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Drinking Water Contamination at Mahabaleshwar, Maharashtra, India due to Equine Waste: A Case Study in Environmental Risk Management[1]

By Priti Mastakar, Disha Sawant± & Nikhil Atak°*

Water contamination falls in the high health risk band and is a critical issue for health risk assessment globally. The present research on the health risk management of contaminated drinking water in Mahabaleshwar focuses on diseases caused by water pollution, generally of zoonotic origin, and specifically of equine origin, an area where not much scientific research is documented. It assesses the health risk to citizens, especially vulnerable populations like children, due to the presence of salmonella, faecal coliform bacteria and Rotavirus in drinking water sources, in Mahabaleshwar, a prominent and popular tourist destination with horse-related activities, exposing both local and tourist populations to this high health risk of contaminated drinking water. It investigates empirically the correlation between horse excreta and water contamination, assessing pollution channels, extent, and health risks using medical records and scientific laboratory assessments. Prior research indicates that mismanagement of horse waste can cause environmental contamination through bacteria and viruses, particularly Rotavirus, Salmonella, and E. coli bacteria. However, its effects on human health remain under explored. This study fills this gap by applying risk management principles to assess hazard exposure in a tourism-dependent location, where horse excreta is a major contaminant. The study suggests a solution strategy for decontamination while not compromising the economic survival of the horse owners.[1]

Keywords: *health risk management, equine waste management, drinking water contamination, faecal coliform bacteria, Rotavirus*

*Professor, Gokhale Institute of Politics and Economics, Centre for Sustainable Development, India.
±Research Assistant, Gokhale Institute of Politics and Economics, Centre for Sustainable Development, India.
°Research Assistant, Gokhale Institute of Politics and Economics, Centre for Sustainable Development, India.

[1]Pursuant to the findings of the authors and their presentations to the local governments and media, action was taken on two accounts: as advised by Dr. Priti Mastakar, the equine waste is being collected and transported to the biomethanation plant in Mahabaleshwar, following the organic Waste to Energy model. Two, the water treatment plant was repaired under her supervision using organic methods of filtration. After regular monthly lab tests of the water samples from January to May 2024 during which the water treatment process was repaired, at last, the water sample collected on the 31st May 2024 came completely free of both bacteria and viruses. The National Institute of Virology (NIV) which is the only authorized institution in India to handle viruses certified that the water was safe from Rotavirus and other viruses. This was the biggest achievement for the research team – to provide completely safe drinking water to the residents of Mahabaleshwar.

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Introduction

Water contamination is a significant global issue that poses serious threats to public health and the environment. Water pollution is caused by a variety of factors, including industrial waste, agricultural runoff, sewage discharge, and improper waste disposal. As per scientific rankings of environmental problems given by the Environment Protection Agency, (EPA), U.S., (EPA 1992), contamination of drinking water falls within the band of 'high risk to human health'. Exposure to a risk of this grade can lead to grave consequences for human health if not managed adequately in time. When robust risk management strategies are in place to combat the high health risk especially to children and older populations due to the pollution of drinking water such events can be prevented.

In many parts of the world, water contamination is a growing concern, especially presence of faecal coliform in drinking water in tourist destinations where local and floating populations are exposed to this high health risk. Faecal coliform bacteria and Rotavirus are found in the faeces of warm-blooded animals like cattle and horses. Rotavirus affects young foals and children severely, leading to morbidity and even mortality. When these bacteria and viruses enter water sources, they can cause a range of illnesses, including diarrhoea, dysentery, gastroenteritis, acute abdominal cramps, and fever. The dry excreta can rise into the air with high footfall and wind and cause acute respiratory infections (ARI) too. This is especially concerning in areas where water sources are used for drinking, bathing, and recreational activities. Therefore, a comprehensive risk management approach is essential to identify, assess, and mitigate the risks associated with water contamination, particularly in vulnerable areas like tourist destinations where the exposure to this risk is high.

Mahabaleshwar is a popular tourist destination, renowned for its scenic beauty, diverse flora and fauna, pleasant weather attracting a high footfall. Mahabaleshwar, situated in the Satara district, is nestled in the Western Ghats Mountain range. Positioned at an altitude of 1,372 metres above sea level, it is approximately 120 kilometres southwest of Pune and 285 kilometres from Mumbai, (Urban Development Department, Government of Maharashtra n.d.). The city population is 13,405, with a total number of 1751 households (HH) and a total area of 19.55 sq km, attracting around 10 to 15 lakh tourists annually, (Urban Development Department, Government of Maharashtra n.d.). Venna Lake is the source of drinking water both in the hill stations of Mahabaleshwar and Panchgani, however it is exposed to contamination because of the two leisure activities of boating and horse riding offered to tourists right on the lake.

Horses are commonly used for tourism activities, such as horse riding and carriage rides, in this mountainous region of Mahabaleshwar. It hosts as many as 150-170 horses that are parked next to and above the drinking water source, raising concerns about the safety of drinking water due to the run off of equine waste into the water source**.** The proximity of horses and horse excreta and human activity on the lake is therefore a strong reason for the drinking water contamination posing high health risk to the local and visiting population as viruses and bacteria are present in equine waste as per scientific data.

Horse manure contains nutrients like nitrogen and phosphorus, as well as pathogens like E. coli, Salmonella, Rotavirus and Hendra virus (Nemoto 2021), which are harmful to human health. When manure is not managed properly, it can lead to the contamination of water sources, resulting in various problems. In terms of surface water, it is concerning when excreta enter lakes, streams, ponds, drains, ditches, and wetlands. To prevent damage to stream banks and shorelines, it is important to control horse access to waterways. Hoof traffic can compact the soil, disturb vegetation, and increase erosion and runoff. By restricting access, the occurrence of "direct deposit events" can also be reduced. Horse excreta containing nitrates also contaminates groundwater as light-textured soils are prone to the leaching by excess nitrogen, which is not utilised by plants, and enters groundwater as nitrates. This leads to health problems, particularly in infants and the elderly. Additionally, if manure washes overland and comes into contact with drinking water wells, it can seep down around well casings, transporting both nitrates and pathogens to the groundwater. Proper management practices are crucial to mitigate these risks and protect the water quality.

Drinking water contamination falls within the highest risk band and requires immediate action. Drinking water contaminated with horse faecal matter can cause a range of health problems, including gastrointestinal illnesses like Diarrhoea, Typhoid, and Cryptosporidium Campylobacteriosis, Giardiasis, and may also pose a long-term risk of chronic diseases like Leptospirosis. Little is known about the ill effects of horse manure containing excessive phosphorus and nitrogen on the local fauna. Horse Owners in developing countries usually cohabitate with the horses and due to lack of awareness of diseases and contamination from animal excreta due to a gap in research within this area. Understanding the extent and nature of the contamination is important for developing effective management strategies to prevent such contamination and safeguard public health.

The present research on contamination of drinking water at Mahabaleshwar originated from the local administrative body due to the proximity of horses and cattle next to the drinking water source. The principles of risk management were applied to develop a solution-based strategy. The study aims to conduct a hazard exposure assessment to determine the health risk to the population by assessing the extent of water contamination resulting from the mixing of horse excreta with water. This involves creation of a dose-response analysis by examining water samples to measure the dose of contamination and analysing medical records to determine the number of related medical cases, morbidity, and mortality. Secondly, the study aims to assess various parameters, including the magnitude, frequency, and duration of exposure to contaminated water, as well as the pathways through which contamination reaches the affected population while keeping sensitivities within the population in mind. The third objective is to establish correlations between the severity of contamination in water samples and the occurrence of medical cases based on hospital and clinic records. Finally, the study aims to propose strategies to separate the contaminants from the drinking water source while ensuring that there is no reduction in commercial activity of the resident community and that no population is negatively impacted financially or economically.

This study utilises an empirical methodology, incorporating both quantitative and qualitative approaches to gather primary fieldwork data. In addition to the primary data, secondary data from various sources such as medical publications, government documents, court orders, and similar sources is collected and analysed. The research could enable better management strategies by clarifying the scope and severity of the problem, lead to better health outcomes through change in administration of water resources, increasing awareness among locals, tourists and policymakers and induce enhanced environmental quality and prevention of degradation of natural resources. The solutions worked out here could set a precedent for other tourist hill station destinations facing similar challenges where horses and cattle excreta is not properly managed and develop strategies for mitigating the negative effects of improper waste management.

This research paper is organised in the following manner: the introduction is followed by the Literature Review, then the purpose and objectives of the research, the methodology, the findings and results, solution strategy, recommendations and conclusion. The methodology covers the Human Health Risk Assessment model, the pilot study, data sources and tools. The Findings and Results cover the medical records, water samples laboratory analysis, each has its sub-conclusion, then interviews followed by the estimation of actuarial risk. Recommendations and solution strategy are presented next followed by the final conclusion. The Literature Review presented next shows the gap in the study on contamination by equine waste.

Literature Review

Zoonotic diseases are illnesses passed from animals to humans through harmful microorganisms. They spread through direct/indirect contact, water, food, or carrier insects like ticks and can range from mild to severe, and even fatal. ("Zoonotic diseases," 2021). Over 60% of known infectious diseases in humans come from animals, and 75% of new/emerging diseases in humans originate from animals (Taylor et al. 2001).

While studies have primarily concentrated on the transmission of respiratory and vector-borne pathogens from animals to humans, like Ebola and West Nile Virus, there has been an insufficient emphasis on pathogens present in animal faeces that are spread through water, sanitation, and/or hygiene (Penakalapati et al. 2017). Several pathogens originating from animals can be transmitted through contact with animal faeces, leading to acute gastrointestinal symptoms. Exposure to these pathogens can result in long-term growth impairments in children, as well as severe and lasting health consequences for pregnant women. (Penakalapati et al. 2017). The Global Burden of Disease Report of 2015 estimated that one third of deaths due to diarrhoea in the group of children below the age of 5 are associated with pathogens found in animal faeces. (Wang et al. 2015). Cryptosporidium, an important aetiology of childhood diarrhoea, is heavily transferred through animal faeces and poses severe repercussions such as child growth faltering, in the absence of vaccination and treatment options against it. (Penakalapti et al. 2017). These health risks

necessitate further research and innovation in disposal practices to safeguard humans against germs from animal faeces.

