Occurrence and fate of SARS-CoV-2 and Pharmaceuticals in Ambient Aquatic Ecosystems: A review on Emerging Antidrug Resistance, Detection and Treatment Technologies

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Abstract*- the COVID-19 pandemic has brought about significant changes in various aspects of human life, including healthcare systems, medication usage, and waste management practices. As a result, an increased presence of pharmaceuticals in aquatic ecosystems has been observed, raising concerns about potential ecological consequences. This study aims to provide an overview of the effects of pharmaceuticals and SARS- CoV-2 on aquatic ecosystems. The pandemic has led to an amplified use of pharmaceuticals, such as antiviral drugs, antibiotics, and pain relievers. Consequently, the disposal of pharmaceutical waste, including unused or expired medications, has become a global challenge. Once pharmaceuticals enter aquatic ecosystems, they can exert various effects on the resident organisms and overall ecosystem health. Studies have indicated that exposure to pharmaceuticals can lead to physiological and behavioral changes in aquatic organisms, including fish, amphibians, invertebrates, and algae. Some pharmaceuticals have been shown to disrupt endocrine systems, impair reproduction, and alter growth patterns in aquatic organisms. To mitigate the environmental impact of pharmaceuticals on aquatic ecosystems, several measures can be taken. These include promoting proper medication disposal practices, implementing efficient wastewater treatment systems capable of removing pharmaceutical residues, and enhancing public awareness regarding the potential ecological consequences of pharmaceutical pollution. Understanding the effects of pharmaceutical pollution on aquatic organisms and ecosystems is crucial for implementing sustainable strategies to mitigate these impacts. The detection techniques like FTIR, NMR, RT-PCR, RAMAN, LSPR, Nano photonics sensor technique, Fluorescent based virus detection, Mass spectrometry etc. being utilized for detection of SARS-CoV-2 and pharmaceuticals have been discussed in detail.

Keywords: FINFET, Transistors, SRAM Cell, Bulk -Si MOSFET.

I. INTRODUCTION

The COVID-19 pandemic worldwide outbreak has become a major public health concern as it produces severe health threats. Fever, cough, headache, dyspnoea, diarrhoea are some common symptoms observed under this condition. The acute respiratory syndrome corona virus 2 (SARS-CoV-2) has been released by both symptomatic and asymptomatic patients (Chen et al., 2020).A positively sensed single stranded RNA covered SARS -CoV-2 virus has been associated with Betacoronavirusgenus, order Nidovirales and family Coron- aviridae. The resultant infection of this virus has been majorly identifies by respiratory disorders indicating air borne as well as droplet emanation (Chan et al., 2020). Certain proportion of COVID-19 infected patients also exhibits some symptoms of gastrointestinal disorders as well as shedding of virus in feces (Wu et al 2020, Xu et al 2020). The infection of SARS -CoV-2 could be divided into three stages wherein first stage is considered as period of asymptomatic incubation where virus may be detected or may not; in second stage symptomatic non-severe period shows viral presence and in third stage serious respiratory symptomatic stage has been found with maximum load of virus (Wang et al., 2020).

The care and management concern regarding COVID-19 give rise to several dilemmas from initial phase to present scenario. Strict adaptation of accurate public health measures for prevention and cure from COVID-19 resolve some level of hurdles and risk associated with diagnosis, intervention as well as therapies regarding pandemic (Mao et al., 2020).

The first coronavirus strain has been detected in Wuhan, China and further spread globally on rapid scale resulting as serious infectious disease after pandemic attack of influenza in 1918. The huge loss of lives has been witnessed due to the spread of COVID-19 breaking many records of the past. The normal social life is far from sight even after some relaxation of lockdown norms. Most of the countries have observed two waves of COVID-19 outbreak. The Indian context, the first and second wave was separated by 5 months. The first wave peak was observed in September 2020 with increment of 0.1 million cases per day. However, the second wave of COVIC-19 from February 2021 in India was much hazardous than first wave due to out of control situation (Iftimie et al., 2020; Ranjan et al., 2021).

Pharmaceuticals have received major attention in past years being a potential bioactive compound and they are also considered as emerging pollutants of water bodies. Their introduction in natural environment and presence in small concentration could also affect quality of drinking water, ecosystem and ultimately the human health. These bioactive compounds were present in water for decades, however, their impact and quantification has started recently by recognizing them as potential hazardous compounds for ecosystem (Rivera-utrilla et al., 2013) there are several drugs used for treatment of COVID-19 viral infection. Other than that utilization of serum from recuperated patients as they carry antibodies to neutralize the virus and help in its elimination (Keni et al., 2020). To prevent the replication of virus in SARS-CoV-2, chloroquine and hydroxychloroquine, the anti-malarial drugs have been used for treating the infection caused by corona virus, however, on larger scale the drug was not validated (Cheng et al., 2013; Sheahan et al., 2020; Tai et al., 2007). The antiviral agents like Lopinavir, Remdesivir and Ritonavir have been listed by WHO for solidarity trial. Remdesivir drug shows most promising results against COVID-19 currently. The incorporation of nucleotide analog (Remdesivir) for adenosine into RNA of virus reduce the replication process ultimately terminating the chain formation. Remdesivir was first developed for treatment of Ebola virus disease (Wang et al., 2019; Warren et al., 2016).

In order to facilitate humanity welfare and research in medical advancement field, hospitals and health centers plays very crucial role. Indian health sector worth has been expected to enhance from 140 billion U.S. Dollar to 372 billion U.S. Dollar from 2016 to 2022 (Majumder et al., 2020). Hospital and pharmaceutical wastewater contain several emerging contaminants and microorganisms including pharmaceutically active compounds, persistent viruses, antibiotic resistant genes etc. as well as higher level of chemical oxygen demand, biological oxygen demand, nitrogen and ammonia content (Verlicchi et al., 2015; Lien et al., 2016; Nielsen et al., 2013). Several nations have detected the presence of SARS -CoV-2 in wastewater, some of them are Japan (Haramoto et al., 2020), Italy (Race et al., 2020), Netherland (Medema et al., 2020), Cyprus (Michael-Kordatou et al., 2020), Ireland (Cahill et al., 2020), Australia (Ahmed et al., 2020), France (Wurtzer et al., 2020), Switzerland (Stringhini et al., 2020), Spain (Randazzo et al., 2020), USA (Peccia et al., 2020) and India. In Indian scenario, the wastewater samples containing SARS -CoV-2 has been reported from wastewater treatment plant of Ahmedabad, Gujarat and Jaipur, Rajasthan (Arora et al., 2020; Kumar et al., 2020). The presence of SARS -CoV-2 in treatment plant can be utilized as imperative tool by health experts and government bodies to investigate restriction and relaxation measures.

