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Effects on human health caused by improper disposal of effluent from the sewage treatment plant of Ahmedabad city

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ABSTRACT
A rise in the rate of wastewater production has been attributed to improper wastewater disposal and the difficulty of addressing complications caused by the discharge of wastewater into bodies of water. Several factors like domestic waste, industrial refuse from the chemical, textile, and engineering industries, and agricultural runoff have a negative impact on the water quality of the Sabarmati River of Ahmedabad city. High levels of contaminants in a river result in an increase in biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and total suspended solids (TSS). Sabarmati River is not suitable for consumption, irrigation, or aquatic life due to the presence of toxic metals such as Co, Cr, Cu, Mn, Ni, Pb, and Zn; it also poses a significant threat to human health. In this study the risk associated with the use of Sabarmati River water was determined by comparing the concentration of heavy metals in vegetables irrigated with effluent mixed river water to the concentration of heavy metals in the soil. It is found that ~ 70% of the disposed sewage samples having BOD and COD more than the prescribed limit. The heavy metals like Cr, Pb and Mn have the higher risk associated with the human health.
Keywords: *Disposal; Wastewater; Pollutants; Treatment plants; Management*

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INTRODUCTION

Currently, there are many different kinds of sources contributing to water pollution. The main cause of pollution is the release of sewage and industrial waste into bodies of water such as rivers, ponds, and lakes. The effluent originating from septic tanks represents an additional noteworthy contributor to water pollution. The mixture of oils, animal excrement, and waste materials, along with the runoff from roads, parking lots, and walkways, converges with the water body. Based on data provided by the Central Pollution Control Board, it was determined that the estimated volume of sewage generated throughout the nation in 2015 amounted to 61754 million litres per day (MLD), but the corresponding capacity for sewage treatment in developed areas was reported to be 22963 MLD. As a result of an insufficiency in sewage treatment capacity, an estimated 38791 MLD (62% of the total sewage) of untreated sewage is directly dumped into adjacent aquatic bodies [1,2]. The states of Maharashtra, Tamil Nadu, Uttar Pradesh, Delhi, and Gujarat collectively account for almost 50% of the total effluent produced in the country. The state of Maharashtra accounts for 13% of the overall effluent generation in the country. A significant proportion, specifically 67%, of the wastewater treatment capacity that has been developed nationwide is concentrated in the states of Maharashtra, Gujarat, Delhi, Uttar Pradesh, and Gujarat. According to the Central Ground Water Board (CGWB) [3], the release of untreated sewage into water bodies, resulting in the contamination of both surface and underground water, stands as the primary cause of water pollution in India. India has a significant difference between the generation of wastewater and its subsequent treatment. The underutilization of current treatment capacity is attributed to operational and maintenance issues. Based on the survey report conducted by the Central Pollution Control Board (CPCB) in 2005 [4], it was found that around 39% of existing plants and sewage pumping stations fail to meet the general conditions outlined in the Environmental (Protection) Rules for discharging into water bodies. In numerous urban areas, there exists a situation where the capacity for treatment is not fully utilized, resulting in a significant outflow of untreated sewage. The practise of long-term sewage disposal typically results in the accumulation of various metals (such as chromium, copper, lead, nickel, zinc, mercury, cobalt, manganese, etc.) in irrigated soils and plants. This phenomenon can possibly have adverse effects on human health due to the transmission of heavy metals through the food chain [5,6]. Certain heavy metals, such as zinc (Zn), manganese (Mn), nickel (Ni), copper (Cu), and chromium (Cr), are essential for human health when consumed in small quantities. However, an excessive accumulation of heavy metals in the human body can result in many disorders affecting the cardiovascular system, neurological system, kidneys, and bones [7, 8]. The specific objectives of the present study are: (i) to obtain baseline information on the physiochemical properties of the sewage discharged into the Sabarmati River near the city of Ahmedabad; and (ii) to provide a quantitative assessment of the health risk associated with the disposed sewage.