In addition, livestock excreta have a detrimental impact on the environment. Livestock excreta contribute to the degradation of the environment through significant greenhouse gas emissions (12-18%), ammonia volatilization, heavy metal pollution from animal excreta, and the discharge of veterinary antibiotics through livestock excreta (Cai et al. 2021). The expanding livestock production and subsequent increase in excretion have placed additional strain on the global environment. While the application of livestock excreta on land is often considered a beneficial practice for both livestock and crop production, concerns regarding potential biosafety issues associated with its use are currently under scrutiny (Cai et al. 2021). Given the adverse effects of animal excreta on human health and the environment, there is a crucial need for research in this area.

Within the domain of zoonotic diseases spreading through animal faeces, the literature review especially on diseases spread through horse excreta is scanty.. Horses play critical roles worldwide in recreation, food production, transportation, and as working animals. These roles vary across regions and socioeconomic conditions. While modern transportation has made advancements, which have altered human-horse interactions, there remains a global risk of zoonotic pathogen transmission from horses to humans. Despite this, the knowledge and awareness of the diseases that could be spread from horses to humans through direct contact or through their faeces remains poor. The 2013 survey conducted among Canadian public health professionals revealed a lack of awareness regarding common diseases transmitted by horses. Less than 36% of respondents believed that Salmonella, Cryptosporidium, or Escherichia coli could be contracted from horses, and only 61% were aware of the potential for rabies transmission from horses. (Snedeker et al. 2013). This highlights the importance and urgency of creating awareness around equine diseases, especially in tourism-reliant hill stations like Mahabaleshwar where horse riding is a significant contributor. E. coli, particularly the strain E. coli O157: H7, can be transmitted through contact with horse faeces. It can cause severe gastrointestinal illness in humans, leading to symptoms like diarrhoea, abdominal cramps, and sometimes even kidney damage. ("Common offenders: Equine pathogens to keep on your radar," 2020) Salmonella is another pathogen commonly found in horse faeces. Infection can occur through direct contact with horses or by consuming food or water which is contaminated by horse faeces. Salmonella can cause salmonellosis in humans, resulting in symptoms such as diarrhoea, fever, and abdominal pain. In some cases, it can lead to more severe complications. ("Common offenders: Equine pathogens to keep on your radar," 2020). Cryptosporidium parvum is a parasite that can be shed in horse faeces and can contaminate water sources. Ingesting contaminated water or food can lead to Cryptosporidiosis in humans. This parasitic infection can cause gastrointestinal distress, including diarrhoea, stomach cramps, and nausea. ("Common offenders: Equine pathogens to keep on your radar," 2020). Newborn foals frequently suffer from diarrhoea, primarily caused by rotavirus in major equine breeding centres worldwide. Rotaviruses are robust against pH levels of 3 to 7 and resist common disinfectants, including bleach, often used in water purification. Ethanol, phenols, and formalin exhibit efficacy in deactivating the virus

(Magdesian et al. 2014). Human exposure to animal faeces through the contamination of drinking water sources and storage is a significant concern. Numerous studies have indicated that open ponds and surface waters are particularly vulnerable to faecal contamination from animals. However, it is important to note that contamination has also been observed in public and private tube wells (Penakalapati et al. 2017). Exposure to animal faeces often takes place directly within the domestic environment, with animals found to contaminate fields and soil through indiscriminate defecation, as supported by consistent evidence (Penakalapati et al. 2017). Broadly, cohabitation with horses has been found to be one of the primary pathways of contamination. Mahabaleshwar and its neighbouring city Panchgani's primary drinking water source is the Venna Lake.

The lake lacks any segregation measures to separate the horses, which are commonly used for riding, from the drinking water. Horse excreta/manure is a concern for both surface waters and groundwater, as it contains pollutants and, under the right circumstances, can pose a threat to humans and the environment. Excreta entering surface waterways, including lakes, streams, ponds, drains, ditches, and wetlands is likely due to uncontrolled access to waterways and the event of 'direct deposit'. Undisposed excreta that are left to be dried up by the sun, also can either be carried by the air or washed directly into the waterways during monsoons. Hoof traffic compacts the soil, disturbs vegetation, and increases erosion and runoff. As per a report ("One horse or a hundred: Manure and water don't mix (WO1020)," 2015), drinking water supplies, especially those in light-textured soils, are susceptible to contamination through leaching. Excessive nitrogen, in the form of nitrates, can enter groundwater when horse manure is left in piles or spread excessively. Nitrates, which have been associated with health issues in infants and the elderly, can leach into drinking water. Moreover, when manure comes into contact with drinking water wells, it can transport both nitrates and pathogens to groundwater by seeping down around well casings.

The transfer of diseases from horses to humans raises significant concerns, as horses are susceptible to emerging diseases, including zoonotic ones. The impact of emerging diseases on human and equine health was highlighted in Australia in 1994 when a severe respiratory disease outbreak resulted in the deaths of horses and individuals, including a trainer and a stable hand in Queensland. (Bender et al. 2005). There have been several outbreaks of diseases from direct contact between horses and humans that have signified the need for greater research in that area. This is especially important in low-income, developing countries where a lot of groups economically dependent on horses cohabitate with them. There is a lack of awareness about the diseases, hygiene practices, and treatment options. Dermatophilosis, also known as rain rot or mud fever, is a bacterial skin infection that can be transmitted from horses to humans. The disease is caused by the bacterium Dermatophilus Congolensis and is typically contracted through direct contact with infected horses or contaminated objects such as brushes or tack. ("Diseases with horse-to-human transmission," 2021). Ringworm is a fungal infection that affects the skin, hair, and sometimes nails. It can be transmitted from horses to humans through direct contact with infected horses or contaminated objects. The fungus responsible for ringworm in horses is often from the Trichophyton or Microsporum species. ("Diseases with

horse-to-human transmission," 2021). Glanders is a highly contagious and often fatal bacterial infection caused by Burkholderia Mallei. While it primarily affects horses, it can also infect humans through direct contact with infected horses or contaminated materials. Glanders can cause severe respiratory symptoms and can potentially lead to systemic infections in humans ("Diseases with horse-to-human transmission," 2021). Anthrax is a bacterial infection caused by Bacillus anthracis. Although rare, horses can become infected with anthrax through ingestion or inhalation of spores. Humans can be exposed to anthrax by handling infected horses or coming into contact with contaminated animal products. Anthrax poses significant health risks to both horses and humans, and it is considered a zoonotic disease. ("Diseases with horse-to-human transmission," 2021).

Risk assessment is a scientific procedure, commonly used to evaluate the relative risks posed by environmental hazards to human health and ecology (Callan & Thomas 2013, p. 18). The goal of the assessment we conducted is to check if a causal relationship exists between the identified hazard i.e. water contaminated by horse excreta and observed health or ecological effects. Depending on the link established, we quantified the risk posed to society using a dose-response function. Dose-response relationship refers to the quantification of the human response to different doses of a hazardous substance, determining the profile of effects, and identifying a threshold level of exposure based on scientific evidence (Callan & Thomas 2013, p. 130). Threshold level refers to the point of exposure to a hazardous substance up to which no response or adverse effects are observed based on scientific evidence. An exposure assessment was conducted to determine the various pathways for food and water contamination by horse excreta. As per Shah (2012), testing of water samples on parameters such as turbidity, chlorides, pH, etc alongside conducting its microbial analysis is important to get a comprehensive assessment of the water quality. The final step of risk management involved evaluation and selection of the most efficient policy tool to reach at the risk level from the hazard that we determined as 'tolerable' (Callan & Thomas 2013, p. 136).

Purpose of the Research Study

Drinking water contamination poses a high health risk to all populations, this risk is even higher among children and senior citizens. The purpose of this study is to examine and assess the drinking water contamination at Mahabaleshwar if any, to find the causes of this contamination, to assess whether this contamination has a zoonotic origin, and assess the risk posed to the population in Mahabaleshwar, both local and floating. The purpose of the study is also to recommend probable solutions to mitigate the risk of drinking water contamination to the hill station's population.

Objectives of the Research Study

Following were the objectives of the study:

1.Hazard Exposure Assessment:

The process through which a generalised dose-response relationship is applied to specific conditions for an affected population. Assessment of the dose, the extent of water contamination due to mixing of horse excreta with water through water samples testing, and response, the number of related medical cases, morbidity and mortality, was conducted to determine the health risk to the population.

2. Assessing the following parameters:

- the magnitude, frequency, and duration of exposure
- the pathways from the source to the affected population
- any sensitivities within the population group
-

3. Establishing a correlation between

a) The severity of the dose, that is contaminated water through examining the water samples, and the medical cases as an outcome of the exposure to the dose, to be found from the medical records of the hospitals and clinics. b) establishing a correlation between the contamination of water on the days that the water samples were collected to the population, both local and floating as the number of tourists at this hill station is very high in summer.

4. If there was a correlation to look at alternative strategies to separate the pathogens from the drinking water source.

5. To devise the strategy in such a manner that no population is affected economically or financially but are benefitted from it.

Methodology

An empirical methodology with data gathered from primary fieldwork both quantitative and qualitative was used for this study. Secondary data was collated from medical publications, government documents, court orders, and the like.

The following assessments were made:

Risk Assessment: In Mahabaleshwar, horse excreta are contaminating the drinking water, this lies in the highest risk band as shown in Table 1, based on scientific data generated by the Environmental Protection Agency, U.S.A.

