CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Water touches every aspect of life. It is an essential and fundamental source of life and encourages economic growth, a healthy ecosystem, and social development. Industrialization, urbanization, land use, and other anthropological activities are leading to pollution and climate change. The demand for freshwater is rapidly increasing for sustainable life and development, and enormous demand and supply of water is leading to water scarcity.

Climate change leads to variations in precipitation, evapotranspiration, temperature, humidity, etc. The difference in the spatial distribution of precipitation leads to inequality in water distribution; consequently, some areas are getting inundated due to floods. Some of the regions have a significant reduction in the water table, leading to scarcity of water. The higher surface runoff increases the soil erosion due to raised rainfall intensity leading to higher sediment load in rivers. Thus, the river's disturbed sediment load equilibrium leads to flood and drought due to changes in the sediment transport process. The changes in the sediment transport process affect the cross-sectional profile and width, bed profile, meandering pattern of the river, scouring of hydraulic structures, navigation, and watershed over the period.

The river system is essential for lives. Freshwater is substantially unavailable on the earth's surface, and the river is a primary source of freshwater. Soil erosion, entrainment,

transport, and deposition are the necessary processes in the river system; these processes have a considerable effect on the nature of the river and consequently work on the sediments. Erosion and deposition have severe impacts on the scouring of the bed and resultant change to morphology of the riverbank. These processes also lead to meandering and shifting the course of the river, affecting the stability of different structures constructed over or near the river like the dam, bridges, houses, etc. Figure 1.1 shows the photographic view of the collapse of a house built near the riverbank. The collapse of the building was taken due to excessive erosion during the flood in 2019. The riverbed level heaved up due to sediment deposition. Excessive deposition caused an interruption in the river flow, leading to a change in its course and causes a change in the river flow direction. Transportation of sediment depends upon the flow characteristics of the river and the characteristics of sediment load. The sediments load is less desirable for some structures like a reservoir or dam, hydropower and leads to measure distractions. Therefore, understanding the processes related to sedimentation in the river is essential.

Figure 1.1 The collapse of building constructed near the riverbank

The river Ganga is India's most prominent and holy river and has the largest basin of 10,86,000 km2. The Ganga basin aligned between coordinates 73°02'E and 89°05'E and 21°06'N and 31°21'N. It travels through India, Nepal, and Bangladesh, and 79 % of the basin lies in India. Further, it covers 23% of India's land area and supports 46% of the Indian population. The Ganga also acts as a lifeline for the cities of north India like; Haridwar, Kanpur, Prayagraj, Varanasi, and Patna. Uttar Pradesh is one of the populous states of India, and most of the cities lie on the bank of the river Ganga. Varanasi is one third largest city of Uttar Pradesh and situated at the bank of river Ganga. Varanasi is known as the pilgrimage city of India and having a major tourist attraction in the country. The population of Varanasi is approximate 1.2 million and has 80 bathing Ghats. One of the ghats shown in Figure 1.2. Varanasi City has observed frequent floods in recent times. The severe flood at Varanasi was observed in 2013 after 1978, and the same was repeated in 2016. Henceforth, the understanding of the sediment transport process is essential.

Figure 1.2 Ghats of the river Ganga in Varanasi

Anthropogenic activities are generating different types of pollutants. Many of them cause water pollution. In a country like India, it is common practice to discharge polluted water in the stream like; river, which polluted the river water and affects the ecology of the river. It also affects the humans and aquatic life, fishers, and pilgrims. Varanasi is a major pilgrimage attraction center in India and has a large population; therefore, it has high water demand. It also generates a considerable amount of wastewater. This wastewater is being discharged in Ganga majorly without purification treatment. Therefore, the proper management of polluted water is essential.

1.2 SEDIMENT TRANSPORTATION PROCESS

Sediment transport dynamics are very complex phenomena, and the estimation of sediment transport of any river is essential to define river behaviour. The quantification of the physical process of sediment transport is the most significant interest area of researchers. In the meandering river, erosion occurs in a concave bank, and deposition occurs on the convex side, as shown in Figure 1.3. The thalweg shows the lowest point or lowest depression along the river. It is essential to know the lowest bed profile of the river.

