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Level of antibiotic contamination in the major river systems: A review on South Asian countries perspective

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ABSTRACT

Antibiotics are medicines used to forestall and treat bacterial infections. They work by killing the bacteria or by making it difficult for them to develop and multiply. Various types of antibiotics were used worldwide. Due to their partial metabolization inside the body, the leftover antibiotics are discharged into rivers, seas, and oceans without pre-treatment. There are different sewage treatment plants available for antibiotics removal but these are not used efficiently. This review gives insight into the presence of different antibiotics in rivers of major south Asian countries. The area is thus chosen due to the increase in the annual consumption of antibiotics. The study includes five rivers of India named Kshipra, Musi, Ganga, Yamuna, and Gomti; two rivers of Sri Lanka named Kelani and Gin and one river each from Nepal and Bangladesh named Bagmati and Brahmaputra. The amount of antibiotics present varies from country to country and from river to river. The current review will therefore showcase the most prominent antibiotics found in these water sources.

INTRODUCTION

Antibiotics are used in inhibiting or killing the growth of microorganisms by disturbing their metabolic activity. They are generally semi-synthetic, synthetic, or natural in origin. Antibiotics are designed in such a way that they help in combating bacterial and fungal infections in biological systems. Therefore antibiotics are classified as biologically active molecules with antifungal, antibacterial, and antiparasitic properties. Penicillin was the first antibiotic discovered by A. Fleming and was efficiently used worldwide for treating human and plant diseases caused by various pathogens. The consumption of antibiotics across the world is increasing day by day due to its enormous intake to battle upcoming infections. The intake of animal protein has increased over years. This will in turn escalate food production that requires more usage of antibiotics (Anh *et al*., 2020). Antibiotics are also used in livestock and plant growth. The antibiotics are metabolized partially by the digestive tract of humans and animals. These antibiotics are further discharged in the community effluents that end up contaminating water bodies (Chen *et al*., 2018). Due to the widespread use of antibiotics across the world, the contamination of the natural environment is speedily escalating. The improper treatment of wastewater leads to the evolution of antibiotic-resistant genes, and antibiotic-resistant bacteria in different water bodies worldwide (Singh *et al*., 2019). There are plenty of other sources, such as wastes from hospitals, sewage treatment plants, and wastes of unused drugs that contribute to the environmental burden of antibiotics (Khan *et al*., 2013). The effluents from these sources are directly discharged into rivers, seas, and lakes without any pre-treatment. These further form sediments in water bodies. There is an increase in the number of antibiotic-resistant genes in the environmental water bodies due to horizontal gene transfer mechanism, recombination, and gene mutation. (Devarajan *et al*., 2016).

TYPES OF ANTIBIOTICS USED

The widespread usages of antibiotics in the world are of the following types-

Fluoroquinolones—they were discovered and clinically approved in 1962. The most common one is ciprofloxacin. They

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work by inhibiting the synthesis of DNA and also by inhibiting topoisomerase IV and DNA gyrase activities.

Tetracyclines—they were discovered and clinically approved in 1948. *Streptomyces aureofaciens* is the microorganism responsible for the production of this type of antibiotic. The most common is the tetracycline antibiotic. They work by targeting the synthesis of protein and inhibiting the activity of the 30S ribosomal unit.

Aminoglycosides—they were discovered in 1944 and clinically proven in 1946. The most common one is kanamycin A antibiotic that is produced from *Streptomyces kanamyceticus* microbe. They generally work by targeting the synthesis of proteins (Kovalakova *et al*., 2020).

Penicillins—they were discovered in 1929 and clinically proved in 1943. *Penicillium chrysogenum* is the microorganism that is used to produce amoxicillin which is a derivative of penicillin. This class of antibiotics works by targeting proteins that bind penicillin and also by synthesizing cell walls (Hutchings *et al*., 2019).

Cephalosporins—Cephalosporins were discovered in 1948 and proven clinically in 1964. Cefacetrile is a semi-synthetic derivative. They work by targeting the synthesis of the cell wall and binding penicillin proteins (Abramova *et al*., 2020).

