Athens Journal of Health and Medical Sciences

Quarterly Academic Periodical, Volume 12, Issue 1
Published by the Athens Institute
URL: https://www.athensjournals.gr/ajh Email: journals@atiner.gr
e-ISSN: 2241-8229 DOI: 10.30958/ajhms

March 2025

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Front Pages

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The *Athens Journal of Health and Medical Sciences* (AJHMS) is an Open Access quarterly double-blind peer reviewed journal and considers papers from all areas of medicine (including health studies and nursing research). Many of the papers published in this journal have been presented at the various conferences sponsored by the Health & Medical Sciences Division of the Athens Institute for Education and Research (ATINER). All papers are subject to ATINER's Publication Ethical Policy and Statement.

Athens Journal of Health and Medical Sciences
ISSN NUMBER: 2241-8229 - DOI: 10.30958/ajhms
Volume 12, Issue 1, March 2025
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Athens Journal of Health and Medical Sciences

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The current issue is the first of the twelfth volume of the *Athens Journal of Health and Medical Sciences (AJHMS)*, published by the Health & Medical Sciences Division of ATINER.

Gregory T. Papanikos
President
Athens Institute

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- **Dr. Paul Contoyannis**, Head, Health Economics & Management Unit, Athens Institute & Associate Professor, McMaster University, Canada.
- **Dr. Vickie Hughes**, Director, Health & Medical Sciences Division, Athens Institute & Assistant Professor, School of Nursing, Johns Hopkins University, USA.

Important Dates

- Abstract Submission: **3 March 2025**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **26 May 2025**

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Important Dates

- Abstract Submission: **25 March 2025**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **7 April 2025**

Academic Member Responsible for the Conference

- **Dr. Vickie Hughes**, Director, Health & Medical Sciences Research Division, Athens Institute & Assistant Professor, School of Nursing, Johns Hopkins University, USA.
- **Dr. Carol Anne Chamley**, Head, Nursing Research Unit & Associate Professor, School of Health and Social Care, London South Bank University UK.
- **Dr. Andriana Margariti**, Head, Medicine Research Unit, Athens Institute & Lecturer, Centre for Experimental Medicine, Queen's University Belfast, U.K.

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Defence Styles, Alexithymia, Illness Perceptions, and HRQOL in IBD

By Liam Reilly[*]*, Laura Thompson*[±] *& Martin Dempster*[○]

Background/aims: The role of psychological factors in the development and progression of Inflammatory Bowel Disease (IBD) is not completely understood. Several studies have suggested that defence styles, alexithymia and illness perceptions each individually influence the way a person experiences their disease, thereby impacting on health-related quality of life (HRQoL). The study aimed to expand the knowledge base and assist in offering a better understanding of the variables by examining the extent of the relationship that defence styles, alexithymia and illness perceptions have with health-related quality of life. Methods: The study employed a survey design and used opportunity sampling to recruit participants with IBD from a Regional Crohn's and Colitis support group and outpatient Gastroenterology clinics. Participants were given questionnaire packs containing measures and were asked to post them back to the researcher. Results: The study found that defence styles, alexithymia and illness perceptions were all correlated with HRQoL. However, multiple regression analysis revealed that the alexithymia subgroup, "difficulty identifying feelings" and the neurotic defence style were the only variables that had a significant relationship with HRQoL. It was also found that females and people that were recently diagnosed also had a worse HRQoL. Conclusion: These findings suggest that females who are recently diagnosed with IBD and have difficulty identifying feelings as well as a reliance on neurotic defence styles have a worse HRQoL. Therefore, screening of this population and the introduction of psychotherapy to assist with emotional care might be beneficial in improving HRQoL. Practitioner Points: + Gender, time since diagnosis, neurotic defence styles and difficulties identifying own emotional experiences found to potentially contribute to poorer HRQoL. + Therefore, therapy using emotional identification, especially when a person is just diagnosed, might be beneficial to people with IBD. - The study used a cross-sectional design, therefore it is not possible to infer causation. Future research should use a prospective design.

Introduction

Inflammatory Bowel Disease (IBD)

Inflammatory Bowel Disease (IBD) is an umbrella term used to describe a chronic inflammation of the digestive system, large intestine and the rectum. The most commonly diagnosed illnesses under the IBD umbrella are Ulcerative Colitis

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and Crohn's disease (Mawdsley and Rampton 2006). Approximately, three hundred thousand people in the UK and three million people in Europe are currently diagnosed with IBD (Burisch et al. 2013).

IBD symptoms can be both physical (e.g., bloody diarrhoea, joint pain, and fever) and psychological (e.g., stress, anxiety and depression) (Sajadinejad et al. 2012, Neuendorf et al. 2012). Due to both the physical and psychological symptoms, it is estimated that IBD costs society and the health care systems in Europe between 4.6 and 5.6 billion Euros per year (Burisch et al. 2013).

However, to date, emotional support for psychological symptoms has been limited, as psychoactive drugs are offered at a much higher rate than psychotherapy, despite psychotherapies, such as third wave therapy, being widely requested and shown to be effective for people with IBD (Tarricone et al. 2017). As such, recent research has focused on further understanding the psychological factors involved in managing the disease, with the hope of improving health related quality of life and reducing the economic burden. A recent systematic literature review of the psychological correlates in IBD found an association with neurotic defence styles, illness perceptions and alexithymia with negative adjustment outcomes, namely quality of life (Jordan et al. 2016).

Illness Perceptions

A person's illness perceptions are influenced by their personal experiences and the information they hold about the illness, such as personal identity, the cause, the consequence and the curability of the illness (Leventhal et al. 1984).

Previous studies have identified that illness perceptions can vary in people with IBD. Mussell et al. (2004) found that people with IBD tend to have illness perceptions that are either associated with responsibility for the outcome of the illness to themselves, others or fate. Other findings have identified that negative illness perceptions relating to social defamation and rejection, the social limits placed on a person due to the symptoms, and the concern of serious consequences, are related to poor HRQoL outcomes. As well as this, it was found that the perception of stigma felt by people with IBD can contribute to between 10 - 22% variance of their reported HRQoL (Kiebles et al. 2010, Taft et al. 2009, Faust et al. 2012).

It has also been found that being positive about the ability to manage and care for personal symptoms is related to an increase in HRQoL in people with IBD (Munson et al. 2009). This suggests that improving illness perceptions, can also improve HRQoL. However, to improve illness perceptions, a person's defence styles must also be able to cope with the impact of the illness.

Defence Styles

Studies on the role of defence styles in determining HRQoL within IBD populations have been limited; however, they suggest that certain defence profiles can have an impact. Hyphantis et al. (2009) found a significant positive correlation between IBD and immature defence profiles, namely maladaptive action (e.g., avoidance and withdrawal) and displacement (i.e., painful feelings associated with

one person are directed towards another person or thing). These defence styles are regarded as being socially undesirable, such as being passive aggressive, somatisation and retreating into fantasy. In particular, Hyphantis et al. (2005) demonstrated that Crohn's disease patients demonstrated higher levels of immature defence styles when compared to individuals with Ulcerative colitis.

Also, high rates of the immature defence style somatisation, which is a physical manifestation of emotional discomfort, is associated with a deprived HRQoL in people with IBD (Hyphantis et al. 2009). Whereas in contrast, IBD patients who adopted mature defence styles had lower relapse rates and surgical interventions. The mature defence styles, such as humility, mindfulness and forgiveness, are regarded as those that are displayed by emotionally healthy individuals.

Other studies have identified neurotic defence styles, which are regarded as being acceptable defences in the short term but not in the long term (e.g., repression, isolation and reaction formation), as being associated with poorer HRQoL of people with IBD (Moreno-Jimenez et al. 2007, Barbera et al. 2017). Interestingly, the neurotic defence style, reaction formation, which is to behave in a way that is the opposite of how a person wants or needs to behave, has been independently associated with a poor HRQOL in people with IBD (Hyphantis et al. 2009).

Therefore, it is potentially the case that people with IBD struggle to manage the negative illness perceptions and emotions associated with their illness, such as stigma, rejection and shame. As a result, unhealthy defence styles are adopted that offer protection from acknowledgment and resolution of these negative emotions (Vaillant 1992, Freud 1936, Freud 1936).

Alexithymia

A potential reason that some people with IBD struggle to manage their negative emotions, is because they have difficulty identifying and describing them.

Alexithymia can be translated from Greek, to mean "without words for emotions" (Sifneos 1996). It describes a person that is incapable of understanding or recognising their own feelings (Sifneos 1996). Nemiah and Sifneos (1970) described patients that they believed had alexithymia as "seemingly detached, unconcerned, and distant". Alexithymia has been found to be prevalent at a rate of between 5-13% in the general population (Taylor et al. 1997). However, it has been found to be prevalent at a higher rate in people with IBD (Iglesias-Rey et al. 2012, Moreno-Jimenez et al. 2007, Porcelli et al. 1999).