MATERIAL AND METHODS

Study Area

The research region is situated in close proximity to the Vasna Sewage Treatment Plant (STP) disposal site in Ahmedabad, which is geographically positioned alongside the Sabarmati River. Ahmedabad, a metropolis located in India, with a population of six million individuals and encompasses an urban area spanning 464 square kilometres. As to the findings of the Ahmedabad Municipal Corporation (2011), the wastewater treatment capacity of the city is reported to be 1075 million Litres per Day (MLD), but the current demand is at 1186 MLD. The Vasna Sewage Treatment Plant (STP), with a capacity of 240 million litres per day (MLD), is located along the Sabarmati River. It is responsible for treating domestic wastewater originating from residences and small enterprises under the jurisdiction of the Ahmedabad Municipal Corporation (AMC).

Collection of samples

In Vasna Sewage Treatment Plant three different units are there. A single unit of the Up flow Anaerobic Sludge Blanket (UASB) type possesses a capacity of 126 million litres per day (MLD). There are two Activated Sludge Process (ASP) units with capacity of 35 million litres per day (MLD) and 240 MLD, respectively. In order to ascertain the physiochemical attributes of the effluent sample, a total of 30 samples were collected, with 10 samples obtained from each individual outlet. Out of the 30 samples were collected, with 15 samples obtained in the morning and another 15 samples taken in the evening. The purpose of this data collection was to investigate the potential impact of time on the disposal process of treated wastewater. In order to assess the impact on human health, soil and vegetable samples (including brinjal, tomato, cabbage, cauliflower, and spinach) were collected from eight distinct locations (Gyaspur, Visalpur, Kasindra, Saroda, Chandisar, Kaloli, Asmalli, and Khada) in the vicinity of Vasna area of Ahmedabad. Wastewater samples, each measuring 500 mL, were collected from three discrete disposal sites using HDPE bottles. Following the filtration of the samples, a volume of 2 mL of concentrated HNO_3 was added to mitigate the potential deterioration caused by microbial activity. Measurements of pH, electrical conductivity, total dissolved solids, and temperature were conducted on-site. To facilitate the study of heavy metals, the sample underwent dilution until its conductivity reached a value of 300 S. The acidified samples were maintained at a temperature of 4 degrees Celsius until they were ready for subsequent experimentation. During the sampling and processing procedures, precautions were implemented to avoid any contact between the samples and metal surfaces. This measure was taken to mitigate the risk of heavy metal contamination originating from various activities and sources within the vicinity of the workplace.

Analysis of samples

Various physiochemical characteristics, including pH, BOD_5 (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TDS (Total Dissolved Solids), Electrical Conductivity, residual chlorine, and suspended solids, were assessed. Inductively coupled plasma mass spectrometry (ICPMS) has the capability to ascertain the concentration levels of cobalt (Co), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn). Effluent samples were analysed using a multiple parameter kit to evaluate the pH, electrical conductivity, and total dissolved solids.

RESULTS AND DISCUSSION

Table 1 presents the recorded values for pH, BOD_5, COD, TDS, Electrical Conductivity, residual chlorine, and suspended solids. These characteristics offer insights into the quality of a prominent point source, specifically the effluent, which contributes to the contamination of the river's water.

Table-1: Physiochemical Properties of collected samples

Sr. No.	Sample No and Outlet	pH	Conductivity	COD	TDS	Suspended Solid	Residual chlorine	$BOD_{(5)}$
Recommended value	-	7	2 mS	250 mg/L	600 mg/L	100 mg/L	1 PPM	30 mg/L
1	Outlet – 1	6.63	3.42	82	1061	312	0.2	17
2	Outlet – 2	6.57	19.21	617	6360	1023	0.2	70
3	Outlet – 3	6.77	2.42	263	2980	286	0.2	35
4	Outlet – 1	6.57	2.42	250	1050	487	0.2	30
5	Outlet – 2	6.52	20.23	910	6350	1040	0.2	85
6	Outlet – 3	7.80	6.64	428	2990	323	0.2	62
7	Outlet – 1	6.58	2.0	89	1050	437	0.2	18
8	Outlet – 2	6.56	16.31	543	6300	1069	0.2	67
9	Outlet – 3	6.57	6.71	279	3000	500	0.2	34
10	Outlet – 1	6.57	2.52	109	1080	459	0.2	22
11	Outlet – 2	6.42	19.20	528	6500	1110	0.2	62
12	Outlet – 3	7.39	7.52	352	2985	382	0.2	37
13	Outlet – 1	6.55	3.52	456	1035	359	0.2	35
14	Outlet – 2	6.74	28.12	1398	6480	1232	0.2	102
15	Outlet – 3	6.85	11.53	774	3100	491	0.2	73
16	Outlet – 1	6.79	5.34	250	1070	352	0.2	30
17	Outlet – 2	6.55	30.12	596	6345	1214	0.2	67
18	Outlet – 3	7.57	12.63	288	3080	572	0.2	32
19	Outlet – 1	8.55	7.20	250	1035	353	0.2	28
20	Outlet – 2	8.52	8.53	657	6360	1090	0.2	73
21	Outlet – 3	9.02	12.71	410	2850	497	0.2	42
22	Outlet – 1	8.34	5.84	150	1060	362	0.2	20
23	Outlet – 2	8.62	30.21	329	6490	1290	0.2	40
24	Outlet – 3	9.35	13.73	750	2990	549	0.2	18
25	Outlet – 1	7.92	4.24	250	1055	343	0.2	15
26	Outlet – 2	8.72	30.27	1025	6435	1256	0.2	80
27	Outlet – 3	9.22	12.74	520	3150	561	0.2	60
28	Outlet – 1	6.94	4.21	110	1065	354	0.2	22
29	Outlet – 2	7.24	27.20	1150	6400	1250	0.2	83
30	Outlet – 3	7.18	13.52	656	3035	502	0.2	58