SOUTH ASIAN COUNTRIES

In India, sewage treatment plants are not enough to remove antibiotics. The residues of antibiotics were seen in various rivers of India. In 1980, England reported the first case of contamination of surface water by antibiotics. Tetracycline and sulfonamide group of antibiotics were detected at a concentration of 1 µg l^{-1}. Previously, India reported the highest levels of ciprofloxacin at a wastewater treatment plant in Hyderabad (Mutiyar and Mittal, 2014). Due to the growth of the population, the use of antibiotics in Asian countries had been a great challenge. The usage of unregulated antibiotic had been doubled between 2000 and 2015. To check the antibiotic availability in the rivers of India, Indian National Action Plan on antimicrobial resistance (AMR) was declared (WHO, 2008). Rivers are considered to be the medium for the spread of antibiotic resistance bacteria(Kumar *et al*., 2020a, 2020b).

In this study, the rivers of South Asian countries: India, Sri Lanka, Nepal, and Bangladesh were taken into consideration. The geography includes the Indian Ocean to the south and the Himalayas, and the Karakoram mountains to the north (Billah, 2019). South Asian countries occupy 3.5% of the world's land area. The region of South Asian countries is considered to be the most populated ones, and due to this the zones are known as the water-stressed zone of the world (Mukherjee, 2018).

The annual consumption of antibiotics in South Asia has increased in recent decades. The usage of antibiotics in India was 6.5 billion in a year, in Pakistan was 1.3 billion in a year, Sri Lanka was 1.4 billion per day, Nepal 15.54 doses per day, and Bangladesh was 16.34 doses per day (Klein *et al*., 2018) (Fig. 1).

SOUTH ASIAN COUNTRIES ALONG WITH THE RIVERS

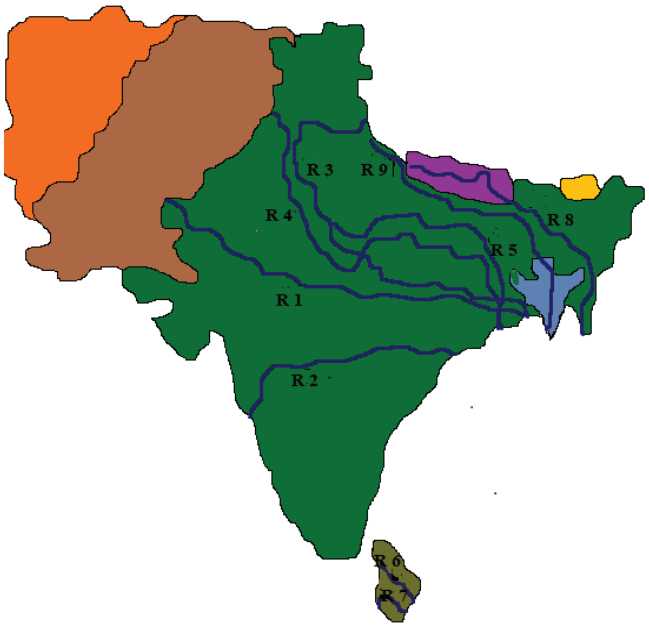
India

It is located in the South region of Asia with a large population of 1.3 billion people. In the 1970s green revolution was started in India to enrich the production of food. But the groundwater started to decline which increased pollutants disturbing the ecological balance of the environment (Pingali, 2012). With the advancement of pharmaceutical companies in India, during production activities, different types of pollutants were released. These released contaminants can deposit in water bodies released by pharmaceutical industries. These small water bodies then lead into rivers, seas, and then oceans. The antibiotics present in aquatic bodies were one of the most prominent issues in the ecological disturbance. Even, when antibiotics were consumed by humans, their metabolism is partial and can easily enter different sources of water bodies. The residues of antibiotics can adverse conditions that lead to the formation of antibiotic-resistant bacteria (Purohit *et al*., 2017).