Recent research has identified that alexithymia, along with defence styles, are related to "severe physical conditions due to both CD and UC (i.e., low levels of physical health) in females with IBD (Barbera et al. 2017). This finding is supported by previous research which suggests that alexithymia, specifically the subgroups, "Difficulty identifying feelings" and "externally oriented thinking" are associated with a low HRQoL in people with IBD (Iglesias-Rey et al. 2012). It has also been found that having a greater difficulty describing feelings is linked to a poorer HRQoL (Moreno-Jimenez et al. 2007). As well as this, it has been suggested, that along with distress, alexithymia might have a significant effect on the symptomology of IBD (Filipovic & Filipovic 2014).

It has been argued that the association might be explained by the difficulty that people with alexithymia have in recognising and regulating their own emotions. This inability to resolve the discomfort then manifests itself physically, which may be attributed to the IBD symptomology, and further contributes to a reduced HRQoL (Serrano et al. 1996, Porcelli et al. 1995, Porcelli et al. 1996, Verissimo et al. 1998).

Rationale

Recent research has found that defence styles, specifically the neurotic defence style, alexithymia subgroups, and illness perceptions are related to HRQoL in the IBD population regardless of disease activity. However, to date no studies have collectively looked at the variables to identify the extent of their relationship with HRQoL and which of these psychological variables is most strongly related to HRQoL in this context.

The findings will expand the knowledge base and assist in offering a better understanding of the variables that influence the HRQoL of people with IBD. The practical clinical benefit of the study is that it will assist in producing empirical evidence that will inform future psychological interventions by assisting in identifying key variables.

Research Question

> What is the extent of the relationship between the independent variables, defence styles, illness perceptions and alexithymia subgroups, with the dependent variable, HRQoL?

Method

Participants

The study used opportunity sampling to recruit participants from an IBD charity and outpatient Gastroenterology clinic.

Inclusion criteria included both male and female participants from the age of 18 years old who had the ability to give consent and had sufficient English language comprehension to understand and complete the questionnaires. The participants had a diagnosis of Inflammatory Bowel Disease. The diagnosis and type of IBD was identified by participants on the demographic self-report form.

Materials

Demographic Self-Report Form

The self-report form consisted of demographic and illness related information. It asked about gender, age, diagnosis, years since diagnosis and co-morbidity. The form attempted to capture any potential confounding variables. Confidentiality of data was ensured as personal details had not been requested from the participants.

Toronto Alexithymia Scale - TAS-20 (Bagby et al. 1994, Taylor et al. 1997)

The TAS - 20 is a 20 item self-report questionnaire of alexithymia. The measure consists of 3 sub-scales which include: difficulty identifying feelings, difficulty describing feelings, and an externally orientated thinking style. A score from 51 to 61 on the measure identifies "possible alexithymia", where as a score above 61 suggests that a person has alexithymia. The TAS 20 has both a high test-retest reliability and internal reliability (Bagby et al. 1994, Bagby et al.1994).

The Brief Illness Perceptions Questionnaire - BIPQ (Moss-Morris et al. 2002, Broadbent et al. 2006)

The BIPQ is an eight item scale measure of illness perception that measures cognitive and emotional representation of illness perceptions. There is also a ninth item that allows for a qualitative response to be given.

The measure consists of an 11 point likert scale (0-10). It is designed to be prompt, valid and effective in large scale studies. The questionnaire can either produce a total overall score or it can produce sub scale scores (Karataş et al. 2017). However, there is no standardised way of identifying the sub scale groups. The measure has good test-retest reliability and validity with relevant measures (Broadbent et al. 2006).

BIPQ Subscales

Subscales have been suggested for the BIPQ, but the psychometric properties of these subscales have not been evidenced. Therefore, principal components analysis was conducted to determine whether any subscales are likely to exist within this sample. The analysis identified two components of the BIPQ; these were named "consequence focused" (i.e. questions 1-4) and "illness focused" (i.e., questions 5-8).

Questions in the "consequence focused" component (e.g., "How much does your illness affect your life?") were closely related to the IBDQ outcome questions (e.g., "How often in the past 2 weeks have you had to delay or cancel a social engagement/ felt generally unwell/ tired and worn out/ unable to attend school or work/?") and were therefore removed from analysis due to overlap. The "illness focused" component questioned a person's perception of their illness (e.g., "How concerned are you about your illness?") and was included in the analysis. Therefore, from here on all analysis excluded the "consequence focused" component of the BIPQ. A higher score on the illness focused sub-scale represents a more threatening perception of the illness.

Defense Style Questionnaire – DSQ-28 (Andrews et al. 1993)

The Defense Style Questionnaire (DSQ-28) is a shortened version of the DSQ-40. The DSQ-40 was lacking in face validity and internal consistency on several items, so these items were removed and the DSQ-28 was created. It is a 28 item questionnaire with a 9 point likert scale ranging from "disagree strongly" to "strongly agree". It assesses mature, neurotic and immature defence styles. With the removal of the items from DSQ-40, the measure was found to have improved discriminant and criterion validity (Saint Martin et al. 2013).

Inflammatory Bowel Disease Questionnaire - IBDQ (Irvine et al. 1996)

The IBDQ is a 32 item self-administered or interview administered measure of the health related quality of life (HRQOL) of people with IBD. The measure consists of four differing domains which include; bowel symptoms, emotional health, systemic systems and social function. The questionnaire produces scores on a range between 1-7, with 1 representing a poor HRQOL and 7 representing a good HRQOL. The IBDQ is a widely used instrument that has demonstrated its reliability and validity cross-culturally (Han et al. 1998, Pallis et al. 2004).

Design and Statistical Analysis

The study employed a cross-sectional survey design. Exploratory analysis of the data identified that the variables met the required assumptions of normality and linearity for statistical analysis. Pearson product-moment correlation coefficient (r) was conducted to identify the strength of the relationship between the independent variables (defence styles, alexithymia and illness perceptions), and the dependent variable; health related quality of life.

Also, a multiple regression analysis was conducted to determine the amount of variance in HRQoL that is explained by the independent variables.

Procedure

Information and invitation sheets were displayed on the IBD charity website and in the newsletter. Questionnaire packs were then posted out to members of the IBD charity by the charity organisers to ensure confidentiality. Posters were also put up in the outpatient Gastroenterology clinic and a nurse gave out the application packs when requested by interested potential participants.

The questionnaire pack which contained the information sheet, one demographic self-report form and four questionnaires were returned by post, using the stamped addressed envelope, to the University, Psychology Department.

520 questionnaire packs were given out to participants, 420 through the IBD charity and 100 through the Gastroenterology clinic. 145 questionnaire packs were returned and 139 were eligible and used in the study.

The study was granted ethical approval by the NHS Research Ethics Committee (REC) and the local trust health board.

Results

Demographics

One hundred and thirty-nine participant questionnaire packs were included in the study. The majority of participants were female, with 73.5% of responses compared to 26.5% of males. Participants were most commonly aged between 30 and 49 years old and most people identified that they were diagnosed with the disease between the ages of 20 and 29. Crohn's Disease was the most common type of IBD identified, and 57% stated that they also had another medical condition. Most participants (60.4%) felt that stress and worry was the cause of their IBD (see Table 1).

Table 1. *Descriptive Data for Demographic Information*

Demographic information (total sample size – 139 participants)	N	Percentage
Age	138	
18 – 19	9	6.5%
20 – 29	22	15.9%
30 – 39	28	20.3%
40 – 49	28	20.3%
50 – 59	23	16.7%
60 – 69	23	16.7%
70 and above	5	3.6%
Gender	136	
Male	36	26.5%
Female	100	73.5%
Diagnosis	138	
Crohn's Disease	74	53.6%
Ulcerative Colitis	57	41.3%
Both	2	1.4%
Not clearly diagnosed with either	5	3.6%
Diagnosis age	138	
19 and below	39	28.3%
20 – 29	41	29.7%
30 – 39	27	19.6%
40 – 49	17	12.3%
50 – 59	10	7.2%
60 - 69	4	2.9%
Other medical conditions	138	
Yes	79	57.7%
No	57	42.3%
Anxiety or depression named as other medical condition	138	
Yes	20	14.4%
No	118	85.6%
Colostomy or ileostomy	139	
Yes	22	16.2%
No	114	84.8%
Perceived cause of IBD	139	
Stress or worry	84	60.4%
Hereditary or genes	54	38.8%
Diet or food	45	32.4%

Measures

The illness focused perceptions mean score was found to be similar to other IBD population studies (Knowles et al. 2013, Knowles et al. 2013). The Alexithymia mean score was found to be higher than the general population and other studies investigating IBD populations, suggesting higher levels of alexithymia (Franz et al. 2008, Barbera 2017). For defence styles, the immature defence style was the most common response, similar to previous studies (Hyphantis 2005). The HRQoL total score was found to be lower than in other IBD studies (Pallis et al. 2002, Han et al. 1998), but higher than the De Boer et al. study (1995), suggesting a low quality of life (see Table 2).