The quality of treated water from sewage treatment plant and wastewater treatment plant is of main public concern especially during the pandemic situation. Study reveals that caffeine could be used as significant indicator for elimination of SARS -CoV-2 from sewage treatment plants (Chakraborty et al., 2021). The pandemic situation of COVID-19 has shifted the focus of researchers and medical experts towards removal of viruses, antibiotic resistant genes and antibiotic resistant bacteria from hospital wastewater. Several removal methods such as membrane bioreactor, constructed wetlands, activated sludge method, moving bed bioreactor and advanced oxidation processes like Fenton process and photocatalysis etc. have been utilized for treatment of hospital and pharmaceutical wastewater. Most of the conventional method requires high financial input, high maintenance and operational cost are some drawbacks that should be addressed properly in order to secure public health (Majumder et al., 2020).

In this review, a thorough study of COVID-19 pandemic and spreading of infection due to SARS -CoV-2 has been done. Other than that, utilization of several medicines for treatment and enhancement of their concentration in wastewater as well as the problems associated with their presence have also been studied. The current level of SARS -CoV-2 in wastewater, their detection, and monitoring and prevention mechanism has been discussed. The occurrence and life cycle of pharmaceutically active compound in environment along with SARS -CoV-2 as emerging pollutants, their impact on environment as well as possible remediation methods have also been taken into consideration.

II. PHARMACEUTICALS: OCCURRENCE, FATE & RESISTANCE IN WASTEWATER; PRE AND POST COVID SCENARIO

The occurrence of pharmaceutical compounds in the environment has emerged as a serious health concern worldwide. Pharmaceuticals and personal care products (PPCPs) are the groups of compounds that are frequently termed emerging contaminants. Pharmaceuticals are defined as prescription, over the counter, human and veterinary curative drugs cast off to treat human and animal diseases (Boxall et al., 2012; Singh et al., 2021). These compounds are designed to have a specific mode of action, and many are persistent in the body. They have been detected in low concentrations in many countries in many environmental samples, for example sewage-treatment plant effluents, surface water, seawater, and groundwater (Weigel et al., 2002; Fent et al., 2006). The predominant pathway for entry of pharmaceuticals to the wastewater treatment plants (WWTPs) is thought to be post-consumption discharge to the sewer system and consequent passage into the WWTPs. Indeed, recent studies note that, for an individual pharmaceutical, contribution by means of discharge to the aquatic environment could be as high as 90% of the parent compound (Zuccato et al., 2005). In WWTPs, a large variety of pharmaceuticals undergo a series of reactions resulting in a complex mixture of daughter compounds (Bound and Voulvoulis, 2005; Zuccato et al., 2005) that may produce synergetic effects and become more bioactive than the parent compounds. At environmentally relevant concentrations, some of these pharmaceuticals can adversely affect phytoplankton and algal growth, can cause reproductive defects in aquatic wildlife, including sex reversals, production of intersex individuals, alterations in mating, and prevention of gonadal maturation, and can aid in development of antibiotic resistance in bacteria ('superbugs') (Diwan et al., 2010; Huber et al., 2005; Moore et al., 2010).

Advancements in medical science have dramatically increased the consumption of pharmaceuticals, particularly in developing countries due to their rapid economic expansion and steep population growth. Indian Healthcare Industry is right now assessed at USD 40 billion. The business is likely to develop to USD 280 billion by 2020 (KPMG, 2011). With expanding urbanization and issues related to urban lifestyles, disease profiles in India are shifting towards lifestyle associated diseases such as cardiovascular diseases and diabetes. Also, a change in consumption pattern of pharmaceuticals is being noticed over the course of time. Between 2000 and 2010, 36% increase in antibiotic consumption has been reported, mostly in developing countries (Van Boeckel et al., 2014).

India is among the top five producers of pharmaceutical chemicals, with an expected turnover of USD 45 billion per year by 2020 (KPMG International, 2006). The organized sector of Indian pharmaceuticals consists of around 250–300 companies, with its drug exports growing 30% annually (KPMG International, 2006). In other words, every third pill taken in the world is manufactured in India. Among the bulk formulations, around 80% have been reported to be consumed indigenously (Kallummal and Bugalya, 2012). On the other hand, treatment capacity of domestic sewage in India is far below the quantity of sewage generated from 1.3 billion people; only 31% of the total sewage produced (□38,254 million liters per day) in 908 cities were treated in 2008 (Subedi et al., 2015a).

Surface water pollution is a topic of great concern as we are beginning to understand the true extent to which we influence our environment and the role that emerging contaminants may play in that context. Emerging contaminants, pharmaceuticals are designed to have a high degree of stability and mediate their biological effect at low concentrations, which as a consequence leads to ideal conditions for an environmentally persistent and potentially damaging contaminant (Leckie et al., 2019; Ebele at el., 2017). The increasing use of pharmaceuticals, coupled with the unknown ecological impact of pre- existing and novel active pharmaceutical ingredients (APIs), has led to increased concern (Tahar et al., 2017). Direct and indirect effects are exerted at or even below the measured environmental concentrations (MEC) in surface water.

Direct effects include the biochemical interaction with receptor molecules (e.g. hormone or enzymes receptors) and disruption of cellular processes, resulting in perturbations in gene expression, intracellular ion concentrations, cellular metabolism and the disruption of the endocrine system (Vasquez et al., 2014). Indirect effects can include the proliferation of antimicrobial-resistance and the bio-accumulation of pharmaceuticals via trophic transfer from invertebrate larva to predators, which consume them. However, the risk posed by the transfer of pharmaceuticals through the food chain is not thoroughly understood (Richmond et al., 2018).

The intentional and unintentional release of pharmaceuticals to the environment across a variety of point (illegal dumping, industrial wastewater and effluent from hospitals and domestic wastewater treatment plants (WWTPs)) and diffuse sources (runoff from agricultural farms and leaching from domestic septic tanks) leads to widespread contamination by both human and veterinary pharmaceuticals in surface waters across the world (Iglesias et al., 2014; Iglesias et al., 2012; Fenech et al., 2013).

The presence of pharmaceuticals found within liquid waste streams of landfill can contain similar or even higher concentrations of medicine than is found in the influent from WWTPs (Clarke et al., 2015). Although lined and properly managed land-fills should not affect the watercourse, landfill leachate treated in WWTPs is shown to be a potential source to the overall environmental load (Tischler et al., 2013).The wide variety of pharmaceutical drugs pose significant challenges for both environmental monitoring and toxicity testing. To address this knowledge gap and minimise environmental risk, existing environmentally relevant pharmaceutical drug must be identified and prioritized (Küster and Adler, 2014).

Pharmaceuticals are known to be poorly removed from WWTPs, are persistent in the aquatic environment and have all been included in numerous published prioritisation studies. The recent developments in chemical analysis have led to the discovery of a multitude of trace level hazardous chemicals andresidues (metabolites, transformation products, conjugated products) in surface waters at mg L-1 to ng L-1 concentrations.

Generally pharmaceutical drugs are used to treatment of dieses in human being as well as animals.

There are many medicines such as Dexamethasone, hydroxyl chloroquine or chloroquine, azithromycin, ivermectin, paracetamol, zincovit etc., used to treatment of disease but this medicine were frequently used against Covid-19. In the world and Indian scenario.