In India, many rivers are used for various purposes and play an important role in the economic growth of the country. In this country, many holy festivals are celebrated near rivers that include lots of gatherings. A very high amount of antibiotic residues is seen in some of the rivers (Zhang *et al*., 2009). Some of the rivers where contamination of antibiotics is on large scale are as follows-

Kshipra river

It is a river situated in the central India state Madhya Pradesh. The word Kshipra means a symbol of purity. The river rises in the hills of the Vindhya range which is located to the north of Dhar. The river flows north toward the Malwa plateau to join



R1- Kshipra River	R6- Kelani River
R2- Musi River	R7- Gin River
R3- Ganga River	R8- Bagmati River
R4- Yamuna River	R9- Brahmaputra River
R5- Gomti River	

Figure 1. Map showing major river systems of South Asian countries.

other rivers (Diwan *et al*., 2018). The water of the Kshipra River ranges from medium to bad quality. Many rural livelihoods sustain on the water of this river. Even Simhastha Mahakumbh Mela organized after every 12 years is hosted near to Kshipra River. Many devotes came from all over the world to bathe in this sacred river (David and Roy, 2016).

The level of antibiotics and antibiotic-resistant bacteria in the Kshipra river has shown a tremendous increase in the past few years. River water collected during four seasons of the year was tested for total dissolved salts, pH, the temperature of the water, quantity of dissolved oxygen, the quantity of carbon dioxide, alkalinity of carbon, and conductivity parameters. There were several tests performed in the laboratories including biochemical oxygen demand, chemical oxygen demand, total phosphorus, and total suspended salts. The hardness of water, turbidity, chloride, and phosphorus content was also measured. The main test was to check the level of antibiotics and their residues. The main antibiotics found in the geographical region of Madhya Pradesh were norfloxacin, ceftriaxone, ciprofloxacin, metronidazole, ofloxacin, and sulfamethoxazole (Diwan *et al*., 2013).

The water samples taken were homogenized and further filtered through membrane filter paper with a pore size of 0.45 µm. To adjust the pH of the sample, sulfuric acid was added. The sample after pH adjustment was added to an activated C18 cartridge which was composed of methanol and acidified water in a fixed proportion. The prepared solution was evaporated for the process of drying in nitrogen gas. The detection of antibiotic residue was done by liquid chromatography and mass spectrometer with different proportions of antibiotics and water samples. The isolation of *Escherichia coli* in colony-forming units (CFUs) was estimated as resistance to the above-mentioned antibiotics.

In Kshipra River water and its sediments, four types of antibiotics were detected. The amount of sulfamethoxazole was in a much higher concentration of 2.75 µg l^{-1}. The concentration of ofloxacin was 0.99 µg l^{-1} and the concentration of norfloxacin was 0.66 µg l^{-1}. The resistance of antibiotics in percentage values was ampicillin in 33%, sulfamethizole in 25%, tetracycline in 29%, cefotaxime in 46%, gentamicin in 5%, meropenem in 28%, and imipenem in 5% (Diwan *et al*., 2018).

Musi river

It is a tributary present in the Krishna River of the Deccan Plateau that flows in the state of Telangana, India. The terrain of this river is rocky and the river originates in the Anantagiri Hills in the city of Hyderabad. There are two dams constructed over it namely Himayat Sagar and Osman Sagar that help to meet the demand for drinking water in the city. There are many industries nearby to it, mainly pharmaceutical industries and drug units. The short sewage plants all over the cities join the major river through various inlets and outlets. The water present in the river contains different types of metal contaminants such as mercury, cadmium, zinc, copper, molybdenum, arsenic, lead, copper, and cobalt. The analysis of these metals was done via spectrometry analysis. Dissolved oxygen, nitrogen, pH, temperature, and total dissolved solids were also measured.

Serial dilutions were performed in the water sample. These serially diluted samples were then placed on agar medium plates with some amount of ciprofloxacin antibiotic. The resistance levels of bacteria were checked by changing the concentration of the antibiotic. The Petri dishes thus prepared were incubated at a certain temperature in an incubator for a specific time and then at room temperature in the dark such that antibiotics were not degraded. After the incubation period, CFU was determined with antibiotics of different concentrations.