Table 2. *Descriptive Data for Illness Factor, Alexithymia, Defence Styles and HRQoL Measures*

Measures	N	Mean scores	SD
Illness factor subgroup			
Total score	138	24.99	6.61
Alexithymia			
TAS-20 Subscale 1 (difficulty identifying feelings)	138	22.15	7.844
TAS-20 Subscale 2 (difficulty describing feelings)	138	15.14	4.785
TAS-20 Subscale 3 (externally oriented thinking)	138	21.19	5.340
TAS-20 Total Score	138	58.97	14.603
Defence styles			
Mature defence style total	137	43.05	11.09
Neurotic defence style total	137	28.65	8.69
Immature defence style total	137	57.98	15.60
HRQOL			
Total score	137	129.39	42.01

Correlation

A series of correlations were performed to examine the relationship between the variables and the HRQOL outcome measure, Inflammatory Bowel Disease Questionnaire (IBDQ). A significant relationship was found between each of the variables and HRQoL. The alexithymia subscale, "difficulty identifying feelings", had the strongest association, with a strong, negative and significant relationship with HRQoL (r = -0.54, p <0.001) (see Table 3).

Table 3. *Relationship between Illness Factor, Alexithymia, Defence Styles as measured by HRQOL*

Measures	HRQOL total
Illness factor subscale	r = -0.26, p =0.002
Alexithymia TAS-20 Subscale 1 (difficulty identifying feelings)	r = -0.54, p <0.001
TAS-20 Subscale 2 (difficulty describing feelings)	r = -0.45, p <0.001
TAS-20 Subscale 3 (externally oriented thinking)	r = -0.22, p <0.01
Mature defence style total	r = 0.21, p = 0.02
Neurotic defence style total	r =-0.23, p <0.01
Immature defence style total	r=-0.22, p <0.01

Multiple Regression Analysis

Multiple regression analysis was conducted to examine the relative strength of the relationship between demographic information, alexithymia, defence styles and illness perceptions (the covariates) with HRQoL (the outcome measure).

Overall, time since diagnosis (beta = .224, p=0.01), gender (beta = 0.20, p<0.01), difficulty identifying feelings (beta = -.339, p< 0.01) and neurotic defence style (beta = -.187, p= 0.04) were all statistically significant measures for explaining variance in HRQOL. Difficulty identifying feelings recorded the highest significant beta value out of all the contributors thereby identifying that it made the strongest unique contribution to explaining the total IBD HRQOL score. A total of 45.1% variance of HRQoL was explained by the model (see Table 4).

Table 4. *Multiple Regression Analysis for Illness Factor, Alexithymia, Defence Styles with HRQoL Total Outcome Score*

Measures	Beta	Sig
Crohns vs colitis	-.162	.060
Unclear vs colitis	-.036	.632
Both vs colitis	-.079	.292
Gender	.201	.009
Age	-.174	.086
Time since diagnosis	.224	.018
Other medical conditions	.111	.139
Difficulty identifying feelings	-.339	.003
Difficulty describing feelings	-.153	.190
Externally orientated thinking	-.021	.802
Mature defence style	.122	.191
Neurotic defence style	-.187	.041
Immature defence style	.066	.458
Illness perceptions- illness focussed subscale	-.062	.466

Discussion

This study examined the extent that defence styles (mature, immature and neurotic), alexithymia subgroups (difficulty identifying feelings, difficulty describing feelings and externally orientated thinking) and illness perceptions, are related to HRQoL in IBD.

It was found that all of the variables were significantly correlated to HRQoL. However, in the multiple regression analysis, only the alexithymia subgroup, "difficulty identifying feelings" and the neurotic defence style had a significant relationship with HRQoL. From the demographic information, gender and time since diagnosis, were also both significantly related with HRQoL, suggesting that females and participants more recently diagnosed with IBD, have a worse HRQoL.

These findings are similar to those found in recent research which identifies that alexithymia, along with the neurotic defence style, are related to severe physical conditions in females with IBD (Barbera et al. 2017). Barbera et al suggested that females with alexithymia are more likely to develop IBD than males because females somaticize their emotional pain, whereas males with

alexithymia develop behavioural issues. It has also been suggested that such difficulties associated with alexithymia might have a significant effect on the symptomology of IBD (Filipovic & Filipovic 2014).

The association between the alexithymia subgroup "difficulty identifying feelings", as was found in this study, and a low HRQoL in people with IBD has also been found in previous research (Iglesias-Rey et al. 2012). It has been suggested that an individual's difficulty in effectively identifying their own feelings can limit their ability to differentiate between psychological experiences, such as anxiety, and IBD symptoms. As a result, IBD symptoms may be interpreted as an emotional response or emotions may be interpreted as a symptom of IBD. Therefore, people who have "difficulty identifying feelings" might be more likely to somaticize psychological experiences such as emotional distress, and potentially experience them as physical pain (Barbera et al. 2017, Bar-On & Parker 2000, Sifneos 1996, Taylor et al. 1997).

The significant relationship between neurotic defence style and a poor HRQoL has been identified in previous research (Jordan et al. 2016, Moreno-Jimenez et al. 2007, Barbera et al. 2017, Hyphantis et al. 2009). The neurotic defence style includes thoughts and behaviours such as repression, isolation and denial which attempt to avoid the experience of painful emotions, such as shame and anxiety. Therefore, "difficulty identifying feelings" which may involve the misinterpretation of feelings, combined with more neurotic defence styles, can lead to an emotional detachment from the IBD symptoms and an inaccurate perception of the illness (Hyphantis et al. 2009, Moreno-Jimenez et al. 2007).

Illness perceptions have been identified as being important in the IBD population (Knowles et al. 2013, Rochelle & Fidler 2013). However, for this study, the lack of a significant relationship between illness perceptions and HRQoL is potentially due to only a subgroup of the BIPQ being investigated. Therefore, it is potentially the case that the inclusion of only the illness focussed perceptions, without the consequence focussed perceptions, distorted the relationship with HRQoL.

Future Directions

A recent systematic literature review has identified that a small proportion of people with IBD have access to psychotherapy despite it being found to be effective in treating psychological issues (Tarricone et al. 2017).On the basis of this study, psychological interventions could be tailored to individual needs, and might benefit from focusing on emotion based psychoeducation to provide an in depth awareness and understanding of a person's abilities to recognise individual emotions, the purpose and function of emotions and the positive and negative connotations associated with each.

The Tarricone review (2017) also found that third wave psychotherapies that assist in developing a mind-body link are effective in improving adjustment outcomes. Such psychological therapy may contribute to encouraging a better awareness of emotional recognition and the importance of self-care in attempting to manage IBD as a chronic condition.

Limitations

When measuring complex personality traits such as alexithymia and defence styles, questionnaires might not give a true representation of the complex nature of such personality constructs. Therefore, perhaps a thorough interview and observation of participants might give a better representation of their personality.

Summary

These findings were similar to those recently found in the Barbera et al. (2017) study, suggesting that females who are recently diagnosed with IBD and have difficulty identifying feelings as well as a reliance on neurotic defence styles have a worse HRQoL. Therefore, it might be beneficial to conduct a screening at the time of diagnosis to identify this population and offer psychotherapy to assist with emotional care and long term HRQoL.

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Athens Journal of Health & Medical Sciences – Volume 12, Issue 1, March 2025 – Pages 23-38

Examining the Socioeconomic Dynamics of Beta-Thalassaemia Screening Carriers and Dropouts among Secondary School Adolescents: A Comparative Study in Sabah and Sarawak

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This study provides a novel analysis of the socioeconomic factors influencing screening dropout rates among beta-thalassemia carriers in Sabah and Sarawak, Malaysia, using 2018 data from the National Thalassemia Screening Programme. Our retrospective design focused on form four students, examining the interplay of ethnicity, locality, and gender with dropout rates. Notably, male carrier rates were higher in Sabah (49.90%) compared to females (50.10%), while Sarawak showed 51.56% for males and 48.44% for females. Gender disparities in dropout rates were particularly pronounced in Sabah, where females had double the dropout rates of males (70.62% vs. 29.38%). Extreme dropout rates were found in certain localities, namely Pitas, Sabah (47%) and Belaga, Sarawak (55%). The study highlights the substantial prevalence of thalassemia carriers among natives, with 93.9% in Sabah and 59.7% in Sarawak, underscoring the critical need for targeted, gender-sensitive screening interventions. This research contributes significantly by demonstrating the importance of precision in thalassemia screening programs to mitigate dropout rates and reduce the incidence of thalassemia births. These findings strongly advocate for early carrier identification as a strategic measure to improve educational outcomes and public health in high-risk regions.