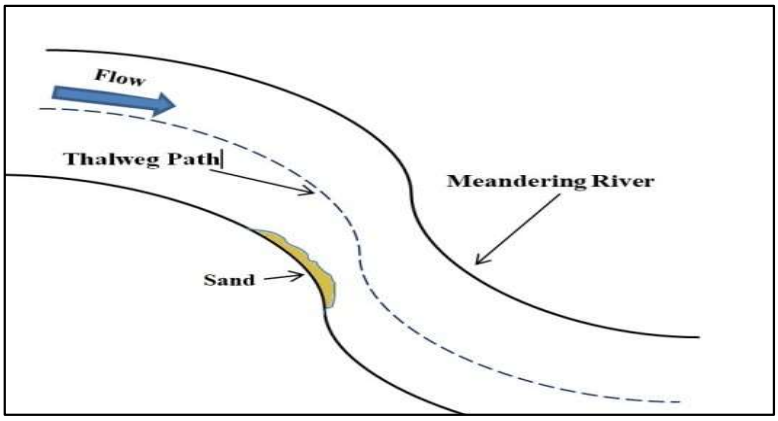

Figure 1.3 Meandering river with thalweg path

Distribution of sediment transport estimation along with different depth and banks for the alluvial river is necessary for hydraulic structures and river habitat. Therefore, the understanding of this complex behaviour is essential.

The whole basin contributes sediments to the river. The characteristics of sediments of any basin depend upon their size, shape, concentration, etc. The river erodes or transports gravel-sized particles in the upper reach and high flow conditions. While in the middle or lower reach, the smaller size can be carried by the river.Sediment transportation takes place in four ways as rolling, saltation, sliding, and suspension. The sediment gets transported by the rolling or sliding process near the bed. The grains of soil remain suspended when the magnitude of vertical force due to turbulence velocity becomes higher than downward force. River water carries a lot of sentiment with it, and when its speed slows down, it starts depositing the sediment on the convex bank. The river Ganga deposited sand on a convex bank at Varanasi, as shown in Figure 1.4. This sand deposition covers a 3 square kilometre area. The characteristic of basin-like geomorphology and land uses, etc., affects the sediment yield. The land cover with vegetation contributes to lesser sediments than barren land or land without vegetation. Due to urbanization, the sediment yield is affected significantly nowadays.

Traditionally, the flow velocity is measured by a current meter connecting cable and anchored with a boat to apply the area-velocity method for discharge measurement. (Smith and McLean 1977; Kostaschuk and Villard 1996). However, the Acoustic Doppler Current Profiler (ADCP) was used for velocity measurement to estimate the discharge in the case of a large alluvial river. An additional feature of this tool is that it provides backscatter data, which is helpful for the estimation of suspended sediment concentration (SSC). The

acoustic technique of ADCP was developed for the marine study (Reichel and Nachtnebel 1994) for the ocean, sometimes multiple frequencies instrument of order one MHz used to estimate SSC for a short-range (Hay and Sheng 1992; Thorne and Hanes 2002).

Figure 1.4 Sediment deposited at the convex bank of river Ganga near Varanasi

However, ADCP is also beneficial for the riverine study, i.e., to estimate SSC in the riverine environment. Various researchers used a bedload sampler to estimate bedload (Klingeman and Milhous 1971; Ryan and Porth 1999). On the other hand, the estimation of SSC is essential to know the dynamics of sediment transportation for any river system (Reichel and Nachtnebel 1994; Lane et al. 1997; Alvarez and Jones 2002). The mechanical sampler and acoustic sampling technique are used commonly to know the dynamics of sediment transportation for any river system . In the mechanical sampler, some sampling of sizeable vertical depth gives the more precise and accurate result (Gray et al. 2008; Gray and Simoes 2008; Topping et al. 2011). Meanwhile, these techniques are too labour and

time-consuming. The ADCP used to measure the bed profile, velocity, discharge, and backscatter (Admiraal and Demissie 1996; Wewetzer et al. 1999; Kostaschuk et al. 2004), as it is a valuable tool for estimating SSC for any large river (Latosinski et al. 2014). A professional instrument, like ADCP, provides quantity estimation of SSC along the river section in terms of backscatter. The conversion of backscatter intensity to the mass concentration of sediment is complicated and depends on multiple factors like grain size, sediment density, temperature, and pressure. On the other hand, instrument characteristics like the size of the transducer, power, and various frequency instruments also affect the estimation.