The total amount of fluoroquinolone type of antibiotic was measured in the river water sample prepared. The concentration of ciprofloxacin was much higher in the sample with an amount of 5.528–6.59 µg l–^{1}. The next antibiotic found was ofloxacin with a concentration of 1.55–318 µg l^{-1}. Followed by enrofloxacin with a concentration of 2.57–123.4 µg l^{-1}, then comes perfloxacin with a concentration of 0.74–44.34 µg l^{-1}. Next comes difloxacin with a concentration of 0.47–37.4 µg l^{-1} and lomefloxacin with a concentration of 3.59–10.32 µg l^{-1}. Apart from antibiotics in river water, heavy metals, other dissolved salts, and other pollutants were also present. Arsenic, mercury, and cobalt were the highest metal contaminants present in Musi River water, followed by zinc, chromium, and copper in the river water.

The river is highly polluted in urban areas and cities. As the flow of water mixes with the Krishna River, dilutions make it less contaminated. Ciprofloxacin antibiotic concentration was seen to be highest due to more usage by people in urbanized localities and due to more usage, the production of this antibiotic is on a large scale which directly causes pollution of water. Fluoroquinolones are a type of antibiotic that is synthetic and help in the treatment of urinary tract infections. This polluted water is unsafe for drinking purposes and also for global public health (Gothwal and Thatikonda, 2017).

Ganga river

This river originates from the glaciers of the Himalayas in Uttarakhand that forms the Ganga River Basin. It covers a much larger area that extends over Nepal, India, and Bangladesh. Almost 11 states of India use the water of the Ganga that includes Haryana, Uttar Pradesh, Rajasthan, Bihar, West Bengal, Uttarakhand, Delhi, Chhattisgarh, Jharkhand, Himachal Pradesh, and Madhya Pradesh. From hills to planes, many industrial effluents from industries and other wastes were released and discharged into the river which leads to pollution and other major problems. About 40% of the people live on the banks of the river Ganga. It is one of the most congested basins that have a much higher amount of population supporting many people with their essential needs of drinking, washing, and other purposes. The pollution level of the Ganga River has always risen, especially during the Kumbh festival that is celebrated in this holy river. Even in the year 2013, it was made clear that due to the increase in the level of contaminants in the Ganga, the water was not suitable even for bathing purposes. Millions of foreign visitors came every year to take bath in this festival (Chakraborty *et al*., 2018).

According to the research finding, it was found that the contamination takes place due to distilleries, tanneries, paper mills, sugar mills, and pharmaceutical companies, especially in the areas of the above-mentioned states. There is no well-organized and planned sewerage system to lift the pollutants and the effluents produced by these industries and also the domestic sewage, discharge from restaurants and hotels too. These in the end lead to the Ganga River. On the ghats of holy cities like Haridwar,

Varanasi, Patna, Allahabad, Delhi, and Kedarnath, pollutants like flowers, idols, and ashes are thrown into the river which directly leads to the pollution of water.

Antibiotic resistance uses antibiotics in high amounts in treating infectious diseases that cause loss of humans, foods, plants, and animals that causes loss of economy all across the world. They are responsible for many diseases like typhoid, gonorrhea, tuberculosis, and pneumonia. Many bacteria became resistant to some of the antibiotics like ciprofloxacin, tetracycline, ampicillin, and erythromycin. In bacteria, resistance to antibiotics is interlinked by processes like the inactivation of drugs, efflux of drugs, and modification of ribosomes (Kumar *et al*., 2021).

Samples from the river water Ganga were collected from various sites. These samples were collected from the region where wide activities like effluent discharge, bathing of animals and humans, drainage openings of large cities, and wastewater discharge from pharmaceutical companies take place. Some of the samples work on the activated sludge process and some of them work on the batch reactor process. The initial treatment was done using filtration by physical means and the rest of the treatment was done using biological means.