Table 1. *Scientific Ranking of Environmental Problems*

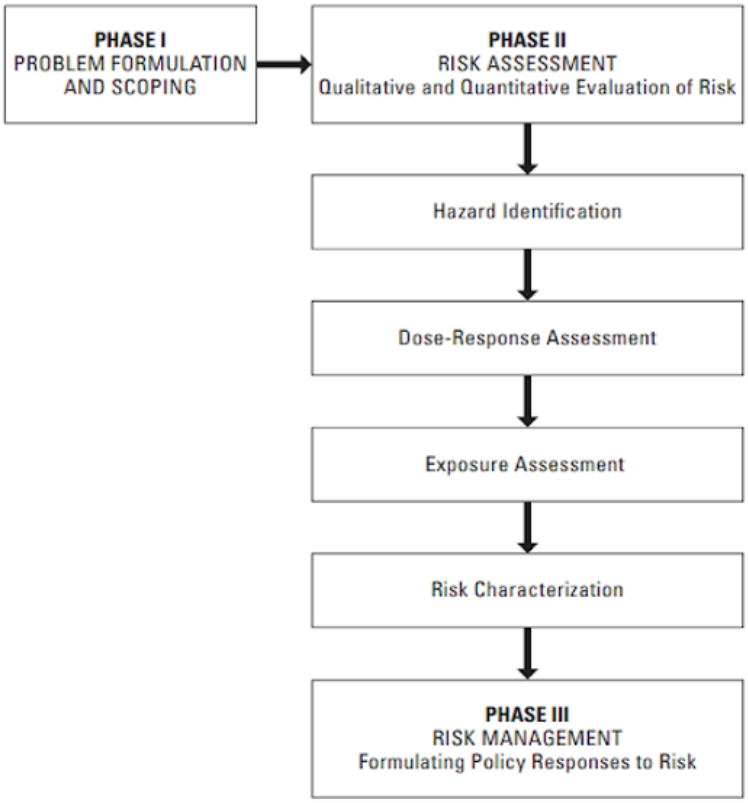
Relative Risk Ranking	Environmental Problem
High risk to human health	Ambient air pollutants Worker exposure to chemicals in industry and agriculture Indoor pollution Contamination of drinking water
High risk to natural ecology and human welfare	Habitat alteration and destruction Species extinction and loss of biological diversity Stratospheric ozone depletion Global climate change
Medium risk to natural ecology and human welfare	Herbicides/pesticides Contamination of surface waters Acid deposition Airborne toxics
Low risk to natural ecology and human welfare	Oil spills Groundwater contamination Radionuclides Thermal pollution Acid runoff to surface waters

Source: U.S. EPA, Office of Communications, Education, and Public Affairs (April 1992), p 9; U.S. EPA, Science Advisory Board (September 1990)

In Table 1 one can see that contamination of drinking water is in the high-risk band because it is linked to human fatalities. Mahabaleshwar's single largest drinking water source is Venna lake, the presence of horse excreta in its vicinity in large quantities and along its pipelines have implications for contamination of both surface waters and groundwater. Thus, a risk assessment and risk management methodology had to be adopted.

Figure 1 shows the steps in human health risk assessment process:

Figure 1. *Human Health Risk Assessment Process*



Source: Adapted from U.S. EPA, Risk Assessment Portal, (August, 2010); National Research Council of the National Academies (2008).

The following steps were used for assessing and finding a solution to the problem:

1. Exposure Assessment:

The process through which a generalised dose-response relationship is applied to specific conditions for an affected population.

2. Assessing the following:

- the magnitude, frequency, and duration of exposure
- the pathways from the source to the affected population and the routes into the body
- any sensitivities within the population group

Accordingly, the scope of the work to be done for the water study in Mahableshwar was:

1. Study of water supply systems.
2. Identifying areas of drinking water and horse excreta interface.
3. Assess the amount of the horse excreta discharge. Laboratory testing of the water was conducted on different days and particular times.
4. Identify alternative locations for housing the horses.
5. Assess the feasibility of installing a biogas plant for the horse excreta
6. Prepare the documents and strategy for the resolution of the problem.
7. Water tests were done on the following parameters:

pH, Turbidity, Total Dissolved Solids, COD, BOD, Total hardness (CaCO3), Total alkalinity, Sulphate, Iron (Fe), Calcium (Ca), Magnesium (Mg), Copper (Cu), Zinc (Zn), Total coliforms, E.coli, Salmonella, Pseudomonas, Hendra and Rota viruses. Methane contamination, Nitrogen, Phosphorous.

Methods to assess and quantify the dose response between the water contaminated by horse excreta and the medical cases linked to such a dose were applied.

At Japalouppe equestrian farm a sustainability and ESG project has been launched by the owner Mr. Rohan More, the author Dr. Priti Mastakar is designing the sustainability study to bring solutions to the challenges of water contamination and soil contamination due to animal excreta waste disposal. The author, along with the owner is establishing sustainability at the farm, this includes the building of organic STPs and waste to energy plants converting animal waste to biogas for community kitchens along with comprehensive solar systems, and sustainable management practices are being documented. In the very short run water contamination and waste disposal will be streamlined as speedily as possible. This pilot study will set the design for solutions for the Mahabaleshwar drinking water contamination study.

Data

For data collection, bespoke surveys, questionnaires, and interview questions were developed to source both quantitative and qualitative data.

Data Sources

Field observations: Field study and empirical data were collected, and secondary sources supplementing the on-field analysis were processed, these have been elaborated below.

Primary Data

I. Quantitative

1. Interviews with the government hospitals, medical superintendents, and local medical clinics were conducted and medical records of government hospitals were checked and data collated for the number of related cases.
2. For selecting the locations for collection of water samples to assess drinking water contamination random sampling was used. The following strategy was used in consultation with the Urban Planning officer and the water department staff of Mahabaleshwar Giri Parishad for the selection of the sample points:
   a) Water samples were collected from the drinking water sources of Venna Lake and Glen Ogle dam.
   b) Water samples were collected from the water purification plants at Wilson Point in Mahabaleshwar and MJP plant at Panchgani.
   c) For assessing the water contamination at residential area, commercial areas and schools two factors were taken into consideration, density of population and a geographical representation of all areas.
3. Collection of disease data from medical records at hospitals and clinics.
4. Water samples were collected from the source of water, Venna lake at three times during the weekend, Sundays and mid-week, Wednesday
5. Water samples were collected from Panchgani on Wednesday, mid - week and Sunday, weekend. Water samples were collected three times, at 9 am, 1 pm and 5 pm from the centre and the pumping station at Venna lake. Consistent timings were maintained for all the samples for reducing bias.
6. Interviews with Panchgani doctors and recording of a number of medical cases.

II. Qualitative

a. Visits to the water cleaning and pumping stations
a. Visit to the drinking water source in monsoons - Glenogle tank
b. Help was taken for maps and selection of sampling sites
c. Visit to Panchgani plateau
d. Visit to the Panchgani water cleaning station
e. Interviews with veterinarians for data on horses.
f. Interviews with horse owners/horse handlers.
g. Interviews with residents on water quality.
h. Interviews with commercial and business owners
i. Interviews with NGOs.

Secondary Data

Besides gathering empirical data from government websites, court orders, official documents were also used for secondary data.

Data Collection/Processing Tools

Surveys and questionnaires were used for data collection. A risk management approach as indicated in Figure. 1 was used.

Regression analysis was used for the correlations established in the research study.

Steps of Risk Assessment:

Phase I Problem Formulation and Scoping

We first formulated the water contamination problem and the scope, what could be the reasons for this contamination and to what extent the problem was. We identified the sources of contamination, mainly the horse excreta present in close proximity to the drinking water source.

Phase II Risk Assessment: Qualitative and Quantitative Evaluation of Risk

- We conducted both qualitative and quantitative evaluation of the water sources to identify the hazard.
- We then established the Dose-Response relationship. The dose was the contaminated water, contaminated with Coliform and E Coli bacteria.
- We then conducted the Exposure Assessment, that is the extent to which citizens were affected by disease due to the water contamination.

Phase III Risk Management: Formulating Policy Responses to Risk

We then assessed the risk of the diseases of zoonotic origin and lastly formulated the strategy and solutions to the problem.

The research in this format has been presented below.

Results

The findings and results section has been divided into quantitative and qualitative observations. Data from medical cases has been presented first, then water data, both are quantitative, and then information shared by the corporation officials, residents, business owners, and NGOs has been presented.

Medical Records Findings

Horse excreta have bacteria and viruses that show symptoms of the following diseases and as per the data shared by the hospitals and clinics, the following contagious diseases were found in their medical records that could be connected with the horse excreta contaminating the drinking water:

1. Gastroenteritis
2. Diarrhoea
3. Dysentery
4. Typhoid
5. Rotavirus cases among children.
6. Acute Respiratory Infection (ARI)
7. Dermatological cases of fungal and ringworm infections among horse handlers were found too.

Medical Records Red Cross Hospital (RCH), Mahabaleshwar

Quantitative data analysis: We studied the medical records of the government hospital RCH from the year 2019 to 2022. We looked at the data for the months of high footfall, that is April to August and then November as this would give the highest exposure of patients to the diseases, both local and floating populations.

When we divided the data between the seven contagious diseases associated with contaminated drinking water, we found that diarrhoea has been prevalent since 2019. This disease can be caused by Rotavirus, Norovirus, E. coli, or parasites (NHS, 2023). Table 2 indicates some interesting developments for this disease in Mahabaleshwar.