The abundant prescription of antibiotics during the pandemic, as compared to pre-Covid-19 period in 2018. Drugs, which do not metabolise in the body, are often expelled out as it is or as a by-product in the form of bodily waste, such as excreta and urine, and this faecal matter mixes in wastewater through the sewer system. Not only faecal matter, but improper disposal of unused or expired drugs in households and hospitals, also end up in wastewater (Kumar et al., 2021).E-coli, a coliform bacterium that is found in the lower part of large intestine and also in faecal matter, was isolated from the water samples and these isolated cultures were then checked against six specific antibiotic drugs to determine the susceptibility, whether bacterial culture growth was inhibited by the antibiotics, indicating good function of the drug or whether growth went unchecked, indicating resistance against the antibiotic.

The six drugs included three non-fluoroquinolone drugs-kanamycin (an antibiotic used to treat severe bacterial infections and tuberculosis), tetracycline (currently widely prescribed doxycycline, which is also a part of Uttar Pradesh's issued treatment protocol, and belongs to the tetracycline class, used to treat bacterial pneumonia), sulfamethoxazole (used for bacterial infections such as urinary tract infections, bronchitis).The three other drugs are fluoroquinolone-norfloxacin (used to treat urinary tract infections, gynaecological infections, inflammation of the prostate gland, gonorrhea and bladder infection), ciprofloxacin (used to treat chest infections, including pneumonia) and levofloxacin. The study has found that broadly there is an increase in resistance for nearly all antibiotics except kanamycin, in 2020 vis-a-vis 2018, across all the six sites. At one of the WWTP effluent points, that is the treated water, resistance was shown of two fluoroquinolone drugs-ciprofloxacin and norfloxacin.

The high resistance towards quinolone drugs is attributed to the discharge having domestic origin, because these drugs are prescribed for treatments of respiratory and urinary tract infections, their use has increased significantly during the Covid-19 pandemic. The study states that an "increased pharmaceutical pollution during Covid-19 spread can increase environmental stress on bacteria or microbes causing more mutation" and result in genetic mutations and mechanistically resistant pathways in the infecting bacteria, making it resistant against particular antibiotics. "Thus, the highly infected regions or hotspots of Covid-19 spread around the globe have a greater probability of emergence of superbugs having multidrug resistance. Drugs like Remdesivir, Ivermectin, Azithromycin, Favipiravir, Chloroquine, Umiferovir, Ritonavir, Aspirin, and Hydroxychloroquine are going to remain under scanner," the study warns.It also found that the E-coli prevalence, especially at the two sewage treatment plants, was higher in 2020 as compared to 2018, could be because of the reduced industrial wastewater, which otherwise provides a hard environment for E-coli to survive" (Kumar et al., 2021).

2.1. Pharmaceutical compounds and their lifecycle

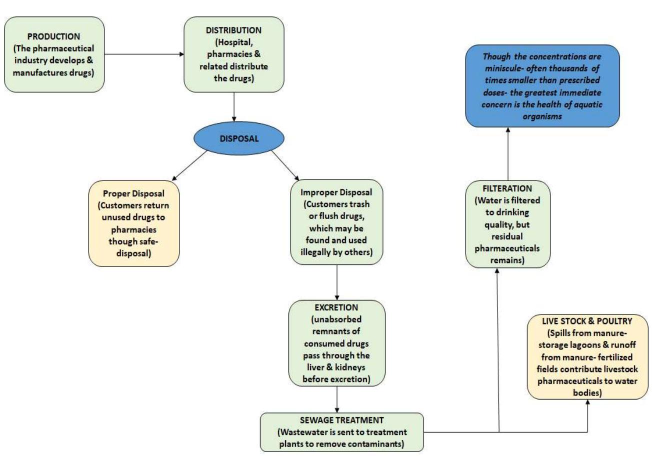

Figure 1: Pharmaceutical compounds and their lifecycle in water.

A lifecycle assessment (LCA) is an inclusive tool, which gives the opportunity to measure all inputs, outputs and influencing factors from the creation to the disposal and the associated environmental effects as a result of a process (Fig. 2) (Jiménez-González and Overcash, 2014). An LCA additionally expands the discussion on the sources of pharmaceutical pollution by addressing a range of possible inputs, which enables smart decision making for policymakers and stakeholders. Conducting a LCA of pharmaceuticals not only helps track the pathway of pharmaceuticals into the environment, but it additionally helps meeting the targets of the Sustainable Development Goals (SDGs). This review contributes to Sustainability Goals 6 (Clean Water and Sanitation), 12 (Responsible Consumption and Production) and 14 (Life Below Water) and the WHO One Health approach by highlighting influencing factors that lead to pharmaceutical pollution (United Nations, Envision2030; World Health Organisation).

III. IMPACT OF PHARMACEUTICALS ON HUMAN HEALTH AND ENVIRONMENT

3.1. On Human

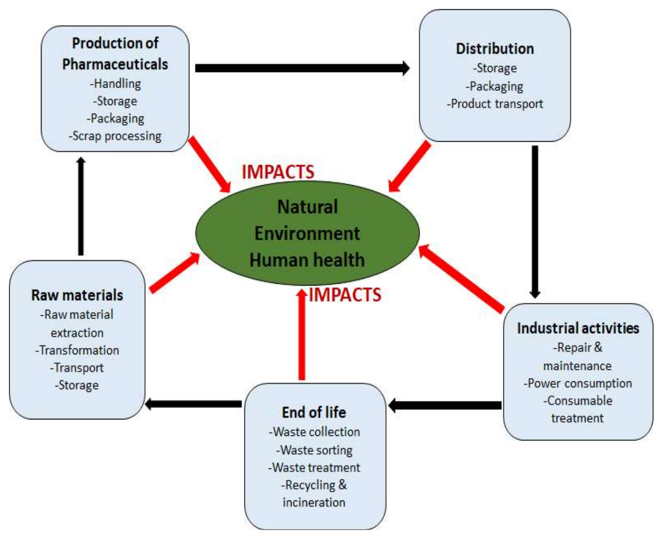

Figure 2: Impacts on the natural environment and human health

Human exposure to pharmaceuticals comes from direct (actively taking medicine) and indirect (environmental exposure) pathways. The routes of human exposure to pharmaceuticals from environmental pathways are well understood, with the main routes coming from the consumption of contaminated food and drinking water. However, exposure to pharmaceuticals may additionally come from soils, dust and exposure to contaminated surface/coastal waters from swimming (Boxall 2018).

The incomplete removal of pharmaceuticals during drinking water treatment and their frequent detection in surface waters has resulted in a wide variety of APIs being found in drinking waters globally.