Dissolved oxygen, biological oxygen demand, and chemical oxygen demand were calculated, and were found that the concentration of chemicals was found in more amounts as compared to others. The pH of river water was neutral. The average biological oxygen demand was found to be between 0.86 and 4.55 μg l^{-1}. Many types of organic matter, suspended particles, clay particles, and turbidity also plays a vital role in the absorption process of personal care products present in river water (Singh and Suthar, 2021).

Yamuna river

Antibiotic resistance genes found in bacteria increase the risk of the spread of antibiotics in water. These bacteria proliferate at a rapid speed which leads to an increase in drug-resistant bacteria. Human health has been affected severely. The antibiotic-resistant bacteria have been found in the tap water of New Delhi. Different strains are detected from the water coming from the Yamuna river. This river is the main deposition center as all the untreated discharge comes from different sources that contaminate the river water. About 40% of the wastewater was treated in Delhi and the leftover 60% was directly discharged into the river without any type of treatment methods. This shows the number of antibiotics discharged inside the Yamuna river which was left untreated (Lamba *et al*., 2017). In addition to antibiotics, there were other contaminants like pesticides, detergents, and heavy metals that also help increase antibiotic resistance. Delhi has a stretch of river Yamuna that has discharged agriculture, domestic, and hospital pollutants. Yamuna river includes arsenic and mercury that helps bacteria in the accumulation of metallic constituents which were present in bacterial plasmids or chromosomes. River Yamuna is a tributary of river Ganga. It stretches over 22 km in the Delhi area itself. The sampling of water was done in this stretch of 22 km (Azam *et al*., 2018).

Samples from the river Yamuna were collected from different sites in Delhi. Different sites include industrial areas, residential and domestic purpose areas, agricultural land areas, and other unauthorized access areas. From all the directions of Delhi including north, south, east, and west, samples were taken. From the drains of this river, samples were also taken including other sediment sample sites. These samples were collected in sterile containers and were stored in refrigeration at 4°C. Within 12 hours of sampling, analysis of microbes is done and extraction of DNA is performed within 24 hours of a water sample taken from sites. Other parameters including conductivity, total dissolved salts, pH, and temperature were measured using different instruments.

Other than these parameters, microbial testing of fecal and total coliform testing was done. These were specifically done in selective media obtained from Himedia. On agar plates, streaking was done and incubation for 24 hours was done. Different types of strains were used for further analysis of tests (Siddiqui *et al*., 2020).

More concentrations of antibiotic-resistant bacteria were observed. The concentration of different antibiotics was also taken into consideration. Eight types of antibiotics had been detected. They were tetracycline, glycopeptides, aminoglycosides, beta-lactams, macrolides, sulfonamides, trimethoprim, and chloramphenicol in the surface water of river Yamuna. The amount of tetracycline was present in drinking water too.

Gomti river

Gomti river is a tributary of the river Ganga. It covers an area of 960 km in the state of Uttar Pradesh. It meets river Ganga at Varanasi city. Antibiotics are present at most levels as a matter of discharging animal wastewater and also from urbanized cities. Inside the water, antibiotic-resistant genes are transferred using the transformation methods of bacteria. The main sources of pollution in river Gomti are sugar-making factories, distillery units, and wastewater coming from domestic and other residential areas. These also affect the life of aquatic flora and fauna (Goel, 2015).

Water was collected from three different sites of the Gomti river along the bridges. Inside polypropylene plastic bottles, the sample was taken and kept at 4°C till the samples reach laboratories. Using the plate dilution method, the concentration of antibiotics was found. Varying concentrations of antibiotics that range from 2 to 100 μg l^{-1} are taken. Inside the nutrient agar plate, these antibiotics were supplied to it. Now looping was done such that the inoculation of microbial cells was done properly. These agar plates were then incubated at a temperature of 37°C for a time of 24 hours.

Five antibiotics namely amoxicillin, ciprofloxacin, tetracycline, erythromycin, and penicillin were obtained in varying concentrations. The drug-resistant coliform bacteria helps in the detection of fecal pollution in the water of river Gomti at Lucknow, Uttar Pradesh. On sites 1 and 2, the concentration of antibiotic erythromycin was more, then followed by ciprofloxacin, amoxicillin, tetracycline, and penicillin. But in site 3, the trend was different that includes ciprofloxacin first and then followed by other antibiotics (Akhter *et al*., 2014).