Table 2. *Medical Records of Red Cross Hospital Mahabaleshwar, Diarrhoea*

Medical Report Rural Hospital						
Sr No	Month and Year	Diseases	Gender		Morbidity	
			Male	Female	Male	Female
1	Jan-19	Diarrhoea	3 (18)	4(12)	2 (3)	2(5)
2	Feb-19	Diarrhoea	6	5	0	0
3	Apr-20	Diarrhoea	30	15	7	5
4	May-20	Diarrhoea	30	15	7	5
5	Jun-20	Missing				
6	Jul-20	Diarrhoea	23	10	3	0
7	Aug-20	Missing				
8	Nov-20	Diarrhoea	12	8	3	2
9	Apr-21	Diarrhoea	11	14	3	6
10	May-21	Diarrhoea	10 (17)	11 (20)	3 (1)	1(3)
11	Jun-21	Diarrhoea	17	20	1	3
12	Jul-21	Diarrhoea	9 (12)	14 (15)	2 (4)	3 (3)
13	Nov-21	Diarrhoea	10 (18)	16 (12)	4	5 (3)
14	May-22	Diarrhoea	85 (92)	53 (67)	29 (23)	24 (15)
15	Jun-22	Diarrhoea	92	61	30(46)	33(20)
16	Jul-22	Missing				
17	Aug-22	Diarrhoea	12 (14)	8 (16)	0 (11)	0 (10)
18	Nov-22	Diarrhoea	40 (51)	50 (59)	22 (26)	26 (31)

Source: Red Cross Hospital Mahabaleshwar, May 2023.

It was found that, singularly, till the year 2022, there were only cases of diarrhoea, no gastritis or any other disease. In 2019, though data on high footfall months of April and May are missing, one finds the evidence of diarrhoea. In April and May of 2020, there is a spike in the diarrhoea cases. Though June data is missing, July still shows an increased number of cases, slightly lower than the high visiting tourists' season of May. In November 2020, diarrhoea cases are lesser yet present. In 2021, there is a gradual increase in diarrhoea cases from April onwards, with the highest in June and November again. The year 2022 shows a record increase in diarrhoea cases. They spike up in May, go to a record high in June, taper down in August and spike up again in November, though not as high as May.

Morbidity was defined as the number of patients that had to be admitted in hospital. If we look at the morbidity, it is the highest in May-June 2022, and in November. Approximately, 50% morbidity was seen in 2022 indicating the strength of the bacteria or virus responsible for the medical cases. The male to female ratio shows at least 40% more infections in males, morbidity seems to be similar for both genders. These conclusions match the opinion of Dr. Deshmukh, the Medical Superintendent at the RCH as presented in the next section.

If we look at gastroenteritis, this looks like a new disease in Mahabaleshwar as indicated in Table 3. Before 2022 there is no evidence of the disease in Mahabaleshwar.

Table 3. *Medical Records of Red Cross Hospital Mahabaleshwar, Gastroenteritis*

Medical Report Rural Hospital						
Sr No	Month and Year	Diseases	Gender		Morbidity	
			Male	Female	Male	Female
1	Jun-22	Gastroenteritis	1		4	9
2	Aug-22	Gastroenteritis	5 (12)	0 (5)	0(8)	0 (3)
3	Nov-22	Gastroenteritis	25 (33)	40 (52)	15 (18)	13 (15)

Source: Red Cross Hospital Mahabaleshwar, May 2023.

As observed in Table 3, the disease appeared in 2022, it is currently prevalent in Mahabaleshwar, as is evident in data sourced from the other clinics too. Also, there is a spike in cases in November. The most common way to develop stomach flu is through contact with an infected person or by ingesting contaminated food or water (Apollo hospitals 2023). The main gastroenteritis causes include viruses, bacteria, parasites, chemicals, medications, and bacterial toxins (Godfried 2023).

Acute Respiratory Infection (ARI) cases also started in 2022, this is quite unusual as COVID occurred in 2019-20 and cases came two years afterward. Table 4 below indicates the growing number of cases from May to November.

Table 4. *Medical Records of Red Cross Hospital Mahabaleshwar, ARI*

Medical Report Rural Hospital						
Sr No	Month and Year	Diseases	Gender		Morbidity	
			Male	Female	Male	Female
1	May-22	ARI (Acute Respiratory Infections)	12 (23)	20 (15)	1	2
2	Jul-22	ARI (Acute Respiratory Infections)	23 (20)	15 (23)	0	0
3	Aug-22	ARI (Acute Respiratory Infections)	42 (26)	0 (27)	0 (20)	0 (15)
4	Nov-22	ARI (Acute Respiratory Infections)	45 (29)	40 (47)	15 (1)	12

Source: Red Cross Hospital Mahabaleshwar, May 2023.

Rota virus is observed among children. Typhoid cases have been an occasional every month. Dysentery has also been occasional. Dermatological cases were not reported in the hospital but reported in private clinics in the next section.

Interviews with Health Professionals

We had two interviews with Dr. Deshmukh, the Medical Superintendent at RCH. He said there were sporadic cases of gastro, single cases of typhoid (Salmonella), rare cases of dengue and malaria. Multiple gastro cases were related to food poisoning. Acute cases were sent to Satara in the absence of micro bacterial infections as no testing facility was available in Mahabaleshwar. Nature's carrying capacity is high in Mahabaleshwar, he said due to high rainfall, all pollution is washed out so not many serious cases. In the second interview, Dr. Deshmukh gave water, food and non-vegetarian food as the three main causes of gastroenteritis. Norms of food providers like restaurants and hotels were lax he said and even after the Giriparishad (local administrative body) had been warned, there was no strict action against them resulting in the spread of disease. The food providers stored non-veg food in freezers for weeks, it was common for electricity to go off, in the absence of generators as costs for maintaining and diesel were high, the food was putrefied. To add to this, unfinished food was put back in the fridge to be re-served, it was contaminated too, so the contaminated food was again served to the population resulting in gastroenteritis cases. Rota virus, Salmonella, of two types, Elta Vibro, with fever and one with no fever, intestines getting swollen were prevalent. Food handlers, who could be carriers with no symptoms would be the cause of the spread of disease along with coughing cooks, and food handlers with no hygiene. These microbials are thermophilic, that is they do not die with heat, hence the spread of disease. Gola, a crushed ice street dessert, is also allowed to be sold, but there is no control by the corporation, he said. The floating population of tourists with their demand for restaurant food exposed them to these viruses and bacteria. The nurse, Sister Sonali Chormale shared the medical records with us (with permission), she said there were high gastro cases,

typhoid was occasional, seasonal cases of gastro were high in 2023. She also felt the increase in seasonal cases in the monsoons.

Cases in Private Clinics

Our visits for data collection to the private clinics in Mahabaleshwar and Panchgani can be divided into two parts, one, paediatric where data on diseases that are probable due to zoonotic origin was collected and two, where data on adults was collected.

Cases in children: Health risk is very high among children and so data on the paediatric cases is presented first. There were two main paediatricians, one in Mahabaleshwar and one in Panchgani. As seen in Table 5 the presence of gastritis, diarrhoea, and Rotavirus are commonly prevalent. More importantly, a vaccination for Rotavirus has been made and administered by the government hospital, and all children vaccinated, however, even then the children get affected with the virus and the cases go into morbidity with much suffering.

Table 5. *Data from Paediatric Clinics in Mahabaleshwar and Panchgani*

DATA FROM PAEDIATRIC CLINICS			
No	Name of hospital/Clinic	Paediatric Clinic - Mahab'r	Paediatric Clinic Panchgani
	Name of Doctor	Dr. Jangam	Dr. Bhilare
	Education	BHMS	BHMS
	Experience	22 Yrs	
	Diseases		
1	Gastritis	Yes - in children	Yes - in children
2	Diarrhoea	Yes - in children	Yes - in children
3	Dysentery	Occasional	
4	Frequency of such cases	30 children in April May	Seasonal
5	Morbidity	Fever vomiting, dehydration loss recovery 2-3 days	Fever vomiting, dehydration loss recovery 2-3 days
6	Rota Virus	Yes - in children	Yes - in children/even if children are vaccinated, they suffer from infection and morbidity
8	Typhoid	Rare	Rare
9	Skin diseases - Fungal	Yes - horse community	Yes
10	Ringworm	Yes - worm infection	Yes
11	What is age group of such patients	Children 4 -12 years	Children
12	Area of the clinic	Market	Market
13	Do any horse owners come for treatment	Yes	Yes

Source: Compiled by authors from Paediatric clinics in Mahabaleshwar and Panchgani.

Cases in adults: Examining the seven parameters, besides diarrhoea, gastroenteritis, and ARI, private clinics noted dermatological cases, of which fungal were quite common and ringworms were common in certain clinics. The data on diseases is presented in Table 6.

The data presented in the table is as below:

1. Dr. Ajit Prabhale's clinic. He has three years' experience in his clinic and 7years at RCH. He has treated Gastritis cases about 8 to 10, due to acidity, in the

months of May, June and July. No Typhoid cases, yes to fungal skin diseases. He said respiratory cases increase in Nov-Dec and May, June, July.

2. Dr. Dabade, MBBS, from Sai Clinic said he records 5-10 cases of Gastro daily, 5-7 of diarrhoea daily, typhoid was rare 2-3 in a season, ARI also 2-3, skin fungal infections, 3-4 daily, Rota virus, 2-3 daily, morbidity was 1-2 weekly, ringworm infections were there, horse owners had fungal infections, about 1-2 weekly.

3. Dr. Kiran Bawalekar, BHMS, had 10 years' experience. He said sporadic cases of Gastritis occurred in June July, no summer diarrhoea, no typhoid – if there was then June July, he recorded 4-5 Ringworm cases per month and Fungal skin diseases.

4. Dr. Mankar, BHMS, recorded Gastritis twice in a week, no Typhoid cases or Respiratory, he recorded Fungal cases with no seasonal variation.

5. Dr. Alaka Thoke, MBBS, practising since the 1970s had very good information to share. She said Gastritis occurred due to food and water contamination, there were fungal and ringworm cases, diarrhoea from March to June cases were frequent, reduced after June. She said there was a definite correlation of horse excreta with disease, since dry horse excreta flies into the air it results in respiratory infections. She said population has doubled and that maximum viral cases are between March to June, till 2013 there were frequent cases, they reduced after 2013, same number of cases throughout earlier, but now increase in seasonal cases. She said Ringworm was currently increasing, dysentery cases recording blood mucus was decreasing, Hendra related cases, there was no mortality but morbidity yes. Typhoid, malaria dengue was rare.