An indirect consequence of pharmaceutical exposure for human health is associated with exposure to AMR organisms, as AMR poses a severe threat to both animal and human health. The presence of the antibiotics such as sulfamethoxazole and ciprofloxacin in surface water and soil can lead to the development, maintenance and spread AMR bacteria, fungi and biofilm in natural environments (Marti et al., 2013; Kaeseberg et al., 2018; Aubertheau et al., 2017; Graham et al., 2011). Furthermore, AMR bacteria present in fish from aquaculture has been shown to pass this resistance to humans. However, this transfer is not currently fully known, and further investigation is needed (Rhodes et al., 2000).

3.2. On ecosystem

The increasing global awareness of the presence of pharmaceuticals in the environment has focused on the presence and transfer of APIs in different environmental compartments (biota, sediments and water) (Ebeleet al., 2017). When testing for aquatic toxicity, it is common practice to determine acute and chronic toxicity. Fish, invertebrates, algae, and aquatic plants are the four categories investigated when determining ecotoxicology endpoints. A study conducted by Li et al.2020, investigated the potential toxicity of azithromycin to Chlorella pyrenoidosa (C. pyrenoidosa) and Daphnia magna (D. magna) via aqueous phase exposure and food phase exposure. In this study, azithromycin had inhibited digestive enzymes and shown to cause oxidative stress within D. magna. This led to an alteration of feeding behaviour. Furthermore, azithromycin had also been shown to inhibit growth, accumulation of crude fat, polysaccharides, and total protein content in C. pyrenoidosa (Li et al., 2020).

Sulfamethoxazole's mode of action involves the inhibition of the folate biosynthetic pathway in bacteria. This mode of action is similar in many photosynthetic organisms, thus causing the inhibition of growth as seen in Lemnagibba. Sulfamethoxazole can be classified as highly toxic towards photosynthetic organisms, in particular aquatic plants, algae and cyanobacteria.Ciprofloxacin mode of action involves the disruption of DNA reparation and replication in bacteria. Ciprofloxacin has been identified as being very toxic in particular to the organisms such as Pseudomonas putida, Microcystis aeruginosa, Synechococcusleopolensis and Cyclotellameneghiniana (Christensen et al., 2009).

Diclofenac has a high biological activity which can potentially be toxic to non-target organisms (Parolini 2020). The biotransformation of diclofenac into the reactive intermediate acyl-glucuronides, which can bond with intra and extracellular proteins, has ensuing toxicological results. Diclofenac has been shown to cause oxidative stress and affect carbohydrate and fatty acid metabolism in C. pyrenoidosa at low concentrations (Zhang et al., 2019). It has been linked to reduced growth during the egg phase in Japanese medaka (Oryziaslatipes) fish, causing a reduction in the ability to hatch and time required to hatch (Lee et al., 2011). Environmentally relevant concentrations of diclofenac have been shown to interfere with the biochemical functions of the rainbow trout (Oncorhynchus mykiss) resulting in tissue damage.

Sulfamethoxazole and trimethoprim are commonly prescribed together as co-trimoxazole as they both inhibit different enzymes – trimethoprim affecting dihydrofolate reductase, while sulfamethoxazole targets dihydrofolate synthase, thus increasing their potency (Coors et al., 2016). The presence of these antibiotics has provided evidence to suggest a synergistic interaction with primary producers (S. leopoliensis). However, further research is needed to confirm true synergism (Coors et al., 2016).

IV. ANTIBIOTIC DRUG RESISTANCE (ADR) IN AMBIENT WATER

The exponential rise in the consumption of antimicrobials in various applications such as medical, veterinary, domestic and agricultural and their leak to aquatic ecosystems has caused the global prevalence of antidrug resistance (ADR), which is being considered a major threat to public health (Rodriguez-Mozaz et al., 2015; Chatterjee et al., 2010; Baker-Austin et al., 2006). The ADR is not only limited to the survival and infection by any particular type of microorganism, but can lead to life threatening diseases for both animals and human (Singer et al., 2008; Ferreira da Silva et al., 2007; Jiang et al., 2013). Due to lack of regulations on the prescription and non-prescription use of antimicrobials, its consumption rate in, for example, India has been increased by 105% from 2000 to 2015 while worldwide it is estimated to increase by 63% during 2010–2030 (Klein et al., 2018; Global Antibiotic Resistance Partnership GARP-India Working Group, 2011; Van Boeckel et al., 2015). On top of that, the rate of consumption of certain antimicrobials has escalated during the COVID-19 pandemic in an effort to minimise the risk of severe infections and mortality (Miranda et al., 2020; Liu et al., 2020). Around 70% of COVID-19 patients have received antimicrobial treatment along with overuse of various antibiotics despite only 10% on average show microbial infections (Hsu, 2020; Rawson et al., 2020). As most of the consumed drugs and their metabolites are excreted through urine and faeces, their discharge to aquatic environments depends on the removal efficiency of the WWTPs (Singer et al., 2008; Azuma et al., 2012; Takanami et al., 2010; Auerbach et al., 2007; Kumar et al., 2020a). If the WWTP clearing rate is low, microorganisms exposed to antimicrobials and metabolites develops mutations causing ADR (Aali et al. 2014, Alexander et al. 2020, Guo et al. 2018, Kumar et al., 2020a, 2020c) Thus, the increased use of antimicrobials in the current pandemic will probably pose an increased risk in terms of ADR during post COVID-19 as concerned by a number of recent studies (Kuroda et al., 2021; Lucien et al., 2021; Hsu, 2020; Kumar et al., 2020a; Asaduzzaman et al., 2020).

The high consumption of antimicrobials causes an increase in the prevalence of ADR in several environmental compartments including drinking, waste and groundwater, sludge, sediments and municipal solid waste leachate (Al-Judaibi, 2014; Ferreira da Silva et al., 2007; Kumar et al., 2020d; 2020e; Ram and Kumar, 2020; Zhang et al., 2015; Storteboom et al., 2010; Threedeach et al., 2012). In the case of for example E.coli isolates from the effluent of WWTPs have shown a higher prevalence of antidrug resistance as compared to the influent, which is probably due to poor treatment conditions, prolonged microbial activities, and chemical properties of the antimicrobial drugs (Reinthaler et al., 2003; Silva et al., 2006; Miranda and Castillo, 1998; Marcinek et al., 1998). Specifically, the conventional treatment processes at WWTPs do not completely mineralise the parent antimicrobial drugs, and generate some residues, metabolites or transformation products that may have the same biological activity as the parent drugs (Zhang et al., 2015; Kumar et al., 2020c). Thus, WWTPs are considered hotspots for the spreading ADR due to high microbial density, horizontal gene transfer (HGT), nutritional richness and the availability of antimicrobial metabolites (Zhang et al., 2015; Threedeach et al., 2012; Silva et al., 2006). Previous studies have reported a correlation between the prevalence of ADR and inefficiently treated wastewater discharge, having the abundance of E. coli, extravasating to river and lake waters (Na et al., 2018; Yang et al., 2017; Honda et al., 2016, 2018; Biswas et al., 2015; Akhter et al., 2014; Ram and Kumar, 2020; Kumar et al., 2020d; 2020e). Thus, a better understanding of the occurrence, distribution and frequency of antidrug resistance in the urban waters is needed to prevent or slower the rate of increase in ADR. With the same purpose, presumptive actions are needed to study the prevalence of the ADR during wastewater treatment and the water bodies receiving the WWTP effluents. Wastewater based epidemiology (WBE) is an efficient way to trace the prevalence of ADR in highly COVID -19 infected areas, which are potentially major zones of high consumption of drugs, can be identified with the help of the WBE approach for tracing the SARS-CoV-2 genome concentration in wastewaters (Kumar et al., 2020b). Also, with the help of authorised software and apps (for example: Arogya-Setu app in India), the infected population within a certain region can be predicted. Identifying the WWTPs in such infected areas aids in correlating ADR with the elevated cases of COVID-19. Therefore, the impact of such highly contaminated zones on the prevalence of ADR in wastewaters needs to be studied well.ADR is not included in the water quality standards and guidelines of India mostly due to the lack of proper treatment facilities in many cities where domestic wastewater is directly discharged to aquatic environments (IS10500, 2012).