As per the regulations set by the Bureau of Indian standards (BIS), the pH levels of sewage and industrial effluents that are released into surface water sources and public drainage systems typically fall between the ranges of 5.5 to 9.0. The pH values of the thirty collected samples fall within the range of 6.42 to 9.55. In terms of waste management, it was seen that eleven out of thirty samples demonstrated outcomes that fell below the acceptable threshold. COD plays a significant function in terms of waste management. Out of a total of thirty samples, ten were found to have concentrations below the established allowed level of 250 mg/L. The findings exhibit a comparable inclination with regards to BOD outcomes. All 10 samples exhibited increased levels of chemical oxygen demand (COD) at the second outlet. The concentration of chemical oxygen demand (COD) exhibits a range of values, ranging from 265 to 1390 mg/L. The maximum allowable concentration of total dissolved solids for disposal purposes is 600 mg/L. The total dissolved solids (TDS) values in all thirty samples were found to surpass the authorised threshold limit. The recorded measurements vary between 1035 ppm and 6500 ppm, exceeding the allowable limit by a factor of two to ten. Among the three outlets, the second outlet demonstrates the highest level of pollutants in terms of sample collection. Out of the thirty samples that were taken, just one sample, representing 3.33% of the total, within the designated threshold of 2mS. The measured conductivity values vary from 2.4 to 30 milli siemens (mS). The results in outlet number two exhibit a far higher degree of variability. Suspended solids serve a crucial role in terms of waste management. The acceptable concentration for suspended particles is 100 mg/L. The sample that was gathered displayed a result that surpassed the designated threshold. The observed values span a range of 280 to 1290 mg/L. Outlet number 2 exhibits the most superior outcomes when compared to the other outlets. This may due to improper treatment of the collected sewage by ASP method. The concentration of residual chlorine in each of the thirty obtained samples fell within the permissible range. $BOD_{(5)}$ for the collected samples also analyzed. It was observed that out of 30 collected samples only 10 samples having the range within the prescribed limit of 30 mg/L. The focus of this study is on the levels of heavy metals present in the given samples. The concentrations of Co (2.2-2.4), Cr (1.4-2.1), Cu (0.3-1.2), Mn (0.4-3.2), Ni (1.4-2.1), Pb (0.6-1.8), and Zn (5.3-20.6) were seen to fall within the specified ranges ($g.mL^{-1}$) in the sewage samples. The measured quantities surpass the established permissible thresholds for heavy metals utilised in irrigation as specified by the Indian Standard, the World Health Organisation (WHO), and the European Union Standards. The pH values of the soil samples examined exhibited a range from 6.73 to 7.95. The soil samples in proximity to and at a distance from the discharge location, specifically Gyaspur and Khada, exhibit alkaline pH levels of 7.6. Conversely, the soil sample obtained in Saroda, located 20 kilometres downstream, demonstrates an acidic pH value of 6.4. The pH values of the remaining samples are within the range