Keywords: *Thalassaemia Screening Programme, socioeconomic profile, carrier rates, dropout rates, Sabah, Sarawak*

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Introduction

Thalassemia, a hereditary blood disorder, affects about 7% of the global population, with beta-thalassemia being particularly prevalent in the "thalassemia belt" regions, including Sub-Saharan Africa, the Mediterranean, the Middle East, and Southeast Asia (Lorey et al. 1996, Taher et al. 2021). These regions account for 95% of thalassemia births (Haque et al. 2015), making them a focal point for research and intervention. However, with increasing transmigration and interethnic marriages, thalassemia is now affecting a broader range of populations, including those in Southeast Asia and those of Asian Indian ancestry (Lorey et al. 1996).

In Southeast Asia, the prevalence of thalassemia remains alarmingly high, with approximately 55 million carriers (Shafie et al. 2021). In Malaysia, it is estimated that around 4.5% of Malaysians are beta-thalassemia carriers (Miri et al. 2013). The rate has not seen a rapid decline. Despite these concerning figures, there is a notable research gap in understanding the socioeconomic factors influencing dropout rates among beta-thalassemia carriers, particularly in regions like Sabah and Sarawak. Existing studies have not adequately explored how ethnicity, locality, and gender intersect and impact educational outcomes for these adolescents. This study aims to fill this gap by examining these dynamics to inform more effective thalassemia screening and prevention programs. The findings have the potential to improve educational outcomes and reduce the incidence of thalassemia births in high-risk regions, contributing to more targeted public health strategies.

Literature Review

Thalassemia is recognised as the most common genetic disorder in Malaysia, yet there remains limited information about its prevalence among Indigenous populations, particularly in Sabah and Sarawak (Tan et al. 2010). The Indigenous peoples, or "bumiputra," of these regions represent the majority of the population (Foo et al. 2004), comprising approximately 89% in Sabah and 76.1% in Sarawak (Aaron 2022). Despite this high representation, research specific to these groups, especially concerning the prevalence of thalassemia, is sparse. According to the Malaysian Thalassemia Registry, Sabah has the highest prevalence rate at 22.72%, with the most affected age group being 5.0-24.9 years (Ibrahim et al. 2019). Among the Kadazandusun community, where consanguineous marriages are common, there is a significant risk of producing children with beta-thalassemia major, with 12.8% of the community carrying the Filipino β-thalassemia deletion (Tan et al. 2010).

Beta-thalassemia carrier screening has been widely implemented in several countries as a preventive measure. In Malaysia, the Ministry of Health launched the Thalassemia Prevention and Control Programme in 2004 to reduce the morbidity and mortality of thalassemia patients and to lower the prevalence of transfusion-dependent thalassemia cases (Ministry of Health 2016). However, this program initially targeted only high-risk families and antenatal mothers. Since 2016, Malaysia has made a significant shift in its approach to thalassemia prevention. The introduction of nationwide screening for Form 4 students has broadened the

demographic included in the screening process. This shift towards early screening in adolescents, aligning with global practices, has identified 31,716 carriers out of 689,460 students screened, demonstrating Malaysia's commitment to early detection and prevention (Division of Family Health Development 2009). The programmes are designed to identify asymptomatic carriers and provide them with critical information about their reproductive risks, thereby empowering them to make informed decisions about their health and family planning.

This study uses the Social Determinants of Health (SDH) as the theoretical foundation. It hypothesizes that socioeconomic factors such as ethnicity, income, education, and geographic location influence health outcomes, including the prevalence of genetic disorders like beta thalassemia (Sargolzaie et al. 2018). Using this framework, we could explore how these factors contribute to higher rates of beta-thalassemia carriers and the dropout rates among adolescents in Sabah and Sarawak. Previous studies have highlighted certain demographic factors, such as the prevalence of thalassemia among Indigenous people. However, little, if not none, has fully explored the socioeconomic dimensions that might influence dropout rates among carriers.

A study by Guan Chin et al. (2019) found that only 13.9% of parents were aware of thalassemia before the birth of their first affected child. Almost all parents (91.7%) were not aware of their thalassemia carrier status before marriage, and the majority (94.4%) did not undergo pre-marital thalassemia screening before marriage among thalassemia major patients in Sabah. The study also concluded that the lack of awareness, low education levels, and poor socioeconomic status have been highlighted as significant. The profile of Beta-thalassemia major patients was mostly from the indigenous Kadazan, Dusun, Murut, Rungus, and Sungai ethnic groups, and parents mostly had low education levels and socioeconomic status.

While these studies provide valuable insights, they often fail to offer a comprehensive understanding of how socioeconomic factors influence the prevalence of beta-thalassemia and screening dropout rates among adolescents. The screening dropout rates refer to the proportion of individuals who did not attend, discontinued, or did not complete the screening process at any stage, from initial testing to confirmatory analysis, before completion. This gap in the literature underscores the need for more targeted research that examines the interplay of ethnicity, gender, and locality in these high-risk regions. By addressing these limitations, the current study aims to provide a more nuanced analysis that can inform the development of more effective and targeted thalassemia screening and prevention programs.

Methodology

This study is a retrospective descriptive analysis utilizing secondary data from the National Thalassemia Screening Program conducted by the Ministry of Health, Malaysia. The study focused on 16-year-old school adolescents during the 2018 screening period from January to December 2018. The screening included students from secondary schools in East Malaysia, with a high participation rate of 91.4% in

Sabah and 99.8% in Sarawak. Ethical approval was obtained from the Malaysian Research Ethics Committee and registered under the National Medical Research Register Malaysia (NMRR ID-22-00985-D1X (IIR)) and the Family Health Development Division, Ministry of Health Malaysia provided the anonymized line listing of the study sample of Form 4 students. The data collection process for this study involved several key steps. First, the screening program employed universal sampling, targeting all Form 4 students across Sabah and Sarawak secondary schools. This approach ensured a comprehensive sample that would closely reflect the prevalence of beta-thalassemia carriers among the adolescent population in these regions. Informed consent was obtained from all participants or guardians to maintain ethical standards. The collected data was anonymised to protect the students' privacy, removing any personally identifiable information.

Blood samples were collected from the participants during the screening procedures and tested for beta-thalassemia traits. The results of these tests were then compiled into a comprehensive dataset, which was carefully checked to ensure accuracy and completeness. This anonymised dataset was later retrieved from the Malaysian Ministry of Health and used for the analysis in this study. The data analysis was conducted using SPSS-18 software. It included descriptive statistics to summarize the participants' sociodemographic characteristics and the prevalence of beta-thalassemia carriers.

A chi-square significance test was also employed to examine the relationships between sociodemographic variables—such as ethnicity, locality, and gender— and dropout rates. A p-value of less than 0.05 was considered statistically significant, indicating that the observed associations were unlikely to have occurred by chance. Despite the comprehensive nature of the data collection and analysis, several potential limitations should be considered.

Adopting a retrospective design for this study may limit the ability to establish causal relationships between thalassemia carrier status and dropout rates. Additionally, the reliance on secondary data means that the researchers had limited control over the quality and completeness of the data, which could affect the study's findings if there were any inconsistencies or errors in the original data collection.

The anonymisation of data, while crucial for protecting participant privacy, may also restrict the ability to link certain variables or follow up on individual cases for further insights. Furthermore, the study's focus on Sabah and Sarawak may limit the generalisability of the findings to other regions in Malaysia or other countries with similar demographics. Finally, although the participation rates in the screening program were high, a small percentage of non-consenting students could introduce a selection bias, potentially affecting the sample's representativeness.

By acknowledging and addressing these limitations, this study aims to comprehensively analyse the socioeconomic dynamics that influence beta-thalassemia carriers and dropout rates in East Malaysia. The detailed data collection process and careful consideration of potential confounding factors contribute to the study's validity and relevance.

Results

This study found significant differences in three key sociodemographic profiles among beta-thalassemia carriers and dropouts, namely ethnicity, gender, and location. The total number of samples studied was 36,860 for Sabah and 35,161 for Sarawak. However, the analysis focused on the 65,990 consented students, with 33,142 from Sabah and 32,848 from Sarawak.