Continuous leak of antiviral drugs into the environment leads to antiviral drug resistance which compromises the treatment of human viral diseases. As the intense search for effective drugs against the novel coronavirus (SARS-CoV-2) is progressing worldwide, several antiviral and antiparasitic drugs, including those for Ebola (remdesivir), influenza (favipiravir, oseltamivir), HIV (lopinavir/ritonavir), and malaria (chloroquine), have undergone clinical trials on COVID-19 patients. Since these drugs and their metabolites are mostly excreted in urine, there is the potential for discharge to the environment depending on removal efficiency at wastewater treatment plants (WWTPs). For example, our preliminary worst-case (treatment by activated sludge process only) estimation shows that rivers and lakes receive 430−2120 ng/ L favipiravir hydroxide, the major metabolite of influenza drug favipiravir (Avigan), or 54−270 ng/L GS-441524, the active form of ebola drug remdesivir, from WWTP effluents if 100 new patients per 1 milllion capita are added every day to existing patients who are treated with the drugs (estimated based on Singer et al. 20082 and Azuma et al. 20125). Animals that are a natural reservoir of viruses, including bats, camels, cats, pangolins, and pigs, may then be exposed to the river water containing antiviral drugs, inducing antiviral selective pressures and mutations in the virus leading to antiviral drug resistance.

Viruses are known to rapidly undergo genome mutations with successive replications, increasing the chances of resistance to existing antiviral treatments. To date, antiviral drug resistance has been reported for human viral diseases including AIDS, hepatitis B and C, herpes, and influenza.SARS-CoV-2 is potentially capable of acquiring antiviral drug resistance in its animal reservoirs (e.g., bats and pangolins) in the event of exposure to surface waters contaminated with antiviral drugs during the COVID-19 pandemic. As of May 14, 2020, the average mutation rate of SARS-CoV-2 is 25.3 substitutions per year, which equals approximately one in 14 days.Considering this mutation rate and the numerous populations of wild animal reservoirs, the emergence of antiviral drug resistance to SARS-CoV-2 during the current waves ofCOVID-19 could generate challenges for human treatment in the post COVID-19-pandemic Anthropocene. The unprecedented mass use of antiviral drugs is looming as global researchers race to develop them for COVID-19 applications, alongside vaccine development. In March 2020, U.S. health officials estimated that it may take 12−18 months for production and delivery of effective vaccines for COVID- 19, with many hurdles to overcome, placing greater pressure on antiviral drug development.

V. MECHANISM AND PATHWAYS OF ANTIBIOTIC RESISTANCE

Though antimicrobials and antibiotics are among the essential medical interventions, increased antimicrobial resistance threatens the success of patient treatment. Antibiotic resistance has been listed as one of the three major threats to the public health in 21st century by the world health organisation (WHO) (World Health Organization, 2014). Thus, to understand and reduce the consequences of antibiotic resistance, we need to understand its mechanism. Antimicrobial resistance is expected to be the result of the environmental interactions of several organisms. As most antimicrobials consists of naturally produced compounds in nature, many of the bacteria have overcoming molecular mechanism to overcome the drugs thereby being intrinsically resistant to antimicrobials (Blair et al., 2015; Munita and Arias, 2016). However, we are here dealing with the acquired resistance by the bacteria which were originally susceptible to the particular antimicrobial. Summarizing the molecular and biochemical mechanisms of antibiotic resistance (Munita and Arias, 2016). These mechanisms of antidrug are generally categorised based on genetic and mechanistic basis. In a genetic basis, antidrug resistance can be developed due to mutational resistance, horizontal and vertical gene transfer (HGT and VGT). Whereas, in a mechanistic basis, antidrug resistance can be developed due to changes in the target site, modifications of antibiotic molecule, and decreased antibiotic penetration and efflux. The increased pharmaceutical pollution during COVID-19 spread can increase environmental stress on bacteria or microbes causing more mutation. This catalyses both the genetic and mechanistic basis of drug resistance. Also, the higher prevalence of bacteriophage may enhance the transduction related to HGT. Thus, the highly infected regions or hotspots of COVID-19 spread around the globe have a greater probability of the emergence of super bugs having multidrug resistance. Drugs like Remdesivir, Ivermectin, Azithromycin, Favipiravir, Chloroquine, Umiferovir, Ritonavir, Aspirin, and Hydroxycholoroquinine are going to remain under the scanner.

Study conducted by kumar et al. 2021, Over all, domestic municipal wastewater likely possesses higher concentrations of antimicrobials than any other ambient water. Aeration enhances the generation and replication of antidrug resistant E. coli if there is a high density and diversity of the microbial population in a given wastewater.The advanced or hybrid wastewater treatment processes should be adopted to effectively remove the antimicrobials and their residue in order to reduce the possibility of resistance (Dhangar and Kumar, 2020).The abundance in both antidrug resistance and E. coli count in the STPs was found to be statically related. Previously, in case of the Zenne river of Belgium, the abundance of E. coli and antidrug resistance increased from upstream to downstream after merging the effluent from Brussel's WWTP (Proia et al., 2018). Thus, proper and timely monitoring should be done to track such load of E. coli and ADR while discharging the treated effluents to the river water.

The increased cases of COVID-19 are not surprisingly correlated to SARS-CoV-2 genes in waste and natural waters (Medema et al., 2020; Ahmed et al., 2020; Haramoto et al., 2020; La Rosa et al., 2020; Sherchan et al., 2020; Kumar et al., 2020; Nemudryi et al., 2020; Kocamemi et al., 2020). The study conducted by Kumaer et al., 2021, the concentration of pharmaceutical and personal care products (PPCPs) in the ambient environment should be monitored to quantify their increase owing to COVID-19 and then connect back to the corresponding effect on ADR for quantitative evaluation. ADR and COVID-19 spread throughout the globe.