of 7.0 ± 0.2%. In accordance with the prevailing pattern, the mean metal concentrations (expressed in μg g 1) in the eight sediment samples are as delineated below: The order of the elements based on their concentration, is as follows: Zn (443 ± 64) > Mn (338 ± 48) > Cu (209 ± 31) > Cr (73 ± 21) > Ni (53 ± 9) > Pb (44 ± 7) > Co (10 ± 1). The concentrations of Co, Cr, Cu, Mn, Ni, Pb, and Zn in the edible portions of various vegetables exhibited significant variation on a dry weight basis. This suggests that the process of metal assimilation is particular to both the plant species and the individual metal element. The study establishes that the range of Co, as measured by the research, falls within the interval of 0.5 to 4.23μg g-1. It is worth mentioning that the Gyaspur site exhibits the greatest concentrations of Co among all vegetable types. The concentration of chromium (Cr) in various vegetables ranged from 5.6 to 12.2μg.g-1, with an average value of 6.9± 1.5 $\mu g.g^{-1}$. The mean concentrations of plants surpass the permissible threshold of 2 $\mu g\ g^{-1}$. The spinach samples obtained from the Gyaspur region have the highest recorded quantity of chromium (12.2$\mu g.g^{-1}$). The concentration of Cu in the examined samples ranged from 0.06 to 10.2μg/g. According to the given sequence, the order of preference for the listed vegetables is as follows: brinjal > spinach > tomato > cabbage > cauliflower. All of the samples do not surpass the toxicity threshold. The concentration of Mn in the examined vegetable samples varies from 18$\mu g.g^{-1}$ (brinjal) to 112$\mu g.g^{-1}$ (spinach). According to the given sequence, spinach is ranked higher than cabbage, which is ranked higher than brinjal, followed by tomato, and finally cauliflower. Nickel (Ni) plays a crucial role as a constituent of the plant enzyme that facilitates the process of nitrogen fixation from urea or inorganic nitrogen. Additionally, Ni is involved in regulating the regular growth of plant tissues. The content of Ni in the samples varies between 0.9 and 4.4$\mu g.g^{-1}$. The soil's capacity for Ni mobility is a crucial factor in determining its bioavailability, with Ni mobility being notably enhanced in soil conditions that are moderately alkaline. The amounts of Pb in the samples vary between 0.7 and 8.9 $\mu g.g^{-1}$, with an average concentration of 2 $\mu g.g^{-1}$. The observed trend, utilising mean values, exhibits: tomato > spinach > cabbage > brinjal > cauliflower. The samples collected from the Gyaspur site exhibit an average lead concentration of 4.3$\mu g.g^{-1}$, with the spinach sample demonstrating the highest lead content at 8.9 $\mu g.g^{-1}$. The findings of this study underscore the potential hazards associated with cultivating plants in close proximity to a wastewater disposal site, as well as the capacity of leafy vegetables to accumulate and retain lead. The zinc (Zn) content of the vegetables varies, with cabbage having the lowest concentration at 5$\mu g.g^{-1}$ and brinjals from the same site having the highest concentration at a maximum of 47$\mu g.g^{-1}$. The observed sequence of metal content in vegetable samples was as follows: spinach exhibited the highest concentration, followed by brinjal, cauliflower, tomato, and cabbage, in descending order.