6. Dr. Suhas Jangam, BHMS, though not paediatrician gets children for treatment. More than 30 sporadic cases of gastro. 5 go into morbidity. 2% Rota virus. Horse community has skin diseases and ringworm. Age group 4- 12 years worms' problem. Sporadic cases of rota virus are in April to June.

Drinking Water Channels at Mahabaleshwar

Venna lake is the drinking water source for both Mahabaleshwar and Panchgani. From Venna lake the water is transported to the pumping station and then onward and upward to the highest point in Mahabaleshwar for cleaning and filtering to the Wilson Point. From here with gravity the water flows to all consumers. However, open wells and borewells are other sources of water. Water from the pumping station next to Venna lake is also sent to Panchgani by different pipelines and is purified in Panchgani before sending to consumers there. We saw the water cleaning plant, it consisted of the following steps (See Appendix 2).

Table 6. *Data of Prevalent Diseases of Zoonotic Origin*

DATA OF ZOONOTIC DISEASES FROM HOSPITALS & CLINICS IN MAHABALESHWAR							
	Name of hospital/Clinic	RH(Red Cross)	Vishnu Kala	Sai Clinic	Sonai Clinic	Ruby Clinic	Thoke Clinic
	Name of Doctor	Dr. Deshmukh	Dr. Prabhale	Dr. Dabade	Dr. Bawalekar	Dr. Mankar	Dr. Alaka Thoke
	Education	MBBS	BAMS	MBBS	BHMS	BHMS	MBBS
	Experience	30 yrs (3yrs)	3 + (7yrs)		10 yrs	35 yrs	47 yrs
	Diseases with zoonotic origin						
1	Gastritis	Yes	Yes	10 daily	Yes	Yes	Yes
2	Frequency of such cases		8 to 10		2 to 3 -June	Twice a week	
3	Diahorrea	Yes	Yes	Daily 5-7 cases	Yes	Yes	Yes
4	Dyssentry	Yes	Yes		Yes	Yes	Yes
5	Morbidity	2-3 cases in a season	2-3 cases in a season	1-2 weekly	NA		Blood in mucus -Few
6	Rota Virus			Yes 2-3 cases daily			Yes - in children
8	Typhoid		1 case a season		Occasional	No	Yes - Rare
9	Skin diseases - Fungal	Yes	Yes		Yes	Yes	Yes
10	Ringworm	Yes	Yes	Yes	Yes		Yes
11	Frequency of such cases				4-5 per month		
12	Respiratory	Yes	Yes	2-3 daily	Yes	Yes	Yes - Excreta in the air
13	Months with frequent cases	May/June/July	May/June/July		May/June/July	No seasonal variation	March to/June/July
14	What is age group of such patients	0-10 yrs	10-20 yrs	20-50 yrs			
15	Area of the hospital/clinics	Market	Market	Market	Market	Market	Market
16	Do any horse owners come for treatment		Yes	Yes	Yes	Yes	Yes

Source: Compiled by author through interviews and medical records of hospitals/clinics.

Mahabaleshwar Drinking Water Sources Laboratory Analysis

The drinking water purity as defined by the Indian Standards, IS 10500 in conjunction with WHO and World Bank is zero bacteria, zero E Coli, and zero coliform every 100 ml of water. The IS 10500 document is presented in Appendix 1. For the purpose of checking the purity of the drinking water at Mahabaleshwar and Panchgani, samples of drinking water were taken from drinking water sources for laboratory testing.

The drinking water source for both Mahabaleshwar and Panchgani hill stations is one, the Venna Lake situated at the entry to Mahabaleshwar. There is a second

source, Glen Ogle dam in the upper hills of Mahabaleshwar which is used only during the monsoons as a drinking water source.

To mention here, there are two commercial activities that happen in and around the drinking water source, Venna Lake. Tourists entering the hill station can do boating in the lake and horse riding next to and around the lake. The horses are parked on a plateau just above the lake. There is no collection of excreta of the horses on the plateau or around the lake so these excreta can find its way into the lake water during rains and by wind and high footfall during high tourist season in the months of April and May, especially on the weekend when there is even higher footfall. Horses and other cattle are washed and bathed past the Venna Lake dam wall. This water was also the source of the food stalls in front of the entrance to Venna Lake. The food stalls were removed by the Collector's office on the 17th of June but were till then another source, the third source of contamination around the Venna lake.

The water from the Venna Lake is carried through a pumping station (PS 1) on the banks of the lake across the road to a pumping station (PS 2) that houses huge pumps to transport water to the highest point in Mahabaleshwar, Wilson Point and down to Panchgani. The water purification plant at Wilson Point is managed by the Mahabaleshwar Giri Parishad along with monitoring from Maharashtra Jeevan Pradhikaran (MJP) and wholly by MJP at Panchgani drinking water purification plant.

At Wilson Point the water is purified and distributed to the entire Mahabaleshwar hill station using gravity. The process of purification is first aeration then sedimentation then filtration and lastly bleaching to decontaminate the water. The same process is followed at Panchgani MJP water purification plant.

The water samples were taken for laboratory examination from the following cluster places:

1. Drinking water sources: Venna Lake (PS1), Venna Lake Pumping Station (PS 2) across the road, Wilson Point and MJP Plant at Panchgani, and the Glen Ogle dam, the source of drinking water during Monsoons in Mahabaleshwar.
2. Residential places and schools.
3. Commercial areas and marketplace.
4. Groundwater contamination.

Contamination of Drinking Water at Source

The results of the laboratory analyses of drinking water sources: Venna Lake (PS1), Venna Lake Pumping Station (PS 2) across the road, Wilson Point and MJP Plant at Panchgani, and the Glen Ogle dam, the source of drinking water during Monsoons in Mahabaleshwar.

1. Drinking water source Venna Lake Pumping Station 1:

Laboratory analysis of drinking water at PS 1 shows both coliform bacteria as well as E Coli. May is a period of high tourist footfall. Water shows high contamination on 21st of May, a Sunday when the footfall is the highest. The contamination is

lower during the week, on Wednesday the 24th of May. The contamination rises steeply again in June after the rains. The contamination is expected to rise after rains as any waste containing E Coli and coliform bacteria will run into the lake with the rains. The plateau above the lake is the parking lot for the horses from where all the horses take tourists around the lake, on the roads around the lake and in the parking lot. The water contamination is thus expected. This analysis is apparent in Table 7 on the following page. All other parameters in the normal range.

Table 7. *Drinking Water Contamination Laboratory at Venna Lake*

VENNA LAKE PS 1				
Parameters	21-May	24-May	18-Jun	Range
pH at 25°C	7	7.46	6.2	5.5 to 9.0
Total Hardness (as $CaCO_3$)	6	10	12	<200
Total Dissolved Solids	30	38	42	<500
Coliform Bacteria	920	210	>1600.0	0
E Coli	Present	Present	Present	Absent
Sulphates (as SO_4)	6	2.8	2.1	<200
Chlorides (as Cl)	2	9	6	<250
Turbidity	2.3	6.6	4.3	<10

Source: Report of government approved laboratory.

2. Drinking water source Venna Lake Pumping Station 2 (PS2):

Drinking water is carried to PS2 across the road from Venna Lake. Laboratory analysis of this water too shows contamination from coliform bacteria as well as E Coli. All other parameters are within the safe range. This is shown in Table 8 below:

Table 8. *Drinking Water Contamination at Venna Lake PS 2*

VENNA LAKE PS 2		
Parameters	21-May	Range
pH at 25°C	6.88	5.5 to 9.0
Total Hardness (as $CaCO_3$)	10	<200
Total Dissolved Solids	52	<500
Coliform Bacteria	>1600	0
E Coli	Present	Absent
Sulphates (as SO_4)	6	<200
Chlorides (as Cl)	2.8	<250
Turbidity	4.7	<10

Source: Report of government approved laboratory.

3. Water analysis of drinking water distributed from the water purification plant at Wilson Point Mahabaleshwar

Drinking water distributed from Wilson Point to all of Mahabaleshwar indicated high contamination by both Coliform bacteria and E Coli on Sunday the 21st of May and Sunday

18th June. On 24th May, a weekday it shows minor coliform bacteria contamination and absence of E Coli. This is presented in Table 9.

Table 9. *Drinking Water Contamination at Water Purification Plant at Wilson Point*

WILSON POINT MJ PLANT				
Parameters	21-May	24-May	18-Jun	Range
pH at 25°C	7.18	8.52	6.8	5.5 to 9.0
Total Hardness (as $CaCO_3$)	16	16	18	<200
Total Dissolved Solids	48	52	48	<500
Coliform Bacteria	> 1600.0	2	>1600.0	0
E Coli	Present	Absent	Present	Absent
Sulphates (as SO_4)	3.8	2.8	2.4	<200
Chlorides (as Cl)	8	10	7	<250
Turbidity	1.8	1.4	0.6	<10

Source: Report of government approved laboratory.

4. Additional drinking water source during monsoons, Glen Ogle dam:

During monsoons the Mahabaleshwar Giri Parishad has a second source of drinking water, the Glen Ogle dam situated in the upper hills and fed by a natural spring. Laboratory analysis of the water is shown in Table 10 and shows presence of coliforms in May and a reduction in the bacteria after the rains. However, while in May E Coli bacteria was absent in June after the rains when the surrounding waste is washed into the dam there is presence of E Coli.

Table 10. *Drinking Water Contamination at Glen Ogle Dam*

GLEN OGLE DAM			
Parameters	21-May	18-Jun	Range
pH at 25°C	6.82	6.85	5.5 to 9.0
Total Hardness (as $CaCO_3$)	20	56	<200
Total Dissolved Solids	50	106	<500
Coliform Bacteria	220	79	0
E Coli	Absent	Present	Absent
Sulphates (as SO_4)	7	3.96	<200
Chlorides (as Cl)	3.6	10	<250
Turbidity	1.5	0	<10

Source: Report of government approved laboratory.