Table 1. *Gender and Ethnic Distribution between Consented Population, Prevalence by Carrier and Dropout, Gender and Ethnicity of Thalassaemia Carriers and Dropouts*

Sociodemographic profile		**Sabah**		**Sarawak**		**X^2**	**p value**
		n	**(%)**	**n**	**(%)**		
Gender	Male	15, 037	45.4	15, 579	47.3	28.04	<0.001
	Female	18,105	54.6	17, 269	52.4		
Ethnic Group	Sabah natives	29776	89.8	164	0.5	55528.61	<0.001
	Sarawak natives	181	0.5	11828.6	71.8		
	Chinese	1944	5.9	7165	21.8		
	Malay	1130	3.4	1878	5.7		
	Indians	104	0.3	51	0.2		
	Others	7	0	8	0		
Carrier vs Dropout		**Sabah**		**Sarawak**		**X^2**	**p value**
		n	**(%)**	**n**	**(%)**		
Category	Carrier	2036	77.9	576	22.1	352.377	< 0.001
	Dropout	5678	57.9	4129	42.1		
	Total	7714		4705			
Profiles		**Sabah**		**Sarawak**		**X^2**	**p value**
		n	**(%)**	**n**	**(%)**		
Carrier (Gender)	Male	1016	49.90	297	51.56	0.495	0.48
	Female	1020	50.10	279	48.44		
	Total	2036		576			
Dropout (Gender)	Male	1668	29.38	1494	36.18	50.7	<0.05
	Female	4010	70.62	2635	63.82		
	Total	5678		4129			
Carrier (Ethnics)	Sabah natives	1912	93.9	5	0.9	2174	<0.001
	Sarawak natives	5	0.3	344	59.7		
	Chinese	58	2.9	195	33.9		
	Malay	59	2.9	32	5.6		
	Indians	2	0	0	0		
	Others	0	0	0	0		
	Total	2036	100	576	100		
Dropout (Ethnics)	Sabah natives	5237	92.2	27	0.7	8467	<0.001
	Sarawak natives	18	0.3	3043	73.7		
	Chinese	219	3.9	810	19.6		
	Malay	183	3.2	237	5.7		
	Indians	21	0.4	9	0.2		
	Others	0	0	3	0.1		
	Total	5678	100	4129	100		

Table 1 shows the gender distribution among the consented students in both states, revealing proportionate comparability. In Sabah, 45.4% of the samples were male, while 54.6% were female. Similarly, in Sarawak, 47.3% of the samples were male, and 52.4% were female. A chi-square test of interdependency was performed

to examine the relationship between gender distribution across the two states. The results indicated that the proportion of females is significantly higher than males in both states (χ^2 = 28.04, p < 0.001). In Sabah, the Sabah natives account for the largest ethnic population with 89.8%, and similarly, in Sarawak, the Sarawak natives were the highest with 71.8%. Both these distributions were significant (χ^2 = 55528.61, p<0.05). In both states, the Chinese population represents the second-largest ethnic group, followed by the Malays.

There is also a prominent disparity between carriers and dropouts in Sabah and Sarawak, with carriers in Sabah account for 77.9% of the total carrier population (2036 out of 2612) showing a threefold per cent higher compared to Sarawak represent 57.9% of the total dropout population (5678 out of 9807). The study revealed a balanced distribution of beta-thalassemia carriers across genders in both Sabah and Sarawak. In Sabah, the carriers were nearly evenly split between males and females, with a slight predominance of females (50.10%). Similarly, Sarawak showed a comparable distribution, with males constituting 51.56% of carriers (χ^2 = 352.377, p < 0.001. A more detailed examination by gender reveals that in both states, there is a relatively equal distribution of males and females among the carriers, as indicated by the non-significant Chi-Square test. Conversely, when focusing on thalassemia program dropouts, gender differences become apparent. In this case, females (Sabah: 70.62%; Sarawak: 63.82%) outnumber males (Sabah = 29.38%; Sarawak = 36.18%) in both states, but the percentage of dropouts in Sabah surpasses that in Sarawak. (χ^2 = 50.696, p < 0.05).

The same table showed the relationship of thalassemia carriers amongst the ethnic groups. Sabah natives were the predominant group, comprising 93.9% of the carrier population, while in Sarawak, the Sarawak natives constituted 59.7%, and these relationships are statistically significant (χ^2 = 2172.14, p-value <0.001). Likewise, the study showed statistically significant differences between thalassemia programs dropouts by ethnic groups. The dropout rates were calculated based on the total district population. Dropout rates were highest among the Sabah natives (92.2%), followed by Chinese and Malays. Whilst in Sarawak, most dropouts were observed among Sarawak natives (73.7%), followed by Chinese and Malays.

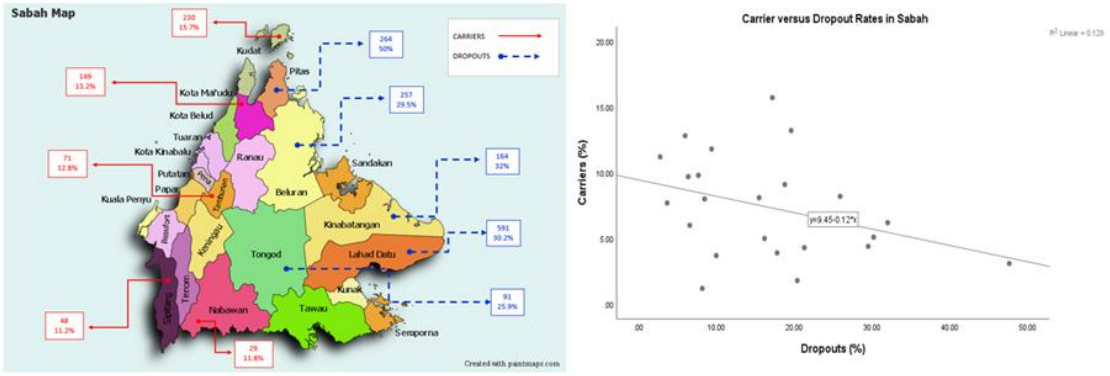
The carriers and dropouts in Sabah were not uniformly distributed. Table 2 shows the distribution of carriers and dropouts by district in Sabah. The table presents these figures both as a percentage of total numbers and in relation to districts' sample enrolment (representing the consented population). The districts with the highest prevalence of thalassemia carriers were Kudat (15.7%), followed by Kota Marudu (13.2%), Tambunan (12.8%), Nabawan (11.8%), and Sipitang (11.2%). The same table also shows the dropouts by locality. More than half of the districts in Sabah were with double-digit dropout rates. Pitas had the highest dropout rate of almost 50%, followed by Kinabatangan (32.0%) and Lahad Datu (30.2%). Additionally, there was a significant relationship between locality by carrier and dropout screened per district (χ^2 = 908.455; p < 0.001).

Table 2. *The Proportion of Carriers and Dropouts by Districts and the Prevalence Rate by Districts in Sabah*

Districts of Sabah	Carriers				Dropouts			
	Frequency	Percentage of carriers per state carriers	Number of students screened in Sabah	Percentage of carriers per district population	Frequency	Percentage of dropouts	Number of students screened in Sabah	Percentage of dropouts per population screened in Sabah
	n	(%)	n	(%)	n	(%)	n	(%)
Pitas	17	0.80	555	3.10	264	4.60	555	47.60
Kinabatangan	32	1.60	513	6.20	164	2.90	513	32.00
Lahad Datu	100	4.90	1960	5.10	591	10.40	1960	30.20
Beluran	38	1.90	871	4.40	257	4.50	871	29.50
Tongod	29	1.40	352	8.20	91	1.60	352	25.90
Sandakan	202	9.90	3220	6.30	793	14.00	3220	24.60
Penampang	59	2.90	1380	4.30	294	5.20	1380	21.30
Semporna	31	1.50	1718	1.80	350	6.20	1718	20.40
Kota Marudu	149	7.30	1129	13.20	221	3.90	1129	19.60
Keningau	212	10.40	2320	9.10	435	7.70	2320	18.80
Tuaran	66	3.20	1672	3.90	297	5.20	1672	17.80
Kudat	230	11.30	1467	15.70	253	4.50	1467	17.20
Kota Kinabalu	203	10.00	4023	5.00	650	11.40	4023	16.20
Ranau	100	4.90	1237	8.10	192	3.40	1237	15.50
Papar	66	3.20	1771	3.70	177	3.10	1771	10.00
Nabawan	29	1.40	245	11.80	23	0.40	245	9.40
Kota Belud	95	4.70	1191	8.00	101	1.80	1191	8.50
Tawau	46	2.30	3804	1.20	313	5.50	3804	8.20
Kuala Penyu	28	1.40	285	9.80	22	0.40	285	7.70
Beaufort	67	3.30	1125	6.00	74	1	1125	6.60
Tenom	79	3.90	812	9.70	52	0.90	812	6.40
Tambunan	71	3.50	554	12.80	33	0.60	554	6.00
Kunak	39	1.90	509	7.70	19	0.30	509	3.70
Sipitang	48	2.40	429	11.20	12	0.20	429	2.80
Total	2036	100	33142	100	5678	100.00	33142	100
$\chi^2 = 908.455$	$p < 0.001$							

Figure 1 illustrates the spatial distribution of both the carriers and drop-out prevalence on the Sabah map. Carriers are higher on the eastern coast, while dropouts are higher on the western coast. The scatter plot in Figure 1, was performed to show if the strength of the relations distribution between carrier rates and dropout rates in different districts of Sabah. The plot reveals an R-squared value of 0.129, indicating that only 12.9% of the variance between carrier rates and dropout rates can be explained by the relationship depicted in the scatter plot.