RISK ASSESSMENT

The hazard quotient, as defined by [9], serves as the risk assessment index for this study. A Hazard Quotient (HQM) value more than 1, regardless of the metal in question, signifies the presence of a potential hazard linked with the metal's consumption through diet. Furthermore, the magnitude of the risk increases proportionally with higher HQ values [10].

$$HQ_M = \frac{C_M \times (1 - f_{Moisture}) \times CR}{BW \times RFD_M} \times 10^{-3} \text{ --- (i)}$$

Where, C_M= average metal concentration on dry weight basis (in $\mu g\ g^{-1}$); $f_{moisture}$= fraction of moisture content in vegetables (a reported value of 0.915 was used); CR= consumption rate of (uncooked) vegetable (in g day^{-1}; value of 300 grams was used); BW= average (kilogram) body weight (kg bw; 58 kg was used based on Indian standard value for an adult); RFD_M = reference dose for metal in mg $(kgbw)^{-1}\ day^{-1}$ taken from values reported in [11]. The HQ values for the elements are as follows: Chromium (Cr) ranges from 0.974 to 0.988, Nickel (Ni) is 0.069, Copper (Cu) ranges from 0.059 to 0.062, Lead (Pb) ranges from 6.143 to 6.421, Manganese (Mn) ranges from 1.009 to 1.266, Zinc (Zn) ranges from 0.024 to 0.043, and Cobalt (Co) ranges from 0.038 to 0.043. The HQ_{Cr} values of 0.98 ± 0.1 exhibit a close proximity to the threshold value, hence emphasizing the potential risks associated with the presence of chromium (Cr) in vegetables. Upon doing an analysis of error propagation, it has been shown that the upper limits of these values exhibit a magnitude above 1. If the computation includes other food components, it is probable that the HQ_{Cr} values will surpass the critical risk threshold of 1. In a similar vein, there exists a potential hazard when Mn quantities surpass a threshold of one HQ_{Mn} (1.03 ± 0.10). The Pb case exhibiting the highest Hazard Quotient (HQ) values, specifically 6.16 ± 0.61, poses the most significant risk. Consequently, the population residing in Ahmedabad faces a substantial level of exposure to Pb through the eating of vegetables.

HEALTH EFFECTS OF DUE TO IMPROPER DISPOSAL

Prolonged exposure to elevated amounts of heavy metals in food has the potential to lead to the chronic accumulation of heavy metals in the kidneys and liver of individuals, hence disrupting many biochemical processes and giving rise to cardiovascular, neurological, renal, and skeletal disorders [12, 8]. The presence of heavy metal ions has the potential to elicit chronic physiological responses in humans, leading to both immediate and prolonged detrimental effects. Micronutrients such as copper, zinc, manganese, cobalt, and molybdenum are essential elements for the nutritional requirements of both humans and animals. Additional elements such as chromium, cadmium, and arsenic have been identified as having carcinogenic properties. Severe developmental problems in new borne babies have been found to be connected with elevated levels of mercury and lead. [13, 14, 15] have documented that prolonged exposure to cadmium is associated with the development of kidney, prostate, and ovarian cancers. Under some environmental circumstances, cadmium has the tendency to accumulate in soil and groundwater, leading to potential exposure to organisms through the food chain. Consumption of fruits and vegetables that are contaminated with heavy metals, such as Cadmium (Cd), Lead (Pb), Copper (Cu), and Zinc (Zn), can provide a possible risk to human health when ingested chronically. This phenomenon has the potential to elevate the probability of getting pancreatic, bladder, and prostate cancer. The ingestion of lead through the gastrointestinal system can pose significant toxicity risks to human beings. One of the primary health issues linked to this condition is brain dysfunction. The presence of lead in the mother's body has been found to be connected with several adverse outcomes, including low birth weight, preterm birth, stillbirths, spontaneous abortions, and hypertension. [16] discovered a positive correlation between the consumption of green leafy vegetables and elevated levels of lead and cadmium in the daily dietary intake of individuals residing in the suburban areas of Bombay, India. This association was observed in conjunction with the increased concentration of particulate matter in the local air. Extensive evidence has substantiated the mutagenic, teratogenic, neurotoxic, and carcinogenic properties of heavy metals. Various hazardous diseases, such as cardiovascular disease, kidney disease, and nervous system problems, provide a susceptibility to the human population [17, 18].

CONCLUSION

The discharged water in the city of Ahmedabad has shown an observed increase in heavy metal concentrations, specifically Co, Cr, Cu, Mn, Ni, Pb, and Zn. This rise can be attributed to the improper disposal of wastewater generated by sewage treatment plants. There exists a potential for a substantial proportion of the urban population, comprising six million individuals, to be subjected to a risk that may adversely impact their physical well-being. A hazard quotient analysis was conducted to assess the potential risk associated with heavy metals in the consumption of vegetables. Nonetheless, it is important to acknowledge that there exists a substantial level of risk connected with the elements Pb and Mn, and it is likely that Cr also poses a similar hazard. The findings from the HQ analysis suggest that there is no discernible danger associated with the elements Co, Cu, Ni, or Zn. Regular testing of heavy metals in plant tissues is recommended to mitigate the potential escalation of these contaminants within the human food chain. In conclusion, it is imperative to effectively implement and enforce adherence to standards pertaining to heavy metals within industrial sectors. This measure is crucial in mitigating the potential hazards associated with heavy metal exposure among the general population.

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