recognition and to explain the variance of a large set of inter correlated parameters (Tiwari et al 2017). It also causes the reduction of the extent of the dataset by establishing relationships between various physico-chemical parameters. One such method of multivariate statistics is correlation analysis. Correlation matrix is applied to physico-chemical parameters to assess the degree of relationship between different water quality parameters.

For the diagnosis of seasonal patterns amongst various physico-chemical parameters, the plotting of box plots representing medians, quartiles and extremes are exceeding useful for estimating the seasonal variability. Apart from this, Hierarchical Cluster Analysis (HCA) is also one among the other effective techniques which separates samples of similar water quality into separate clusters representing specific water quality index. Apart from the above statistical approaches, another approach for the classification of water on the basis of chemical components is piper plot. Piper plots help in identification, grouping and comparison of water samples with similar chemical evolution into various categories. Thus, these multivariate statistical approaches can frequently be employed as a proxy to characterize the quality of water in a given environment at a particular span of time (Güler et al 2012, Mano et al 2013).

1.5 Significance of Land Use/ Land Cover

Furthermore, to know the impact of Land Use/ Land Cover changes on the quality of water of the reservoir, Land Use/ Land Cover analysis has been performed. Since remote sensing provides multi temporal data which gives valuable information about the process and pattern of Land Use/ Land Cover change which may be analysed and mapped in GIS (Zhang et al 2002). For this purpose, satellite imagery has been used as an effective means to acquire information about the earth surface in order to map Land Use/ Land Cover of the area (Lo et al 1986, Reger et al 2007). For the sustainable development and management of natural resources remote sensing based Land Use/ Land Cover (LU/LC) acts as a tool for providing suitable and wide range of information about the area under study. Remote sensing technology is supporting research in LU/LC dynamics with data sources from space that provide information to monitor and estimate changes on the surface (Badreldin and Gossens 2013). Since, LU/LC is also associated with mining activities therefore a contingent understanding of LU/LC with time is important to understand the changes associated with it (Varghese et al 2010). As mining activities disturbs large tracts of land due to overburden dumps released from opencast mining activities, they cause change in the natural topography and drainage pattern of the area (Dhar et al 1991). The studies based on LU/LC have been done to assess the impact of rapid changes which present bias and can be subjective (Crouvi et al 2006). In this study, satellite data from Landsat 5, Landsat 7 and Landsat 8 have been utilized to detect LU/LC patterns in a time span of 1985-2018. In addition to it, change detection for identifying the differences in the state of an object or phenomenon by observing it at different time periods involves the ability to quantify temporal effect using multi temporal datasets (Othman et al 2013). Changes can be detected from overlaying multiple land use and land cover maps produced from multi temporal aerial photos or satellite images in a geographic information system (Kaufmann et al 2001). Repetitious and up to date land use change information is necessary to assess environmental impacts of such changes (Giri et al 2005). Thus, in this thesis an attempt has been made to identify the conversion of one class into the other class over a time span of 1985-2018 to detect the changes taking place in the study area.

Apart from studying the water quality as well as the LU /LC pattern of the study area, the change in volume of the reservoir due to deposition of sediments at the bottom of the reservoir was also evaluated which can be attributed from the change in LU/LC pattern studied in this research work.

1.6 Importance of Volume Estimation of Reservoir

Lakes or Reservoirs are a source of freshwater and make it accessible for domestic, industrial, hydropower generation. The process of water reservoir siltation causes worldwide the annual loss of the reservoir storage capacity in the range of 0.5-1% of the total storage capacity (White 2010). Govind Ballabh Pant reservoir is Asia’s largest man made reservoir with a catchment area of 13,333.26 km^2. The reservoir was constructed in the year 1950s with an initial mission to provide water for the industrial activities present in the vicinity of the area. Regular and accurate monitoring of water storage variations in lakes and reservoirs is essential for equitable water allocation to water use sectors, ecosystem services and for better understanding of various agents impacting its volume (Crétaux et al 2011). It is not feasible to measure fluctuations in volume of the reservoir from the inflow or outflow to the reservoir through streams, rivers, etc., hence making the use of direct measurements through various techniques such as in-situ monitoring or bathymetry maps etc. is recommended (Duan et al 2013). In this context, satellite imagery data provide more accurate water levels (Duan et al 2013). These satellite monitoring techniques are more satisfactory in extracting surface water extent than any other in-situ techniques. These satellite data are relatively less time consuming and cheap with repetitive coverage at a relatively high resolution than the survey conducted by aerial photography for large area coverage. In this category, analysis of reservoir volume through ASTERGDEM is also one of the most effective techniques using elevation models. In this study, the volume of the reservoir was estimated over a time span of 1998-2018 for four different years i.e. 1998, 2013, 2016 and 2018 on the basis of relatively same rainfall during these years using Triangulated Irregular Network method from ASTERGDEM data and direct linear interpolation.