Figure 1. *The Spatial Distribution of Both the Carriers and Drop-out Prevalence in Sabah*



In Sarawak, the distribution of carriers and dropouts also varies across the state, as shown in Table 3, and the chi-square test showed a significant difference with X^2 862.915, $p < 0.001$. The districts in Sarawak with higher prevalence rates of carriers include Limbang (5%), Lawas (4.3%), and Betong (3.7%); all of them were at least 3 times lower than Sabah. However, like in Sabah, half of all the districts record double-digit dropout rates, with the highest in Belaga at 55%. This was followed by Daro (21.7%), Lundu (20.7%) and Kuching (19.6%). Figure 2 shows the spatial distribution of both carriers and drop-outs in Sarawak. District with high dropout rates were predominantly observed in the southwest districts of Sarawak.

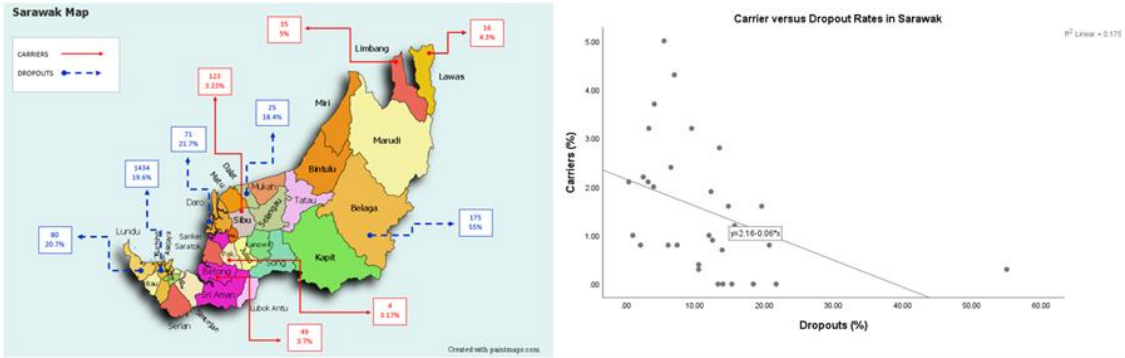
Table 3. *The Proportion of Carriers and Dropouts by Districts and the Prevalence Rate by Districts in Sarawak*

	Carriers				Dropouts			
Districts of Sarawak	**Frequency**	**Percentage of carriers**	**Districts population**	**Percentage of carriers per district population**	**Frequency**	**Percentage of dropouts**	**Districts population**	**Percentage of dropouts per district population**
	n	**(%)**	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**
Belaga	1	0.20	318	0.30	175	4.20	318	55.00
Daro		0.00	327	0.00	71	1.70	327	21.70
Lundu	3	0.50	387	0.80	80	1.90	387	20.70
Kuching	114	19.80	7309	1.60	1434	34.70	7309	19.60
Dalat		0.00	136	0.00	25	0.60	136	18.40
Serian	29	5.00	2411	1.20	379	9.20	2411	15.70
Mukah		0.00	619	0.00	95	2.30	619	15.30
Miri	69	12.00	4449	1.60	657	15.90	4449	14.80
Kapit		0.00	694	0.00	97	2.30	694	14.00
Simunjan	4	0.70	547	0.70	76	1.80	547	13.90
Samarahan	18	3.10	652	2.80	88	2.10	652	13.50
Matu		0.00	180	0.00	24	0.60	180	13.30
Bintulu	21	3.60	2409	0.90	302	7.30	2409	12.50
Kanowit	7	1.20	375	1.90	46	1.10	375	12.30

Asajaya	7	1.20	699	1.00	84	2.00	699	12.00
Julau	1	0.20	275	0.40	29	0.70	275	10.50
Tatau	1	0.20	306	0.30	32	0.80	306	10.50
Pakan	4	0.70	126	3.17	12	0.30	126	9.50
Meradong	4	0.70	498	0.80	37	0.90	498	7.40
Lawas	16	2.80	373	4.30	26	0.60	373	7.00
Sri Aman	18	3.10	749	2.40	49	1.20	749	6.50
Bau	7	1.20	838	0.80	51	1.20	838	6.10
Limbang	35	6.10	707	5.00	39	0.90	707	5.50
Betong	49	8.50	1315	3.70	54	1.30	1315	4.10
Selangau	2	0.30	101	2.00	4	0.10	101	4.00
Sibu	123	21.40	3807	3.23	124	3.00	3807	3.30
Lubok Antu	6	1.00	280	2.10	9	0.20	280	3.20
Sarikei	18	3.10	810	2.20	20	0.50	810	2.50
Marudi	2	0.30	241	0.80	5	0.10	241	2.10
Song	2	0.30	196	1.00	2	0.00	196	1.00
Saratok	15	2.60	714	2.10	3	0.10	714	0.40
Total	576	100.00	32848	100	4129	100.00	32848	100

The scatter plot depicted in Figure 2 illustrates the regression line that represents the relationship between carrier rates and dropout rates in various districts of Sarawak. The R-squared value of 0.175 indicates that approximately 17.5% of the variance between carrier rates and dropout rates can be explained by the depicted relationship in the scatter plot. This suggests that only a limited portion, specifically 17.5%, of the variation in carrier rates can be clarified by changes in dropout rates. Consequently, there may be additional factors influencing carrier rates that are not captured in the dropout rates. The negative estimated coefficient from the regression implies that as dropout rates decrease, carrier rates may increase. However, without the provision of a t-statistic in Supplementary Figures 1 and 2, it remains unclear whether this coefficient is statistically significant.

Figure 2. *The Spatial Distribution of both the Carriers and Drop-out Prevalence in Sarawak*



Similar to the findings in Sabah, the scatter plot in Sarawak indicates that districts with high carrier rates do not consistently demonstrate high dropout rates. The scattered data points imply a weak correlation or the absence of a consistent pattern between carrier rates and dropout rates across the districts of Sarawak.

The results of this study reveal significant variations in beta-thalassemia carrier rates and school dropout rates among different ethnic groups in Sabah and Sarawak. These variations suggest that ethnicity plays a crucial role in the prevalence and impact of thalassemia, likely due to a combination of genetic factors, cultural practices, and socioeconomic conditions that differ across ethnic groups. Understanding these ethnic disparities is essential for developing effective, culturally sensitive interventions.

The study also identified a significant gender disparity, with a higher proportion of female students in the sample. This gender difference indicates potential gender-specific factors that may influence school retention and health outcomes. For example, the higher dropout rates among females in Sabah could be attributed to cultural or economic pressures that disproportionately affect girls. These pressures may include expectations around family responsibilities or economic constraints that limit girls' access to education and healthcare services.

Geographic differences between Sabah and Sarawak were also evident, with varying rates of beta-thalassemia carriers and dropouts across different regions. This geographic variability may be influenced by factors such as access to healthcare services, educational opportunities, and the broader socioeconomic conditions of each region. The high dropout rates observed in specific areas, such as Pitas in Sabah (47%) and Belaga in Sarawak (55%), highlight the need for targeted interventions in these high-risk locations. These findings underscore the importance of tailoring public health and educational strategies to the unique needs of different communities to effectively address the challenges posed by beta-thalassemia and improve educational outcomes.

Discussion

In Malaysia, thalassaemia affects various states and ethnic groups. Sabah, Malaysia's third most populous state, has the highest number of documented thalassaemia cases, with a prevalence of 0.39 per 1,000 people based on the Malaysian Thalassaemia Registry in 2019. This study found that Sabah has a higher prevalence of thalassaemia carriers among 16-year-old students, with a rate of 6.8 per 100 students, and most carriers are Sabah natives. The study samples in Sabah and Sarawak both have a significant proportion of indigenous populations, accounting for 89.8% and 71.8% of their respective populations. Chinese ethnicity is the second most prominent in Sabah (5.9%) and Sarawak (21.8%), followed by Malays, Indians, and others.

Research conducted by Sena et al. (2019) reported that the Kadazan-Dusun indigenous ethnicity had the highest prevalence of thalassaemia carriers in Sabah, with a rate of 16.2 per 1,000 students. They also identified the β-Filipino deletion (β°) as the main genetic mutation responsible for beta-thalassaemia in 90% of

Kadazan-Dusun individuals (Elizabeth & Ann 2010). Sabah's primary Indigenous ethnic groups, including Kadazan-Dusun, Bajau, Malays, Muruts, and others, were identified based on the most recent national census (Pauzy et al. 2018). Further molecular characterization studies have revealed that each ethnic group in Sabah possesses a unique set of mutations contributing to thalassaemia (Mary Anne Tan et al. 2006). Consequently, the Kadazan-Dusun ethnic group has the highest prevalence of thalassaemia disorders in Sabah, which aligns with findings from the Malaysian Thalassaemia Registry.