1.3 POLLUTANT FLOW IN RIVER

Pollution of river water is increasing day by day due to industrial activities and population growth. Urbanization is generating enormous waste and polluting the river. River water pollution causes many ecological and environmental problems. Such problems have greater risk over human life and the life of other living organisms. The major pollutant point source connected to the river at Varanasi, as shown in Figure 1.5. The economic loss also takes place due to the polluting of the river water. Therefore, the loss of river water quality caused by pollution and understanding the extent of the pollution level is essential. Pollutant transport behaviour of a river depends upon two factors: the hydrodynamic behaviour of the river flow and second, on the characteristic of the pollutant (Mazumder and Dalal 2000). The sewage water (wast water) discharged into the river in the larger cities like Varanasi. The wastewater contains different types of impurities or pollutants. The dilution takes place through the diffusion process after mixing the pollutants with sewage in the river. The drinking water supply system primarily relied on river water in such large

cities. Pollution of water causes drinking water issues and affects the lives nearby the river. The diffusion gets affected by the river flow and flows from the sewerage system in the larger river like Ganga. Understanding the extent of the pollutant flow and its flow behaviour is essential to managing safe human activity to minimize the pollutant impact.

The river Ganga is the lifeline of Varanasi as it is situated on the bank of the river. Different economic, social, cultural, and religious activities of the city depend upon the river Ganga. Various activities have taken place at the Ghats of the river Ganga in Varanasi. Any effect on the river Ganga flow can influence the lives of the people in the city. Change in sediment behaviour, pollutant mixing due to human activities, etc., can cause the difference in the flow of the river Ganga. Therefore, the study of different parameters which impact the flow behaviour of the river Ganga is essential.

Figure 1.5 Sewage discharge in the river

1.4 OBJECTIVES OF PRESENT STUDY

The primary objective of this research work is to study the sediment transport behaviour and its modelling along with pollutant transport dynamics. The specific objectives of the study are:

1. To model the sediment yield of the river Ganga basin near Varanasi through the SWAT model.

2. To study the sediment transport of river Ganga by measuring sediment concentration with the help of ADCP.

3. Modeling of the sediment transport of river Ganga near Varanasi through HEC-RAS.

4. Computational Fluid Dynamics (CFD) modelling of the pollutant transport dynamics in river Ganga through ANSYS.

1.5 ORGANISATION OF THESIS

The various chapters of the thesis have been organised in the following manner :

Chapter 1 is introductory, which deals with the background study of the sediment transport and pollutant transport processes, the study scope, objective and organisation of the thesis.

Chapter 2 gives an overview of the relevant literature review on sediment transport modelling and pollutant transport modelling. The review has been conducted on watershed sediment modelling, identification of sediment transport study, review on sediment transport modelling, pollutant dynamics. The existing gaps in the study of model the

sediment transport behaviour of river Ganga and pollutant dynamics behaviour of river Ganga has been discussed in this chapter

Chapter 3 deals with the complete details of the study area, data selection for modelling, pre-processing of raw data and software used for modelling.

Chapter 4 deals with the methodology used and results and discussions of the modelling done to estimate the river Ganga basin sediment yield near the Varanasi. The input data used for modellings, including DEM, Soil Map, LULC map and Metrological data, have been discussed. Hydrological Response Units (HRU) analysis and the SWAT analysis have been done. In addition, the results and discussion for the model's outcome have also been presented.

Chapter 5 deals with the methodology used, results and discussions on the analysis of the sediment concentration obtained from the ADCP on the different cross-sections near Varanasi. The result and discussion from the field survey, calibration, validation of sediment transport behaviour has been presented.

Chapter 6 is presented the methodology used, results and discussions. The acquired data from DEM, metrological and hydrological data sediment data has been delivered. The results of sediment modelling obtained from direct measurement results and the HER-RAS is presented and discussed.

In **Chapter 7,** the methodology used, results and discussions are presented. The pollutant transport model and related mathematical formulation, assumptions, governing equation

and boundary conditions have been discussed. The result obtained with the help of CFD modelling is presented and discussed.

In Chapter 8 summary of the study and essential conclusions drawn are presented. Also, the scope of future research is presented in this chapter to provide better insight into the related research area.