1.7 Remediation of Water Pollution

And lastly, the management of water contaminants at one of the source i.e. Balia Nala which was pouring the effluent released from mining industries directly into the Govind Ballabh Pant Reservoir was done with the help of experimental set up shown in the preceding chapters. As the presence of contaminants in water bodies are unfit for human consumption, industrial, domestic or agricultural use, its proper remediation to arrest these contaminants becomes necessary. The legacy of the removal of contaminants released from industries has been inherited from the last few decades which serves as an aspiration for present research. Traditional remediation strategies involve dosing of chemicals for the treatment of wastewater. Such approaches involve high operating cost (Saeed et al 2018). In addition, the dosage rate of the chemicals were difficult to determine without trial and error due to significant variations in wastewater characteristics, geographic locations and environmental conditions (Saeed and Sun 2012). Immobilisation or extraction by physicochemical techniques can be expensive and is often appropriate only for small areas where rapid, complete decontamination is required (Martin et al 1996). Conventional chemical treatment options include chemical processes involving the addition of chemical neutralizing agents or oxidizing agents (RoyChowdhury et al 2019). These chemicals are expensive and result in the formation of large volumes of sludge that is difficult to dispose off (Mokolobate et al 2002). Hence, a sustainable, effective and economical remediation technology should be adopted to address the water quality degradation problems. In this context, phytoremediation acts as a source of green renewable energy, sustainable and cost effective treatment for combating the pollution caused by discharging of wastewater. Nutrients and other constituents are absorbed by macrophytes which grow on the submerged surface of the floating mats and plant roots (Li et al 2010; Song et al 2011). Invasive aquatic vegetation often colonized freshwater aquatic habitats where velocity is low thereby acting as a problematic invader but these aquatic species can also act as a potential supplemental treatment practice for wastewater treatment. This study shows the treatment of wastewater with water hyacinth and common reed creating changes in water quality that are detectable when compared with initial data that has been collected at a particular time period in combination with sandstone filtration system. This experimental approach helped us to detect the effect of presence as well as treatment while accounting for changes in water quality that occurred over the course of 15 days of the study. This experimental set up makes control efforts, crucial for maintaining the socio-economic and ecological functioning of the environment.

1.8 Objective of the Study

The large water bodies located near the coal mines receive mine effluents particularly in rainy season. Beside this, there are other sources of pollution (thermal power plants, chemical industries, aluminium industries, etc.) which are responsible for decreasing the water retaining capacity of reservoir along with quality. The reservoir is a big water body catering the irrigation requirement and industries near and away from the reservoir. After going through literature, a little work has been attempted to minimize the impact of industrial activities around the reservoir. Hence, in this thesis an attempt has been made to assess the water quality of the reservoir and the various sources responsible for deterioration of reservoir. It has been considered that following factors have bearing on water quality and water retention capacity of the reservoir.

(i) Quality assessment of surface water

(ii) Land Use impact

(iii) Estimation of volume of reservoir and

(iv) Suggestive measures

Therefore, the objective of the research is **to assess the impact of coal mining on the water quality of the Govind Ballabh Pant reservoir and to suggest management in order to protect the quality and volume of the water**. To achieve the above objective following studies have been carried out:-

1) Qualitative assessment of surface water of study area during pre and post monsoon season by using Water Quality Index (WQI) along with multivariate statistical analysis.
2) Preparation of Land Use Land Cover Map of Study area for different years.
3) Estimation of Volume of the reservoir over a time span of 20 years.
4) Mitigating the quality of water at one of the major sources of pollutant entering into the reservoir using Phytoremediation.

Thus, this chapter provides the background and importance of the research work carried out later in this thesis. A detailed literature review of past studies related to the objectives enlisted in the thesis is elucidated in the next chapter.