VI. POSSIBLE DETECTION AND TREATMENT TECHNIQUE FOR SARS-COV-2 AND PHARMACEUTICAL COMPOUNDS

Corona viruses have the characteristics of being enclosed virus, with a unique extensive RNA genome, which provides an abundant malleability for the accommodation, modification also acquires gene to acclimate to several species (Jones et al., 2020). The factors which are related for the recognition of the receptors as well as permits the entrance in the host cell is the S-glycoprotein (Park et al., 2019), this allows the cross species transmissions. Their physiopathology is still being deliberated, nonetheless this is well-known that these viruses were generally very infectious when the patients are indicative likewise which includes the maturation period (days 1-14) (Di Gennaroet al., 2020) when the person is usually asymptomatic. The communal pathway of the transmissions was aerosol, while the person talk, respires, coughs, or sneeze, also fomites, after the dewdrops were dense as well as triteness remains into the air, follows then on the grounds (Pacheco et al., 2021; El Baz and Ruel 2021; Nghiem et al., 2020). The viruses can gets enter in the sewerage via the different sources like phlegm, vomitus, faeces, even already mentioned about hand washing (Amankwah-Amoah 2020; Nghiem et al., 2020), also it tends to be more resilient than the microorganisms to free the chlorine in reference to World Health Organization (WHO). Though, the technical communities are utilizing these types of polluted water entries as the opportunities for the conduction of epidemiological studies (Hart and Halden 2020), meanwhile the monitoring as well as studies of these magnitudes, this might appear more demonstrative outcomes of the patients which are not being identified because of the nonexistence or insufficiency of the indications, and therefore uses this as a warning systems for the upcoming new COVID-19 epidemics (Panchal et al., 2021).

In the passing months publics were more responsive to words the sanitation, moreover isolation as well as quarantine centers had been built in the supervision of the government in majority of nations, therefore the consumption of the water have been amplified considerably reached to great heights according to the researches performed in India wherever the utilization of the water have been five times extra in the assessment to the average usage, producing the consequences of a 25% of the requirement as well as generation of the polluted water (Pacheco et al., 2021). Consumption as well as freshwater facilities were essentials, and the lack of these could have an impact on the economy, public health, safety, and welfare of the population.Riverine water, sea water, or polluted water which contains infectious individual's feces were implausibly to contaminate the other persons above-mentioned, surface which were repetitively utilized through the infectious individuals by severe indications, this could lead to the liberal accumulations of the viral loads if the surfaces were infected (Ricci et al., 2017). SARS CoV-2 present in water (Myers 2020) must be deliberated as the threat especially in pitiable as well as vulnerable populaces by the threatened resources. The SARS-CoV-2 quantification as well as detecting into the polluted water also the discharges in different nations (Hasan et al., 2021). Though, the facts that certain polluted water gets discharged unswervingly in the tributaries also in the sewerage system which consists viruses (Pacheco et al., 2021), micro-organisms (Manyi-Loh et al., 2018), antibiotic resistant microbes (Rueda-Marquez et al., 2020), as well as evolving pollutants (Soliman et al., 2021), generally without the pretreatment is the issues which is essential not to leave apart, this may also hurt humans healthiness as well as environs. Following are some of the techniques for detection of the SARS-COV-2 and for pharmaceutical compounds have been described below.

6.1. Detection techniques for SARS-COV-2

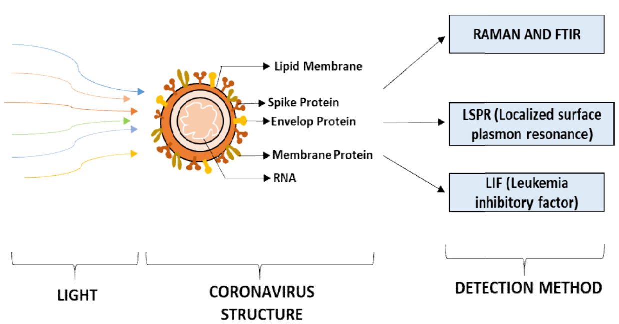

Figure 3: SARS-CoV-2 detection method

6.1.1. Spectroscopic Technique

6.1.1. A. Reverse transcription polymerase chain reaction (RT-PCR)

Mostly the common tools for detecting RNA of the SARS-CoV-2 is the real time reverse transcription polymerase chain reaction (RT-PCR) (Ishige et al., 2020). This technology is extremely delicate, exclusively if it identifies more than two targets of region. Though most RT-PCR experiments were accomplished on the respirational tract sample, the genomic materials of the original corona virus can be detected into other sample likewise in the serums, peripheral bloods, feces as well as different functional parts (Ramirez et al., 2020). Quick antigen examinations may subsidize to complete COVID-19 analysis capacities, offers benefits in relation of short reversal intervals also reduces charges, specifically in conditions in which RT-PCR analysis capability is restricted, though its thoughtfulness were usually lesser for the RT-PCR (Pulia et al., 2020). Rapidly the testing of the antigens may lead for the detection of SARS-CoV-2 (including variant viruses) but cannot distinguish the types of the VOC (WHO 2021) it can be helpful for the reduction of further transmissions by the initially detecting in the extremely infectious cases.

Diagnosis of SARS-CoV-2 infections were presently established on the real time reverse transcriptase-polymerase chain reaction (RT-PCR) implemented on each nasopharyngeal swabs (NPS) (Bastug et al., 2020) or oropharyngeal swabs (OPS) (Patel et al., 2020). Even though sub-optimal detection rates, assemblage of exudations after the upper airways through the NPS/OPS still characterizes the first line analytic modalities for the testing of the patients as well as asymptomatic peoples for COVID-19 (Torretta et al., 2020), providing about it timely as well as adequately implemented once the symptom get detected.

6.1.1. B. Fourier-transform infrared (FTIR)

Vibrational spectroscopy, including attenuated total reflection Fourier-transform infrared (ATR-FTIR) spectroscopy, have remained extensively utilized to categorize and to organize normal as well as pathological population utilizing diverse varieties of cells, tissues or bio fluids (Ferreira et al., 2020). Willingly manageable bio fluids, like blood plasma/serum (Parachalil et al., 2020), saliva (Paraskevaidi et al., 2018) or urine (Leal et al., 2018), were considerably perfect for the experimental application because of the routine ways of collections, and minimum samples preparations. Examination of the sample by the infrared spectroscopic technique which permits for the generation of the spectral fingerprints, this consequently assists the discernment of the diverse populaces as well as identifications of the possible bio-markers (Baker et al., 2014). within passing centuries, bio fluid based ATR-FTIR spectroscopy has been utilized for the diagnosis, screening or monitoring the movement/recession in the varieties of the infections (Barauna et al., 2021). Spectroscope based technologies were rapidly, cost effective as well as nondestructive which makes them an impeccable aspirant for the transformation for the hospital. ATR-FTIR spectroscopy was utilized for the interrogation of slaver samples on the pharyngeal swabs taken after the persons with or without assumed to be infected by the SARS-CoV-2 (Barauna et al., 2021).