5. MJP Plant, Panchgani

Water from the Venna Lake is carried to the drinking water purification MJP plant in Panchgani. The laboratory analysis is presented in Table 10 below. On Sunday the 21st of May there is presence of both Coliform Bacteria as well as E Coli. When GIPE RAs visited the residential areas on 21st May, citizens had complained of contaminated drinking water. In the subsequent visit, the citizens had reported that water was now clean. The MJP plant staff reported that they had fixed the broken pipes that had been exposed to external contamination after the citizens' complaints. On 24th May, a week day and in June the both Coliform bacteria and E Coli are absent.

Table 11. *Drinking Water Contamination at Water Purification Plant Panchgani*

MJ PLANT PANCHGANI				
Parameters	21-May	24-May	18-Jun	Range
pH at 25°C	7.57	7.32	6.18	5.5 to 9.0
Total Hardness (as $CaCO_3$)	18	10	10	<200
Total Dissolved Solids	46	40	54	<500
Coliform Bacteria	>1600	0	0	0
E Coli	Present	Absent	Absent	Absent
Sulphates (as SO_4)	9	1.9	2.7	<200
Chlorides (as Cl)	3.9	9	10	<250
Turbidity	0.9	2.1	1.8	<10

Source: Report of government approved laboratory.

All the drinking water sources in both Mahabaleshwar show heavy contamination of Coliform bacteria and also show presence of E Coli, both are not permissible by Indian standards IS 10500 quoted earlier in this section.

a. Results of the laboratory analysis of drinking water contamination at residential places and schools in Mahabaleshwar

The following residential complexes were selected for drinking water samples, Ranjanwadi, Devi Chowk, Ganeshnagar Society, Gavali Mohalla and a sample school. All the residential areas including the school show the presence of Coliform bacteria in May and after rains except for the school in May, in June the school drinking water has Coliform bacteria too. All the areas also show E Coli after rains in June except Ranjanwadi. Ranjanwadi does not show E Coli in May either, however the drinking water was from an RO filter. In May Ganeshnagar Society and the school show no E Coli presence. All other parameters in the limits of the range as specified by the IS 10500 Indian standards for drinking water. This is presented in Table 12.

Table 12. *Drinking Water Contamination in Residential Areas and School*

	RANJANWADI		DEVI CHOWK		GANESHNAGAR SOCIETY		GAVALI MOHALLA	SCHOOL 1 MAHAB'R		
Parameters	21-May	18-Jun	21-May	18-Jun	21-May	18-Jun	18-Jun	24-May	18-Jun	Range
pH at 25°C	7.31	6.6	7.16	6.6	6.91	7.36	6.15	7.4	7.16	5.5 to 9.0
Total Hardness (as $CaCO_3$)	20	30	14	20	24	32	18	14	14	<200
Total Dissolved Solids	42	68	40	56	58	106	84	44.O	40	<500
Coliform Bacteria	>1600	14	920	>1600	14.5	350	920	0	920	0
E Coli	Absent	Absent	Present	Present	Absent	Present	Present	Absent	Present	Absent
Sulphates (as SO_4)	8	3.5	2	2.8	9	3.6	2.2	1.6	2	<200
Chlorides (as Cl)	3.3	8	7	7	3.8	11	18	8	7	<250
Turbidity	1.2	0.9	1.6	2.2	2	0.2	1.2	0.5	1.6	<10

Source: Report of government approved laboratory.

Drinking water in both residential complexes and in the school in Mahabaleshwar were contaminated with Coliform bacteria in May and in June after rains, Water showed E Coli bacteria after the rains in Devi Chowk, Ganesh Nagar Society, Gavali Mohalla and the school.

b. Drinking water contamination at residential places and schools in Panchgani

In Panchgani, both residential areas show Coliform bacteria contamination as shown in Table 13 E Coli bacteria is present in the 21st May water sample. All the parameters are in range.

Table 13. *Water Contamination in Panchgani*

	PANCHGANI GAVTHAN	PANCHGANI BHIMNAGAR		NAGAR PARISHAD SCHOOL PANCHGANI		
Parameters	21-May	21-May	18-Jun	21-May	24-May	Range
pH at 25°C	4.14	6.7	7.05	6.88	7.4	5.5 to 9.0
Total Hardness (as $CaCO_3$)	12	16	13	18	14	<200
Total Dissolved Solids	62	44	52	46	44	<500
Coliform Bacteria	240	45	17	0	0	0
E Coli	Present	Absent	Absent	Absent	Absent	Absent
Sulphates (as SO_4)	8	6	2.3	7	1.6	<200
Chlorides (as Cl)	4.5	3.4	10	2.9	8	<250
Turbidity	0.2	1	1.3	1.5	0.5	<10

Source: Report of government approved laboratory.

c) Drinking Water Contamination at Commercial Places in Mahabaleshwar

Laboratory analysis of drinking water at the restaurants offering food are shown in Table 14, the analyses showed Coliform bacteria after rains in June; to note here, Raj Bhavan water sample was from their RO plant and that still after the rains there was presence of Coliform bacteria. Bacteria E Coli contamination was there at Purohit Hotel after the rains.

Table 14. *Contaminated Drinking Water at Commercial Places - Restaurants*

	PUROHIT HOTEL		RAJ BHAVAN		
Parameters	21-May	18-Jun	21-May	18-Jun	Range
pH at 25°C	7.28	7	7.22	6.45	5.5 to 9.0
Total Hardness (as $CaCO_3$)	44	76	28	46	<200
Total Dissolved Solids	102	188	66	80	<500
Coliform Bacteria	0	>1600.0	0	17	0
E Coli	Absent	Present	Absent	Absent	Absent
Sulphates (as SO_4)	8	3.1	9	2.9	<200
Chlorides (as Cl)	3.2	30	5.6	10	<250
Turbidity	0.4	0.8	1.6	0.4	<10

Source: Report of government approved laboratory.

Restaurants showed contamination of drinking water after rains in the form of Coliform bacteria, Purohit Hotel showed E Coli in the after rains June water samples.

Water samples were taken from borewells for examining contamination of groundwater. Well water was also taken for sampling as surface water was showing contamination. Table 15 shows the results of the laboratory examination of water samples.

Table 15. *Groundwater Contamination*

	BERRY HILL HOTEL BOREWELL 1	BH BOREWELL 2	BOREWELL MARKET	BAGICHA OPEN WELL	
Parameters	21-May	18-Jun	18-Jun	06-Jan	Range
pH at 25°C	7.17	6.8	7	6.16	5.5 to 9.0
Total Hardness (as $CaCO_3$)	134	10	76	32	<200
Total Dissolved Solids	282	44	188	156	<500
Coliform Bacteria	280	120	>1600	0	0
E Coli	Present	Present	Present	Absent	Absent
Sulphates (as SO_4)	34	2.1	3.1	8.5	<200
Chlorides (as Cl)	9.1	8	30	29	<250
Turbidity	0.2	3.1	0.8	0.5	<10

Source: Report of government approved laboratory.

Groundwater at borewells from the market as well as Berry Hill showed contamination by both Coliform bacteria as well as E Coli bacteria. Higher contamination was at the market borewell. The open well showed no contamination of bacteria.

Laboratory analysis has shown contamination of drinking water by Coliform bacteria, this includes contamination by faeces too. There was also presence of E Coli bacteria. Another point to note was the contamination was higher on Sunday which has more tourist footfall and after the rains when excreta from the sides of the lake would enter the lake water. This was uniform for residential areas, schools, commercial areas and groundwater in Mahabaleshwar. It is thus very important to review the proximity of drinking water sources to external contamination especially horse excreta which is present next to water pipes and water sources as well as the access given to tourists to the drinking water source by offering boating as a leisure activity. Drinking water source has to be separated from the sources of contamination.

Findings from Interviews

Interview with Mr. Richard Dias:

Name of business: Treacher & Co.

The Dredging of Venna lake proposal was made 10-15 years ago, but nothing was done. STPs are not all working, there are only a couple of them. Municipality has Rs 1800 crores but do not do the projects. Golf ground and Polo ground are good alternatives for horse riding instead of the present grounds at Venna Lake.

Interview with Local Residents and Officials

Interviews with residents from Glenogle Dam, Rajanwadi, Rajbhavan and Gavali Mohalla revealed that while they had not observed symptoms of any diseases or infections associated with water contamination and found fit for consumption, the water quality was noticeably bad. Residents complained of receiving red-yellow brownish water carrying mud and algae. As per a Bhim Nagar resident, they used Alum to filter the water. As per the DRS of Panchgani, proximity of horse-riding activities and the drinking water source was responsible for water contamination induced diseases and shortcuts. He vouched for rehabilitation of the horse-riding activities away from the lake for the prevention of diseases. This opinion was shared by the water pump in charge Mr. Mane as well.

Interview with the Local Veterinarian Dr. Sisodiya

Horses are supposed to be fed a nutritional diet of Kutti (hay), Bhusa (sawdust) and Gram (lentil). Mineral deficiency was observed in the local horses. They most frequently suffered from skin diseases like mixed bacterial and fungal infections and diseases such as colic abdomen and digestive colic. Diseases in horses peaked

during the monsoons but the morbidity rate was rare. The total number of horses in Mahabaleshwar must be around 150-170, with him seeing an average of 5 - 6 cases a day. Glanders was noticed in horses first in 2008 and 2009. It is a noticeable disease with no special treatment required. Horses produce 10 kg of excreta each per day.

Interviews with Horse Owners

Horse owners did not have any knowledge on safe disposal of horse excreta and believed clean-up of faeces to be the Municipality's responsibility. They weren't aware of diseases that could be transmitted from horses to humans. They said that they had built up immunity to the skin infections afflicting horses. They did not use any protective gear while handling horses, nor provided their customers with any. Regular visits were made to the Veterinarian for check-ups. Their income was about 3-4 lakhs for 8 months in the months leading up to monsoon when horse riding took a pause.