Although the study showed no significant difference between male and female carriers in both states, it is worth noting that Laghari has noted a higher prevalence of thalassaemia among males than females (Laghari et al. 2018). The study noted that it may be related to factors such as transfusion-related infections, which are more common among males. On the other hand, iron deficiency anaemia (IDA) is more prevalent among females due to menstruation (Roslie et al. 2019). These gender and ethnic distributions provide valuable insights into the demographic composition of Sabah and Sarawak. They can be useful for understanding the prevalence and impact of various health conditions, including thalassaemia, in different population groups.

While specific studies on gender differences in thalassaemia prevalence are limited, research on sociodemographic determinants related to thalassaemia knowledge has found that males, higher education, and higher income are associated with better understanding of thalassaemia disease and screening services (Manzoor & Zakar 2019). This may align with the observation of higher dropout rates among female students in the present study.

The elevated occurrence of malaria in Malaysia, particularly in Sabah, has posed a significant public health challenge. Nevertheless, initiatives aimed at malaria control, such as the implementation of the Nationwide Anti-Malaria Program in the 1980s, have played a role in diminishing its prevalence. Interestingly, there is a belief that the thalassaemia trait offers a certain level of protection against malaria (Abouelmagd & Ageely 2013). This protective advantage might have contributed to the selective survival and persistence of the thalassaemia mutation in regions with a high malaria prevalence, such as Sabah. Referred to as a heterozygous advantage, this benefit for carriers of the thalassaemia trait could be a contributing factor to the continued existence of the thalassaemia mutation in Sabah, leading to its persistent high incidence over the years.

The distribution of thalassaemia carriers can vary based on ethnic groups and geographical location. Bumiputera Sabah accounted for the vast majority of carriers in Sabah, while Bumiputera Sarawak predominated in Sarawak, reflecting the genetic predisposition of these indigenous populations. Previous studies have identified the Dusun ethnicity, primarily in Kota Kinabalu, as having a significant proportion of thalassaemia patients in Sabah (Chin et al. 2019). Other studies have found high prevalence rates of alpha and beta thalassaemia carriers in Kota Marudu and Hb E carriers in Kudat (Sena et al. 2019). Notably, this study found that thalassaemia carriers are more concentrated in coastal districts than inland districts in both Sabah and Sarawak. High concentrations of carriers, such as Kudat and Keningau in Sabah and Sibu and Kuching in Sarawak, highlighting the importance

of prioritising resource allocation and outreach programs in these areas Understanding the distribution of carriers is essential for planning effective prevention activities.

The study showed that dropout rates were pervasive throughout the districts, with some districts registering higher rates than others. Although the study showed weak associations between the dropouts and locality and that high carrier rates in a district do not necessarily correspond to high dropout rates, the study revealed localities or districts that need serious attention. Half of the states, both in Sabah and Sarawak, have high dropout rates. Notably, Sabah is on the eastern, more rural coast and is far from the capital cities. In Sarawak, the district of Belaga has the highest dropouts, involving 50% of the sample. The result of this study can be a pointer to access issues for some of the less developed support systems in the respective locality.

The aim of countries embarking on thalassemia prevention and control programs is to decrease the incidence of new thalassemia-affected births swiftly. Hence, implementing strategies should focus on easily attainable goals with special emphasis on states with high prevalence and higher risk profiles such as gender, ethnicity, and locality or, namely, the" low-lying fruits". The reasons behind dropouts need to be thoroughly investigated while identifying them to encourage and ensure they undergo thalassemia testing. Mandatory testing can be an option and has been successful for pre-marital screening (Jaffar et al. 2021). However, there are not yet successful reports for adolescents. The key challenges may be fear of negative effects or demands for close follow-up actions for non-compliance.

Thalassemia screening and testing strategies are subjected to long-term outcomes. It requires regular monitoring of the relationships of targeted profiles with choices and the outcomes, would require a simple but robust electronic register across each carrier cohort (Aydınok et al. 2018). With a strong system in place, aiming for zero thalassemia births within the next 10 years is a genuine possibility (Voskaridou et al. 2012). The triumphant achievements in the prevalence of Sardinia, Cyprus, and Greece have prompted many countries to emulate their successful reduction of cases.

The study identifies several potential confounding factors that could influence the observed prevalence of thalassemia and the associated dropout rates. One such factor is transfusion-related infections, which are more common among males. This could contribute to the higher prevalence of thalassemia observed in male students, as the increased risk of infections might exacerbate the condition or lead to more frequent diagnoses in males than females.

Another significant factor is iron deficiency anaemia (IDA), which is more prevalent among females due to menstruation. This condition could be linked to the higher dropout rates observed among female students, as anaemia can affect cognitive function, physical energy, and overall school performance, leading to increased absenteeism and, eventually, higher dropout rates.

Socioeconomic status strongly influences thalassemia prevalence and educational outcomes. Variations in income, education levels, and access to resources between different ethnic groups and regions may lead to disparities in health outcomes and thalassemia prevalence. Additionally, socioeconomic status can influence dropout rates, as students from lower-income families may face greater economic pressures to leave school early to contribute financially to their households.

Access to healthcare services is another important confounding factor. Differences between urban and rural areas regarding healthcare availability and quality can significantly impact the detection and management of thalassemia. In less accessible areas, especially in rural areas, thalassemia may go undiagnosed or inadequately managed, leading to worse health outcomes and higher dropout rates among affected students.

Looking forward, there are several areas where further research could provide valuable insights and guide more effective interventions. A detailed analysis of the genetic and environmental factors contributing to the high prevalence of thalassemia among specific ethnic groups, such as the Kadazan-Dusun in Sabah, would be particularly useful. Understanding these factors could help tailor public health strategies to address the unique needs of these populations.

Finally, analysing the impact of healthcare accessibility on thalassemia detection, management, and educational retention in different regions could provide essential information for guiding resource allocation and policy decisions. It is imperative that ensuring the availability of healthcare services in all areas, particularly in underserved rural regions, may improve both health and educational outcomes for students with thalassemia.

Conclusions

The study's findings highlight the crucial need to consider ethnic, locality, and gender differences when analyzing the prevalence of thalassemia carriers among Form-four students in Sabah and Sarawak. The significant disparities observed underscore the importance of a targeted approach in addressing these differences. Investigating the underlying factors contributing to gender disparities and the higher dropout rates in specific and similar localities is essential for developing tailored strategies to combat the high prevalence of thalassemia in these regions.

The data indicates that native groups, male carriers, female dropouts, and regions with higher dropout rates are particularly affected, necessitating focused efforts to address these vulnerabilities. The geographic variation in thalassemia prevalence, with Sabah exhibiting a notably high prevalence of beta-thalassemia carriers, provides a critical context for prioritizing specific similar high prevalence regions in public health initiatives.

The effectiveness of the National Thalassemia Control and Prevention Program, which successfully identifies carriers in early adulthood, is a positive foundation. However, the dropout rates highlighted in this study suggest areas for improvement. Early identification of thalassemia carriers is vital in preventing the birth of affected individuals, emphasizing the need for precise and effective screening programs.

This research contributes to the understanding of how socioeconomic factors influence dropout rates in screening programs. The study offers valuable insights into the impact of these factors on participation and the overall effectiveness of the program. The study proposes practical interventions through targeted screening based on ethnicity, gender, and locality, providing actionable strategies to reduce thalassemia prevalence among specific demographic groups.

It is recommended that comparative analysis be further conducted with other screening programs that could enhance understanding by highlighting unique challenges and successes in thalassemia screening. Such comparisons can inform improvements in other genetic screening initiatives, offering a broader perspective on effective public health strategies.

For policymakers and public health practitioners, the study provides several key recommendations:

- Develop tailored screening programs considering ethnic, gender, and locality differences to ensure more effective identification and intervention.
- Implement strategies to mitigate socioeconomic barriers that affect participation in screening programs, ensuring broader access and equity.
- Increase awareness about thalassemia, particularly in high-risk regions and among vulnerable demographic groups, to foster early detection and prevention.
- Strengthen efforts to identify carriers early to prevent the birth of affected individuals and ensure better long-term health outcomes.
- Regularly monitor and evaluate the effectiveness of screening and intervention programs, making necessary adjustments to enhance their impact.
- Conducting longitudinal studies to track beta-thalassemia carriers over time.
- Exploring region-specific dropout determinants through qualitative methods.
- Analyzing the impact of healthcare accessibility on carrier outcomes and educational retention.