6.1.1. C. RAMAN

Raman spectroscopy was the vibrational spectroscopy technology which have numerous application in the pharmacological industries (Kalantri et al., 2010). These were utilized for the detection vibrational, rotational as well as additional situations in the molecular systems as well as may be utilized for the investigation of the chemical compositions of the material. Discrepancies of the technology for e.g. surface enhanced raman scattering (SERS) (Lee et al., 2019) or tip enhanced raman scattering (TERS) (Zaleski et al., 2016), further offers the intuitions of the little concentrations or smidgeon investigation. Subsequently, the major stated cases of Severe Acute Respiratory Syndrome Corona virus-2 (SARS-CoV-2) in

December 2019, scientists all over the domain had been working determinedly for understanding of the viruses. Numerous sets have been utilizing Raman spectroscopy for assisting it in the worldwide efforts, apply it for the enhancement for detecting the environment, rapidly the analysis as well as to reconnoiter the fingerprints saliva to the disease-ridden by the SARS-CoV-2 (Lukose et al., 2021). Surface enhanced raman scattering could be utilized for the interrogation of the trace constituents through the exploitation of the electromagnetic fields enrichment results after the excitation of the localized surface Plasmon resonance at the Nano-structured metal based surface, like gold or silver (Bauch et al., 2014). It has been advanced to evaluate by utilizing Surface enhanced raman scattering together through the multivariate investigation for the diagnosis SARS-CoV-2 (Zhang et al., 2020) in an ultra-fast way, deprived of several pretreatments e.g. RNA extraction (Zhang et al., 2021), stated acceptable enactment for interrogation of the existence of the SARS-CoV-2 in the specimen of the environment. On site assessments proves their accurateness as well as tranquil operations for on-spot analysis of SARS-CoV-2 for the evaluation of fumigation enactment, exploring pathological persistence in the media of the environment, assessment of the decaying virus into the polluted water treatment plant also tracking the SARS-CoV-2 in the network of the pipes (Zhang et al., 2020).

6.1.2. Imaging Technique

6.1.2. A. Super resolution microscopy techniques

Microscope based technique is the vital in present bio medical researches as it is the only technique have ability for the quantitative addressing multifaceted spatio temporal dynamics for the existing system at a adequate determination to provide the utmost truthful demonstration of the biological system (Laketa, 2018). Certainly, individual could finds the light as well as electron microscope imaging statistics in the mainstream of the technical article got available in the bio-medical streams (Falagario et al., 2020). In addition, microscope have frolicked the main part in the transmittable diseases study, subsequently the finding of the first micro-organisms (Laketa, 2018). Microscope had been vital for the detection of the infection causing agents through straight observations and also for analyzing the compliances by the Koch hypothesizes in the direction for the identification of the novel pathogen. This have been too had the main role in the transmittable infections diagnosis (Laketa, 2018).

The significance of the microscope in the transmittable diseases researches have been in continuation in the present times, this have demonstrated in the enduring the SARS-CoV-2 epidemic (Cortese and Laketa 2021).Electron microscope is the technique of the choices for the straight visualization of the virus. Though current advance in the super resolution microscope allows for the resolution of the molecular dissemination of the viral protein on the viroid surfaces (Touizer et al., 2021). Electron microscope still remains the one technology which able to offer the organizational as well as morphological informations (Zhang et al., 2020). Because of their dominant roles in the researches of the viruses, electron microscope have stayed widely exploited throughout the 2020 SARS-CoV-2 epidemic for studying the altered the traits of SARS-CoV-2 infections as well as pathogenesis (Sadegh et al., 2020). Certain of the imageries together through the accuracy illustration generates after the electron microscope fundamental researches accomplished the wide spread recognitions amongst the overall public as well as became an imperative resource to raise the alertness on the corona virus infections, fight deception also for promoting the health endorsements to combat against SARS-CoV-2 (Chakraborty et al., 2020).

6.1.2. B. Fluorescence based virus detection

Fluorescence based senses and images offer the exclusive benefits like good sensitivity, highly sequential resolutions, accessibility of the bio-compatible images agent, as well as non-invasive characteristic which makes this appropriate in the researches as well as scientific setting (Maddali et al., 2021). Fluorescence based visual biosensor were the only major groups of the sensor in present-day, owed to the profitable accessibility of various fluorescence probe, the great qualities of visual fibers as well as appropriate visual equipment's (Maddali et al., 2021). Highly exciting of the power were not necessary for the fluorescence, creating this at low-cost, easily accessible device. Though a feasible natural imaging technology, there were definite restrictions like fluorophore intermittent, photo bleaching as well as positioning of the alteration dipole (causing artifacts), also the incapability for various aimed molecule for the demonstration of detectable fluorescence indication which needs to overcome beforehand it could remain utilized of the detection of viruses (Li and Vaughan 2018).

Fluorescence biosensor has different parameters' such as intensity (Borisov and Wolfbeis 2008), energy transfer (Mehrotra, 2016), life time (Jeong et al., 2018) and, quantum yield (Maddali et al., 2021) which could be subjugated of detecting the viruses. The mechanisms which are repeatedly utilized within the biosensor for the detection of close interaction (<10 nm) amongst the analytic as well as the fluorophore were the fluorescence resonance energy transfer (Zadran et al., 2012; Pehlivan et al., 2019). Fluorescence resonance energy transfer is the method wherever the occurrence radiations were immersed as well as none radiatively transmitted from the contributor to the acceptor through the long range dipole-dipole combination (Mohammed 2014). Current improvement in fluorescence resonance energy transfer researches as well as advancement in the visual equipment's had been recognized fluorescence resonance energy transfer microscope as an actual tool for the biological images as well as detecting applications (Shabestari et al., 2017).

6.1.3. Nano photonics Sensor Technique

Numerous nanotechnology based methodologies for the SARS-CoV-2 cataloging as well as detecting its development. Usually, analysis tools for the operation of detecting the antibodies (by enzyme linked immune sorbent assay, or the enzyme linked immune sorbent assay (ELISA)) (Asensio et al., 2008) or the RNA (by the polymerase chain reaction) (Kesli et al., 2009) related by the viruses (after the nasopharyngeal swabs taken from individuals' nose and throat). This depend on its interaction on the surfaces by the corresponding detecting ligands or the strands into the tools. Toward the end, because of its enormously huge surface to volume ratio, nano-sized constituents could originate the high proficient surface interfaces amongst the sensors as well as the analytic, allows the quicker as well as more trustworthy detecting the viruses (Rashidzadeh et al., 2021). Therefore, the groups of the investigators had developed the colloidal gold based testing kits which allows tranquil conjugations of the gold nano-particles to immunoglobin-M/ immunoglobin-G antibody into the humans serum, plasma also the complete sample of the blood (Liu et al., 2021). Though, the battered immunoglobin-M/ immunoglobin-G antibody in the kit remained unspecific to SARS-CoV-2, as well as the results in certain circumstances produces the incorrect outcomes related through the patients that were distress due to the extraneous toxicities (Talebian et al., 2020). Subsequently, investigators of the University of Maryland, USA, established the colorimetric (Talebian et al., 2020) test centered on the gold nano-particles covered by the appropriately intended thiol modified DNA anti-sense oligonucleotides precise for the nucleocapsid phosphoprotein (N-gene) of SARS-CoV-2, which remained utilized for the diagnosis of positive SARS-CoV-2 cases in 10 minutes via the isolated RNA samples (Moitra et al., 2020). Such analyzing tools might be possibly gives the favorable outcomes, though its enactment must be still exaggerated via the quantities of the pathological loads. For the inadequacy, the scientists have recently stated the unique dual functional plasmonic bio-sensor conjoining the plasmonic photo thermal effects as well as confined surface plasmon resonance recognizing the transducing for providing the alternate as well as encouraging solutions for the medical diagnosing the SARS-CoV-2 (Talebian et al., 2020; Alhalaili et al., 2020).