Estimation of Actuarial Risk

Since May 2023 records were still not available, we collated cases from the 2022 records and combined with the clinic's information found an approximate conservative number of zoonotic origin cases of 785. The population of Mahabaleshwar was 13,405 as per the Swachh Bharat Mission government sources, so the actuarial risk to the population was

0.0585, that is as per the government sources. However, this number is very conservative as data on the number of cases in private clinics was not maintained and we have considered only recorded cases. This is a monthly risk assessment. The risk will be much higher when we assess the annual risk, 0.7027. However, in the absence of accurate data for the other months in the year we cannot say this risk is accurate.

Besides this there is a floating population that is about 3,500 plus during Sundays and holidays. All the tourists are also exposed to the contamination, they do not get treated in Mahabaleshwar so their cases are not recorded here, however, the risk exposure to the population increases because of this additional tourist population at the hill station during holidays.

Recommendations

In this study we have established that there is heavy water contamination due to the proximity of the horses being parked on a plateau next and above the drinking water source Venna Lake, and the horses' carrying tourists around the lake, there are also other cattle around the lake, the excreta of the horses and cattle is not collected and finds its way into the lake in two ways. During May when there is high footfall, the dried excreta rise into the air, and during June the rain carries this horse excreta waste into the lake. Apart from this, all the water pipelines to and from

Wilson Point have excreta in close proximity. Pipelines have valves that get exposed to external pollution from time to time, excreta can find its way into the water system.

At Wilson Point, the water purification plant post-treatment water sample also shows Coliform bacteria and E Coli. We found that the treatment plant had not been attended to for nine years, parts of the plant were broken and bleaching powder was being added to the water to purify it, this could be a major cause of drinking water contamination, and also the presence of horses in the vicinity but more so because the water is not getting purified with the existing method. As mentioned in the Literature Review and we quote here:

"Horse excreta/manure is a concern for surface waters and groundwater. Manure and water don't mix well. Manure/horse excreta contain pollutants …contain pathogens (including E. coli, Hendra virus, Salmonella) that can be hazardous to human health. When manure is not managed properly, these contaminants can make their way into our water and cause problems."

Also, the bleaching agent being used at the plant may not be enough to decontaminate the water as recorded in this research quoted in the literature Review: "Viral Diarrhoea -Equine Rotavirus: Diarrhoea is a frequently encountered medical problem of newborn foals, and rotavirus is the most common cause of foal enteritis in major breeding centres of the United States, Ireland, and England, as well as other countries. Rotaviruses are stable within a pH range of 3 to 7 and are resistant to iodophor, quaternary ammonium, chlorine, and hypochlorite (bleach) disinfectants."

Solution Strategy

At Venna Lake it is very important to separate the contaminant from the drinking water source, it is very important to cordon off the area of drinking water and prevent access to the water by both humans and animals. This would mean separating the horse parking from the drinking water sources and relocating the horses to a part of Mahabaleshwar where there is no connection to the drinking water. There is a Polo ground towards the other side of the hill station, away from the water sources that is much bigger than the horse park next to the lake that could house a proper training centre for tourists to engage in a horse training leisure activity. This could give a better and more steady income to the horse owners community. Second, the Polo Ground has access to the various sightseeing points of Mahabaleshwar and this access could be extended to more of such points.

The original tourist activity in Mahabaleshwar used to be such sightseeing and not the boating and horse riding at the entry point so close to the drinking water source. Such sightseeing on horseback can be promoted to sustain the Horse owners' community.

Importantly, a complete repair of the drinking water treatment plant with a monitored chlorine gas injection would decontaminate the water in a better way.

Conclusion

Mahabaleshwar is a very popular tourist hill station with a high footfall during summer holidays when the climate remains cool even when there is extreme heat elsewhere. Thus, along with the local population there is a high number in the floating population. The leisure activities offered to tourists are boating and horse riding, both are offered at the Venna Lake at the entrance to Mahabaleshwar. However, the Venna Lake is the major source of drinking water for Mahabaleshwar and Panchgani. The drinking water at Venna Lake is thus exposed to heavy contamination from both activities, especially the horse excreta that runs down from the plateau above the lake where the horses are parked and from whence the horses are taken around for tourists right next to the lake. During high footfall months this study found some vital data in the water contamination and medical cases due to exposure to the contamination in the population, that is the Dose-Response and the exposure to the health risk was very high, especially to the vulnerable populations of children and the elderly. This research study was initiated with the aim to assess the extent of contamination and propose effective solutions to safeguard the drinking water supply.

Reviewing relevant literature, sources discussing disease transmission via animal faeces, including zoonotic infections from horses were noted. The literature covered horse excreta's effects on water sources and the environment, yet the human health impact was scarcely documented. Thus, a research gap was identified in water and foodborne diseases linked to horse excreta, particularly in developing nations where horse-human cohabitation is common. Similar scarcity exists for direct horse-human contact diseases. Barring a few high court petitions demanding the relocation of horses, there was no available research on the water contamination issue in Mahabaleshwar.

Speaking to the Superintendent of the Rural Hospital Mahabaleshwar, other hospitals/clinics, and examining their medical records, it was found that Salmonella cases and Rotavirus among children were the most common. They received an estimated 150 combined cases of Diarrhoea, Dysentery, Gastrointestinal illnesses, and Acute Respiratory Infections on a daily basis and an occasional case of Typhoid. The cases came mostly from the age group of 0-10 years, 10-20 years, and above 50 years. It was also observed that there were frequent cases of Rotavirus among children in the region, which manifested in the form of vomiting, diarrhoea, fever and morbidity. Morbidity, defined as the number of patients that had to be admitted in hospital, was the highest in May-June 2022, and in November. Approximately, 50% morbidity was seen in 2022 indicating the strength of the bacteria or virus responsible for the medical cases. The male-to-female ratio shows at least 40% more infections in males, morbidity seems to be similar for both genders. This information was corroborated by the private practitioners in the area who strongly believed there exists a correlation between horse excreta and drinking water contamination. Local medical facilities noticed a recurring pattern: from April to June, corresponding with peak tourism in Mahabaleshwar, the highest cases occurred due to increased horse riding and accompanied spread of contaminants. The cases would remain within the normal range in the following few months. Post-2020, cases decreased possibly due

to improved hygiene due to COVID-19 and heightened local awareness, though tourist months could still see a rise due to visitors' lack of awareness.

Since 2008 Maharashtra Jeevan Pradhikaran (MJP) has been supplying water to approximately 25 lakh people across the region. People residing in Ranjanwadi and near Glenogle Dam complained of receiving muddy water with algae in it. Similar complaints were observed in Panchgani. In order to establish a scientific correlation between the contaminated water and horse excreta, we collected water samples for lab testing varying across locations, times of the day, and months. Water samples were drawn from Venna Lake, nearby pumping stations, the MJP filtration plant, different localities, schools, and hotels. All the drinking water sources in Mahabaleshwar show heavy contamination of Coliform bacteria and also show the presence of E. coli, both are not permissible by Indian standards of water quality IS 10500. Drinking water in both residential complexes and in the school in Mahabaleshwar was contaminated with Coliform bacteria in May and in June after rains, water showed E. coli bacteria after the rains in some places. The analysis of water samples showed that the contamination was higher during days of high tourist footfall and after the rains when excreta from the sides of the lake would enter the lake water.

The combined analysis of water samples, medical records, site visits, and interviews, mandates the review of the proximity of drinking water sources to external contamination especially horse excreta, as well as the tourist access given to this source via boating. The horse parking must be relocated in a manner that the interface is completely cut off to prevent the flow of contaminants into the water. As per our recommendation, an ideal location would be Polo Ground which offers easy access to all the main sightseeing spots of Mahabaleshwar. It is big enough to allow for the creation of a horse-riding training centre as well, which would be a new and steady source of income for the horse owners. As dried-up excreta rise up into the air, simply cutting off the interface is not enough, implementation of a safe and effective disposal mechanism is necessary. The creation of a biogas plant for added commercial benefits could be considered. Further, as it is revealed by the analysis the current filtration system in place is not effective and resistant against the contaminants. This is especially true for Rotavirus, given its prevalence, despite vaccines being administered in children. Thus, a rectification of the filtration process and instruments is required.

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Appendix 1. *The Analysis for Lab Reports of the Water Sample tested was based Upon the Indian Standards for Bacteriological Quality of Drinking Water. (Bureau of Indian Standards, 2012)*

Table 6 Bacteriological Quality of Drinking Water[1)]
(*Clause* 4.1.1)

Sl No.	Organisms	Requirements
(1)	(2)	(3)
i)	*All water intended for drinking*:	
	a) *E. coli* or thermotolerant coliform bacteria[2), 3)]	Shall not be detectable in any 100 ml sample
ii)	*Treated water entering the distribution system*:	
	a) *E. coli* or thermotolerant coliform bacteria[2)]	Shall not be detectable in any 100 ml sample
	b) Total coliform bacteria	Shall not be detectable in any 100 ml sample
iii)	*Treated water in the distribution system*:	
	a) *E. coli* or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml sample
	b) Total coliform bacteria	Shall not be detectable in any 100 ml sample

[1)]Immediate investigative action shall be taken if either *E.coli* or total coliform bacteria are detected. The minimum action in the case of total coliform bacteria is repeat sampling; if these bacteria are detected in the repeat sample, the cause shall be determined by immediate further investigation.

[2)]Although, *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests shall be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies.

[3)]It is recognized that, in the great majority of rural water supplies in developing countries, faecal contamination is widespread. Under these conditions, the national surveillance agency should set medium-term targets for progressive improvement of water supplies.