Sri Lanka

Sri Lanka is a pear-shaped island present in the Indian Ocean that is 18 miles from India. The island consists of two main sections which are divided into the south-central region of mountains and southwestern coastal plains. It has the largest harbor in the world and handles foreign trade work. The vegetation of Sri Lanka is of dense quality that is particularly in the south and west

coasts. Antibiotics are used in preventing diseases that are caused by various types of viruses and bacteria. They are used in the treatment of infectious diseases in veterinary and human diseases. The antibiotics were dispersed inside the environment that affects human health and other types of flora and fauna (Samaraweera *et al*., 2019)

The private hospitals and the frequency of infectious diseases are serious problems in developing countries like Sri Lanka. The impact of using antibiotics and disposing of the antibiotics in the river of Sri Lanka, near urban areas leads to increase in antibiotic resistance. Near urban areas, antibiotic resistance increases. The seasonal variations of antibiotics and pollution in Sri Lanka were a major polluted thing in the water. Rivers act as a medium for the spread of bacteria and the treatment of sewage and discharge points to the river is critical thing for wastewater. In Sri Lanka, the national policy on Rainwater harvesting came into force in 2005. The waste coming from urban areas was the most important waste that contributes to generating most wastewater. As with years, the population increases with time, and safe food and water shortages were the main leading issues. The presence of pathogenic microbes, other metallic things, personal care products, and other pharmaceutical products in water is a serious issue that needs to be resolved with time. Between the years 2000 and 2010, there was an increase of 36% in pharmaceutical and personal care products. The estimation also says that by the year 2030, this percentage can increase to 67%. The release of antibiotic-resistant bacteria was a serious concern (Kumar *et al*., 2019a, 2019b).

Kelani river

It is the fourth-longest river in the country of Sri Lanka. The flow of this river is from the west coast in the city of Colombo and also it flows to the other four districts before it reaches the Indian Ocean. It is considered to be the most polluted river and has an annual average rainfall of 2,400 mm. About 80% of the people of Colombo depend on this river for their water source. The lower basin of river Kelani is densely urbanized due to the presence of food processing industries, brewery industries, and latex and chemical manufacturing units.

The surface water was collected from the banks of river Kelani. The total dissolved salts, pH, electrical conductivity, dissolved oxygen, salinity sampling, temperature, and bicarbonates were measured using titration methods. The samples obtained from the river sites were filtered using filter paper of size 0.45 µm. Different metals were analyzed in the sample (Kumar *et al*., 2020a, 2020b).

For finding antibiotics, river water was taken in centrifuge tubes and was further transported to the laboratory for further sampling so that these samples could be preserved in microbiological conditions. The extraction of DNA was done from the sample and the number of samples was measured by absorption ratios at a certain wavelength. The genes of the most common antibiotics fluoroquinolones and beta-lactams were taken. These antibiotics were mostly used by the people of Sri Lanka.

From the banks of Seethawaks EPZ of river Kelani, tetracycline and sulfamethoxazole were present in more concentration as compared to levofloxacin and norfloxacin. From the banks of Hanwella Bridge, the concentration of tetracycline was more prominent. Rakshapana and Ambhathale water intake banks also contain more amounts of tetracycline and sulfamethoxazole. So, it states that the concentration of tetracycline and sulfamethoxazole antibiotics was found more (Kumar *et al*., 2020a, 2020b).

Gin river

It is a long river which is situated in the district of Galle in Sri Lanka. There are mountain ranges where this water can flow. The river mouth is at Gintota which flows directly into the Indian Ocean. This river is present in the Southern Province of Sri Lanka. Rivers act as a transmitter that transmits the flow and spread of various antibiotic bacteria. Effective treatment methods are required for effluent treatment methods. The overall goal is to have a sustainable water resource that is understood by the government process leading to water supply and storage (Bhagat *et al*., 2020).