6.2. Detection techniques for pharmaceutical compounds

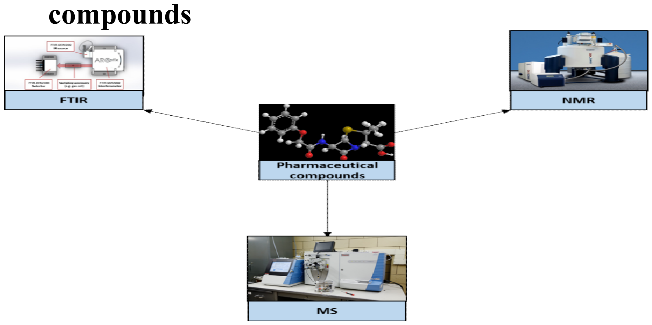

Figure 4: Detection techniques for pharmaceutical compounds

6.2.1. Fourier transforms infrared spectroscopy (FTIR)

Fourier transform infrared spectroscopy is the cherished instrument for identifying the functional group existing in the plants' extracts (Nagarajan and Kumar 2017). This supports the identifying as well as the determining the molecules of the structures. Sample for fourier transform infrared spectroscopy may organized in a various methods (Durak and Depciuch 2020). In case of liquid sample, the easy way is to keep a droplet of the samples amongst the two plates of the sodium chloride (Ingle et al., 2017). The drops form a shrill layer amongst the two plates, in case of solid sample may remain minced with the potassium bromide, after that it gets compacted in the thin pellet that may get investigated (Chan et al., 2011). Then the solid sample could get dissolve into the solvents like methylene chloride, as well as the some drops of the solutions were formerly positioned on the particular High Attenuated Total Reflectance (HATR) plates as well as the spectrum was documented in relations of the percentage transmittance (Ayres 2008). The peaks at the particular wave numbers remained consigned through the bonds as well as functional groups by way of the references specified in varianfourier transform infrared spectroscopy manuals of the instruments (Rees et al., 2007).

6.2.2. Nuclear Magnetic Resonance Spectroscopy (NMR)

Nuclear magnetic resonance spectroscopy provides physically, chemically as well as biologically characteristics of the matters (Mopper et al., 2007). 1-dimensional techniques were usually utilized then the complex structures of the particles can be accomplished by the 2-dimensional nuclear magnetic resonance spectroscopy techniques (Mahrous and Farag 2015). Solid states of nuclear magnetic resonance spectroscopy were utilized for determining the structures of the molecules in the solid state. Radio labelled C-nuclear magnetic resonance was utilized for the identification of carbon type which can be exist within the compounds (Ingle et al., 2017). H-nuclear magnetic resonance (Zhu et al., 2006) utilized for finding out the kinds of the hydrogen that are available within the compounds also for finding out the connection amongst the hydrogen atoms. Nuclear magnetic resonance uses an electromagnetic components of the radiations (radio frequency waves) to ease the transition amongst the rate of the nuclear energies (resonance) (Koshani et al., 2020).The nuclear magnetic resonance may get analyzed quantitatively of the mixture which contains the known compound. Nuclear magnetic resonance may also remain utilized to equalize alongside the spectrum library or for the information of the basic structures straight for the unidentified compound (Dias et al., 2016). When the simple organization is identified, nuclear magnetic resonance may be utilized for the determination of the molecules conformation within the solution and also in the reviewing the physical properties at the levels of molecules like conformational exchanges, phase changes, solubility's, as well as the diffusions (Saal et al., 2017).

6.2.3. Mass spectrometry (MS)

Mass spectrometer was the influential diagnostic techniques intended for identifying the unidentified compounds, quantifications of identified compounds as well as to explicate the structures as well as the chemicals property of the particles (De Vijlder et al., 2018). Dependent on the 2^{nd} law of motion (newton's law) and momentum, the mass spectrometry utilizes these properties of the matters for plotting the ions of variable mass on the mass spectrometry (Rubakhin and Sweedler, 2010). After the laws, it concludes the quantity of masses were appropriate for the inertia and also the accelerating bodies. The principle is applicable to the phase wherever the ions with the diverse masses for charging the ratios were refracted through various viewpoints into the electric or the magnetic fields (Dawson, 2013). Although the mass spectrometer spectra were the weights of the molecules of the samples for its determination. The technique is generally engaged for the organizational explication of the organic compound, intended for the peptide or oligo-nucleotide sequences as well as to monitor for the existing the formerly characterized compound in the multifaceted mixture through the highly specificities via significant the both weight of the molecules as well as the investigative fragments of the molecules instantaneously (Cox and Mann 2011).

VII. CONCLUSIONS

The COVID-19 pandemic has had a significant impact on aquatic ecosystems due to the increased usage and disposal of pharmaceuticals. The presence of pharmaceutical residues in water bodies during this period has raised concerns about ecological consequences and potential risks to human health. However, various measures can be taken to mitigate these effects and treat pharmaceutical pollution in aquatic ecosystems. Wastewater treatment systems also play a vital role in treating pharmaceutical pollution in aquatic ecosystems. Advanced treatment technologies, such as activated carbon filtration, ozonation, and UV disinfection, can effectively remove pharmaceutical residues from wastewater. Implementing these treatment methods at wastewater treatment plants can significantly decrease the presence of pharmaceuticals in effluent discharged into rivers, lakes, and oceans, thus reducing their impact on aquatic organisms and ecosystem. Various sensor, detection and imaging techniques have been discussed along with the effect of SARS-COV-2 and other pharmaceuticals on environment and humans. Continued research efforts are essential to further understand the mechanisms of pharmaceutical toxicity in aquatic organisms and to assess the long-term ecological consequences of pharmaceutical pollution. Researchers should investigate the effects of combined exposure to multiple pharmaceuticals and the potential interactions between pharmaceutical residues and other environmental stressors. In conclusion, addressing the impact of various pharmaceuticals on aquatic ecosystems during the COVID-19 pandemic requires a multi-faceted approach. By promoting responsible medication disposal, implementing advanced wastewater treatment technologies, and focusing on the development of environmentally friendly pharmaceuticals, we can effectively mitigate the effects of pharmaceutical pollution and safeguard aquatic ecosystems for the future.

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