Appendix 2. *Pictures of the Team from Water Sample Collection*

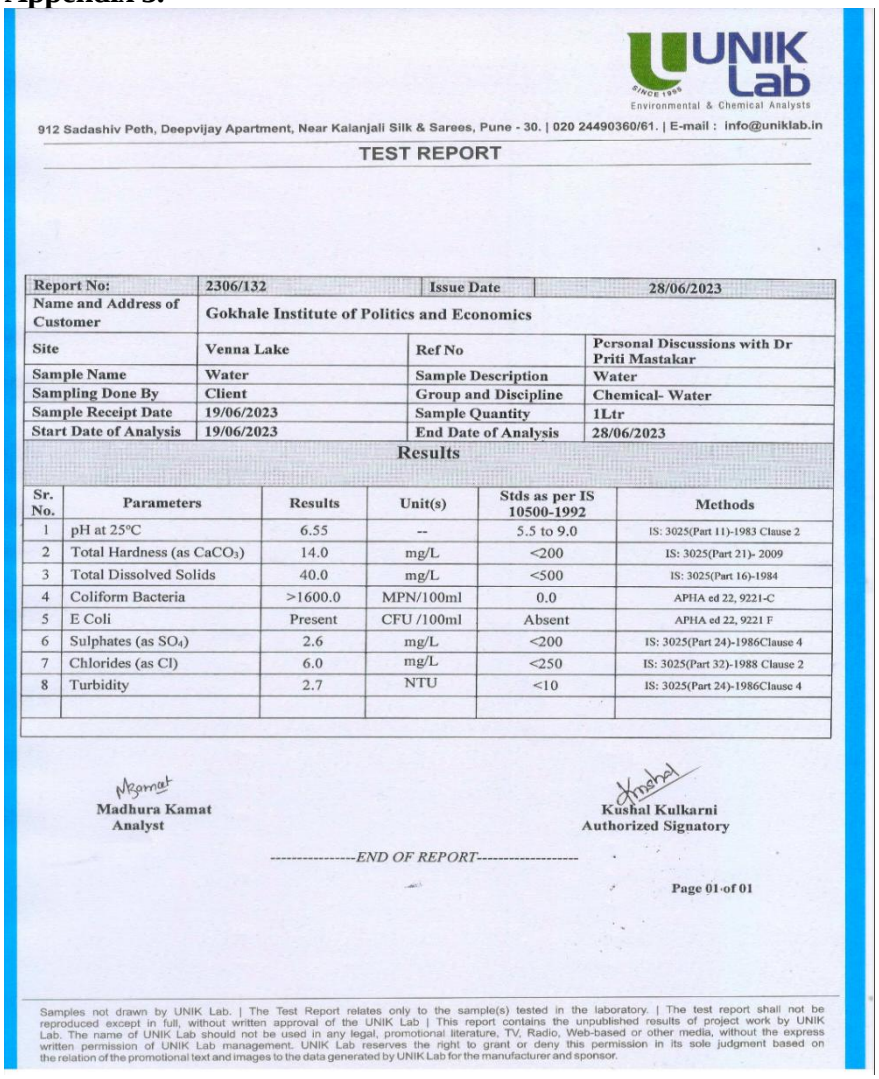
Venna Lake Sample

Power Station Sample

Wilson Point Sample

Raj Bhavan Sample

Appendix 3.



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912 Sadashiv Peth, Deepvijay Apartment, Near Kalanjali Silk & Sarees, Pune - 30. | 020 24490360/61. | E-mail : info@uniklab.in

TEST REPORT

Report No:	**2306/132**	**Issue Date**	**28/06/2023**
Name and Address of Customer	**Gokhale Institute of Politics and Economics**		
Site	**Venna Lake**	**Ref No**	**Personal Discussions with Dr Priti Mastakar**
Sample Name	**Water**	**Sample Description**	**Water**
Sampling Done By	**Client**	**Group and Discipline**	**Chemical- Water**
Sample Receipt Date	**19/06/2023**	**Sample Quantity**	**1Ltr**
Start Date of Analysis	**19/06/2023**	**End Date of Analysis**	**28/06/2023**

Results

Sr. No.	Parameters	Results	Unit(s)	Stds as per IS 10500-1992	Methods
1	pH at 25°C	6.55	--	5.5 to 9.0	IS: 3025(Part 11)-1983 Clause 2
2	Total Hardness (as $CaCO_3$)	14.0	mg/L	<200	IS: 3025(Part 21)- 2009
3	Total Dissolved Solids	40.0	mg/L	<500	IS: 3025(Part 16)-1984
4	Coliform Bacteria	>1600.0	MPN/100ml	0.0	APHA ed 22, 9221-C
5	E Coli	Present	CFU /100ml	Absent	APHA ed 22, 9221 F
6	Sulphates (as SO_4)	2.6	mg/L	<200	IS: 3025(Part 24)-1986Clause 4
7	Chlorides (as Cl)	6.0	mg/L	<250	IS: 3025(Part 32)-1988 Clause 2
8	Turbidity	2.7	NTU	<10	IS: 3025(Part 24)-1986Clause 4

Madhura Kamat
Analyst

Kushal Kulkarni
Authorized Signatory

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Report No:	**2306/129**	**Issue Date**	**28/06/2023**
Name and Address of Customer	**Gokhale Institute of Politics and Economics**		
Site	**Glen Ogle Tank**	**Ref No**	**Personal Discussions with Dr Priti Mastakar**
Sample Name	**Water**	**Sample Description**	**Water**
Sampling Done By	**Client**	**Group and Discipline**	**Chemical- Water**
Sample Receipt Date	**19/06/2023**	**Sample Quantity**	**1Ltr**
Start Date of Analysis	**19/06/2023**	**End Date of Analysis**	**28/06/2023**

Results

Sr. No.	Parameters	Results	Unit(s)	Stds as per IS 10500-1992	Methods
1	pH at 25°C	6.85	--	5.5 to 9.0	IS: 3025(Part 11)-1983 Clause 2
2	Total Hardness (as $CaCO_3$)	56.0	mg/L	<200	IS: 3025(Part 21)- 2009
3	Total Dissolved Solids	106.0	mg/L	<500	IS: 3025(Part 16)-1984
4	Coliform Bacteria	79.0	MPN/100ml	0.0	APHA ed 22, 9221-C
5	E Coli	Present	CFU /100ml	Absent	APHA ed 22, 9221 F
6	Sulphates (as SO_4)	3.96	mg/L	<200	IS: 3025(Part 24)-1986Clause 4
7	Chlorides (as Cl)	10.0	mg/L	<250	IS: 3025(Part 32)-1988 Clause 2
8	Turbidity		NTU	<10	IS: 3025(Part 24)-1986Clause 4

Madhura Kamat
Analyst

Kushal Kulkarni
Authorized Signatory

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Report No:	**2306/130**	**Issue Date**	**28/06/2023**
Name and Address of Customer	**Gokhale Institute of Politics and Economics**		
Site	**Wilson Point**	**Ref No**	**Personal Discussions with Dr Priti Mastakar**
Sample Name	**Water**	**Sample Description**	**Water**
Sampling Done By	**Client**	**Group and Discipline**	**Chemical- Water**
Sample Receipt Date	**19/06/2023**	**Sample Quantity**	**1Ltr**
Start Date of Analysis	**19/06/2023**	**End Date of Analysis**	**28/06/2023**

Results

Sr. No.	Parameters	Results	Unit(s)	Stds as per IS 10500-1992	Methods
1	pH at 25°C	6.8	--	5.5 to 9.0	IS: 3025(Part 11)-1983 Clause 2
2	Total Hardness (as $CaCO_3$)	18.0	mg/L	<200	IS: 3025(Part 21)- 2009
3	Total Dissolved Solids	48.0	mg/L	<500	IS: 3025(Part 16)-1984
4	Coliform Bacteria	>1600.0	MPN/100ml	0.0	APHA ed 22, 9221-C
5	E Coli	Present	CFU /100ml	Absent	APHA ed 22, 9221 F
6	Sulphates (as SO_4)	2.4	mg/L	<200	IS: 3025(Part 24)-1986Clause 4
7	Chlorides (as Cl)	7.0	mg/L	<250	IS: 3025(Part 32)-1988 Clause 2
8	Turbidity	0.6	NTU	<10	IS: 3025(Part 24)-1986Clause 4

Madhura Kamat
Analyst

Kushal Kulkarni
Authorized Signatory

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Report No:	**2306/135**	**Issue Date**	**28/06/2023**
Name and Address of Customer	**Gokhale Institute of Politics and Economics**		
Site	**School No 1**	**Ref No**	**Personal Discussions with Dr Priti Mastakar**
Sample Name	**Water**	**Sample Description**	**Water**
Sampling Done By	**Client**	**Group and Discipline**	**Chemical- Water**
Sample Receipt Date	**19/06/2023**	**Sample Quantity**	**1Ltr**
Start Date of Analysis	**1906/2023**	**End Date of Analysis**	**28/06/2023**

Results

Sr. No.	Parameters	Results	Unit(s)	Stds as per IS 10500-1992	Methods
1	pH at 25°C	7.16	--	5.5 to 9.0	IS: 3025(Part 11)-1983 Clause 2
2	Total Hardness (as $CaCO_3$)	14.0	mg/L	<200	IS: 3025(Part 21)- 2009
3	Total Dissolved Solids	40.0	mg/L	<500	IS: 3025(Part 16)-1984
4	Coliform Bacteria	920.0	MPN/100ml	0.0	APHA ed 22, 9221-C
5	E Coli	Present	CFU /100ml	Absent	APHA ed 22, 9221 F
6	Sulphates (as SO_4)	2.0	mg/L	<200	IS: 3025(Part 24)-1986Clause 4
7	Chlorides (as Cl)	7.0	mg/L	<250	IS: 3025(Part 32)-1988 Clause 2
8	Turbidity	1.6	NTU	<10	IS: 3025(Part 24)-1986Clause 4

Madhura Kamat
Analyst

Kushal Kulkarni
Authorized Signatory

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Page 01 of 01