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From the banks of Wakwella water intake from river Gin, the total coliform count had been counted. In the Gintota Bridge bank, the concentration of kanamycin monosulfate was much more in amount as compared to sulfamethoxazole, levofloxacin, ciprofloxacin, tetracycline (Kumar *et al.*, 2019a, 2019b).

Nepal

It is officially known as a federal democratic republic of Nepal. It is located in the indo-gangetic plain and Himalayas, to the north direction, lies the China border, and to the east, west, and south is India. The geography of Nepal has a diverse nature and Mount Everest the highest point on Earth is located in Nepal. The urban rivers of Nepal are more prone to different types of anthropogenic activities and also receive various effluents from wastewater treatment plants. The presence of antibiotic-resistant genes in these treatment plants is significantly more and is discharged into different water bodies like rivers, seas, and oceans.

Bagmati river-

It is situated in the valley of Kathmandu in Nepal and is an urban river that is polluted with untreated garbage and sewage. The flow of the river water is from north to south. This flow is passed through a heavily populated area. It flows through Kathmandu Valley and the river is fed by rainfall and is a basic source of urbanization. Bagmati river flows along the temple Pashupatinath which is a holy place for the Hindu religion. Hindu pilgrims come from all across the world to perform the bathing activity in this

river. The upstream water of the river is used for several activities for irrigation, drinking, agriculture, livestock, and industrial uses. The river had been densely polluted with more urbanization and more amount of domestic, industrial, and other waste disposals. The pollution of river water affects groundwater, surface water, and other big water bodies. The river Bagmati is a storehouse of different pathogenic viruses and bacteria. About 50% of the local people of Kathmandu is having a livelihood on the surface and groundwater for activities like drinking and bathing. Various types of human viruses like enteroviruses, adenoviruses, and other fecal bacteria were found in the water of this river (Thakali *et al*., 2020).

The water sample was collected in the sterile bottle from various sites like chover, thapathali, and sundarijal. The extracted DNA was diluted serially and the PCR process was done by adding reverse primers and thermal cycling conditions. Amplification processes were used and quantification of the method takes place.

Antibiotic resistance genes were found in the sample. Tetracycline antibiotic was found in much concentration as compared to other antibiotics. These were found in much amount as there was a supply of direct hospital and discharge from household activities. People of the valley of Kathmandu use groundwater and this water river in more amounts. The guidelines were not issued regarding the water which is polluted with antibiotics. So, human beings and other aquatic environments were affected by the antibiotics present in the river water (Aujoulat *et al*., 2021; Pantha *et al*., 2021).

Bangladesh

It is known as the people's republic of Bangladesh which is situated in south Asia. This country is in the eighth position in terms of population. The borders shared by this country include Myanmar to the southeast, India to the east, west, and north, and the Bay of Bengal is present toward the south. Bangladesh is a developing country that has a high proportion of antibiotic resistance genes and antibiotics which is a global threat. They possess a risk of mortality and economic crisis all over the world. The developing countries were affected the most due to misuse of these antibiotics, production of poor quality drugs, chronic infections, malnutrition in children, and unaffordable drugs. Many small rivers in Bangladesh are used for aquaculture activities like fishing, and poultry. These rivers contain a large number of antibiotics (Hofmeier, 2014).

Brahmaputra river in Bangladesh

The targeted antibiotics were selected. They were sulfamethazine, carbamazepine, and azithromycin. These antibiotics were dissolved in methanol and the stock, other solutions were stored under a certain temperature. The samples of surface water were collected from the Brahmaputra river in

Table 1. Level of antibiotics in the water of considered South Asian river systems.

Country	River	Antibiotics	Concentration ($\mu g\ l^{-1}$)
India	Kshipra river	Norfloxacin	0.66
		Ofloxacin	0.99
	Musi river	Ciprofloxacin	6.59
		Ofloxacin	1.55
		Enrofloxacin	2.57
		Perfloxacin	0.74
		Difloxacin	0.47
	Ganga river	Ciprofloxacin	8.62
		Ofloxacin	1.36
		Erythromycin	3.31
	Yamuna river	Kanamycin	1.00
		Ciprofloxacin	1.60
		Amoxicillin	2.00
		Ofloxacin	0.06
	Gomti river	Ciprofloxacin	1.71
		Tetracycline	1.80
Sri lanka	Gin river	Ciprofloxacin	1.71
		Kanamycin	5.43
Nepal	Brahmaputra river	Sulfamethoxazole	1.39
		Sulfadiazine	0.09
		Trimethoprim	3.06
		Sulfamethazine	1.15

Bangladesh. The samples were taken in cleaned bottles made of polypropylene that were rinsed before usage. After the samples were collected, the water sample was filtered through 0.45 µm so that the suspended particles were removed.

In the water sample, 12 types of antibiotics were found. Out of which the concentration of trimethoprim was more. Second, comes metronidazole, followed by tylosin and carbamazepine. Other antibiotics found were erythromycin, sulfadimethoxime, sulfamethizole, sulfamethoxazole, and roxithromycin. The least concentration of sulfadiazine antibiotic was found (Hossain *et al*., 2018). The presence of metronidazole antibiotic in the surface water of this river was found that this antibiotic is commonly used by veterinary and humans. Sulfonamides were more accurate and persistent in the aquatic environment as they were widely found in livestock, and poultry and used by humans in the large amount due to the low prices as compared to other antibiotic drugs (Ahmed *et al*., 2019; McInnes *et al*., 2021) (Table 1).

DISCUSSION

As the results show an increase in the consumption of antibiotics, It is important to understand the degradation of antibiotics in the environment and its effect on various aspects.

The community: Antibiotics intake from the environment through food and drinking water might upset the microbiome, particularly the stomach microbiota in the human body. It causes a hazardous effect on the health of people. Not only humans, but antibiotics can also enter the aquatic community through effluents and can cause detrimental effects.

AMR control practices: AMR is a challenge in the water environment that contributes to its spread and evolution. Human exposure to environmental AMR can happen through water and this incorporates contamination of drinking water and food which can bring about skin, gastrointestinal, urogenital, and respiratory problems.

Further Research: For further research, the results obtained can be useful. Different concentrations of antibiotics in water can help in further studies for antibiotic research. A comparison can be drawn from the previous study and the effects can be seen more prominently.

Policymakers: As the concentration of antibiotics in water is increasing from day to day, there is a strict need for policymakers and governments to take necessary steps. The results obtained in the study can be used by them to make necessary laws and practices.

CONCLUSION

Different pharmaceutical compounds were used in the treatment of various human and veterinary diseases. In recent years the consumption of antibiotics had been increased worldwide. They reach the aquatic water bodies through sewage plants and pose risks to the life of aquatic plants and animals. The antibiotics in rivers of India, Sri Lanka, Bangladesh, and Nepal were studied. Rivers of different countries were taken into consideration. The concentration of antibiotics in each river was studied experimentally. Water samples were tested and the most consumed antibiotic in the specific country was found which ultimately shows the usage of that particular antibiotic in a specific area. From our in-depth research, we found that the highest concentrations of many antibiotics were found in the main rivers of India, Sri Lanka, and Bangladesh. In India, the highest concentration of ciprofloxacin was obtained from the main Ganga River. Kanamycin is the main antibiotic that is found in the rivers of Sri Lanka. However, in Bangladesh trimethoprim is found as the main antibiotic that pollutes the river of that country. The potential impact of these antibiotics directly hampers the environment. The release can put pressure on microbes living in water, permitting them to foster resistance. These microorganisms can then impart their genes to different microscopic organisms living in wastewater and surface waters, possibly exposing humans and other animals. The results obtained in the study show the necessary monitoring of antibiotics in the environment. There are numerous benefits of using antibiotics, but the effects on the environment cannot be ignored. To improve the knowledge of the impact of antibiotic residues in the environment, there is a strict requirement to take necessary steps to avoid the latter consequences.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

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The authors report no financial or any other conflicts of interest in this work.

ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

DATA AVAILABILITY

All data generated and analyzed are included in this research article.

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