By addressing these critical areas, it is possible to make significant strides in reducing the prevalence of thalassemia and improving public health outcomes in Sabah, Sarawak, and beyond.

Acknowledgments

The authors thank the Ministry of Health Malaysia for the support and using the data for this study and the International Medical University for the approval and support in conducting this research under the School of Medicine for the Business Administration in Healthcare Management programme. Funding for this study was supported by the study grant of the International Medical University and approval by the IMU Joint Committee on Research and Ethics with Project ID Number: MBAHM I-2022(02).

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Athens Journal of Health & Medical Sciences – Volume 12, Issue 1, March 2025 – Pages 39-48

Effectiveness of Promoting Colorectal Cancer Screening During Annual Workplace Health Monitoring

*By Thomas A. Mackey**

Colorectal cancer (CRC) is the fourth most common and leading cause of cancer in the United States with a screening rate of 72%. Purposes of the project were to educate environmental investigator workers about CRC screening tools, encourage testing, and measure behavioral effects one year later. Workplace health monitoring programs present an opportunity to educate and encourage eligible workers to seek testing. During a 2023 annual health monitoring program, 552 environmental health workers were examined. Based on CRC risk factors, 74 were encouraged to discuss screening with a primary care provider (PCP), educated about various screening tools, tests' sensitivity, and costs. 54% received a reminder letter encouraging a conversation with a PCP about screening. In 2024, 62 of the 74 eligible workers returned for exams and were asked if they discussed screening with a PCP, if screening occurred and, if screened, what method was chosen. 39 (63%) had the discussion and 25 (40%) completed screening: 14 via colonoscopy and 11 via Cologuard. Of the 41 workers who received reminder letters 17 (41.5%) completed testing. Encouraging workers to seek CRC screening was moderately effective: 40% (n=25) who received a recommendation from a PCP to obtain screening did so while 41.5% who received a follow up letter completed screening.

Keywords: *colorectal, cancer, screening, workplace, health monitoring*

Introduction

Colorectal cancer (CRC) is the fourth leading cause of cancer and cancer deaths in the United States of America (USA) (Centers for Disease Control and Prevention n.d.a, Centers for Disease Control and Prevention n.d.b, U.S. Cancer Statistics Data Visualizations Tool, based on 2022 submission data (1999-2020): U.S. Department of Health and Human Services, Centers for Disease Control and Prevention and National Cancer Institute, https://www.cdc.gov/cancer/dataviz).

In 2021 the US Preventive Services Task Force (USPSTF) recommended changing the beginning screening age from 50 to 45. The Centers for Disease Control and Prevention (CDC) via Healthy People 2030 project set a screening goal of 74.4% for the USA. Table 1 illustrates 2020 screening rates for males, females, insured and uninsured in the USA and Texas.

Worksite screening and health monitoring programs present a significant opportunity to increase screening rates and promote the health and safety of employees. Designed properly, such programs can influence health behaviors, improve knowledge and skills, and facilitate necessary/recommended screenings and immunizations (Centers for Disease Control and Prevention n.d.d).

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The Occupational Safety and Health Administration indicates "the fundamental purpose of surveillance (health monitoring) is to detect and eliminate the underlying causes such as hazards or exposures of any discovered trends and thus has a prevention focus" (U.S. Department of Labor Occupational Safety and Health Administration 2025).

The purposes of the current practice improvement project imbedded into a mandatory health monitoring program were:

1. To educate workers about CRC screening tools.
2. Encourage eligible persons to seek screening.
3. Measure the behavioral effect one year later.

Designing a health screening program requires an understanding of the targeted population's risk factors, national recommendations/standards, participant determinants and predictors of utilization.

Literature Review

The USPSTF recommends screening all adults aged 45 to 75 years for CRC. Recommended methodologies for screening vary and should be determined by patient/clinician discussion. Screening option recommendations include:

- High-sensitivity guaiac fecal occult blood test (HSgFOBT) or fecal immunochemical test (FIT) every year.
- Stool DNA-FIT every 1 to 3 years.
- Computed tomography colonography every 5 years.
- Flexible sigmoidoscopy every 5 years.
- Flexible sigmoidoscopy every 10 years + annual FIT.
- Colonoscopy screening every 10 years (U.S. Preventive Services Task Force 2021, American Cancer Society n.d.).

Vallis and Wang (2022) indicate lifestyle choices in addition to personal and familial risk factors as outlined in Figure 1 contribute to CRC and pre-cancerous adenoma incidence. High alcohol intake, excess weight, inactivity, elevated intake of red and/or processed meat, and smoking are the lifestyle choices most responsible for a higher incidence of CRC. On the other hand, healthy lifestyles seem to be inversely proportional to CRC risk. (Combined effect of Healthy Lifestyle Factors and Risks of Colorectal Adenoma, Colorectal Cancer, and Colorectal Cancer Mortality: Systematic Review and Meta-Analysis (Yu et al. 2022).

Figure 1. *Colorectal Cancer Screening Questionnaire*

Have you ever been screened for colorectal cancer (CRC):
Yes___ No___
If so, how many years ago? (Enter # of years)
_____

Changeable risk factors: lifestyle issues

Are you or do you have the following?

1. Overweight (BMI>25) or obese (BMI>30):
   Yes___ No___
2. Sedentary lifestyle (<150 minutes of exercise weekly)
   Yes___ No___
3. Diet consisting of heavy red meat and/or processed meats
   Yes___ No___
4. Current or former smoker
   Yes___ No___
5. Alcohol use (men >2 drinks/day & women >1 drink/day)
   Yes___ No___

Unchangeable risk factors: personal/family history or other

Are you or do you have the following?

1. Age between 50 & 75
   Yes___ No___
2. Family history of CRC
3. Yes___ No___
4. Personal history of CRC
   Yes___ No___
5. History of intestinal polyps
   Yes___ No___
6. History of irritable bowel disease
   Yes___ No___
7. Ethnicity: African American or Jewish
8. Yes___ No___
9. Diabetes mellitus
   Yes___ No___

Based on the above responses the nurse practitioner recommends you
Yes___ No___
seek CRC screening.

Do you intend to seek CRC screening with your PCP/gastroenterologist?
Yes___ No___

Ouakrim et al. (2013) conducted a literature review of 4,986 journal articles related to factors associated with CRC screening participation for people at increased

risk due to family history of the disease. Findings indicated "receiving recommendations from clinicians was the most consistent predictor identified across studies. The review also revealed a consistent pattern of association with predictors related to familial aspects of CRC, such as strength of family history, and relationship to the affected relative. Among the psychological constructs, social influence emerged as the most consistent predictor of screening participation".

Beydoun and Beydoun (2008) reviewed the literature for predictors of CRC screening behaviors among average-risk older adults in the USA. Findings showed "frequently reported predictors of CRC screening behaviors include older age, male gender, marriage, higher education, higher income, White race, non-Hispanic ethnicity, smoking history, presence of chronic diseases, family history of CRC, usual source of care, physician recommendation, utilization of other preventive health services, and health insurance coverage." Perceived barriers, a key construct in the Health Belief Model, was the greatest predictor of CRC screening. The Health Belief Model suggests health behavior can be predicted based on the constructs of perceived barriers, benefits, self-efficacy and threats (Jones et al. 2015).

Lau et al. (2020) reviewed 30 studies in a meta-analysis of the Health Belief Model and the relationship to CRC screening. Findings indicated "perceived susceptibility, benefits and cues to action were directly associated with screening history or intention. Perceived barriers inversely associated with screening history or intention. The studies included also found other modifying factors including sociodemographic and cultural norms."

The American Cancer Society (2016) indicates there are five top reasons why people do not get screened for CRC: fear of undergoing a painful procedure, belief that since there is no family history of CRC there is no personal risk, symptom free means no personal risk, expense is too great, and inconvenience and other associated costs are too high.

Age, gender and insurance coverage are frequently cited as predictors for health behavior in general and CRC screening in particular (Centers for Disease Control and Prevention n.d.c).

The Centers for Disease Control (CDC) statistics reveal significant discrepancies in those with (75%) and without (39%) health insurance regarding CRC screening (see Table 1).

Table 1. *Colorectal Screening Rates in the USA and Texas 2020*

	USA	Texas
Up to date	72%	67%
Males	71%	64%
Females	74%	69%
Insured	75%	73%
Uninsured	39%	32%

Source: https://www.cdc.gov/cancer/colorectal/statistics/use-screening-tests-BRFSS.htm.

Atlas et al. (2023) tested interventions to improve timely follow up on patients with abnormal breast, cervical, colorectal and lung cancer results. Interventions among 11,980 patients included electronic health record (EHR) reminders and other

outreach efforts such as reminder letters. 31.4% of individuals in the EHR reminder group and 22.9% in the usual care group completed screening within 120 days.

Studies have shown varied improvements in CRC screening uptake when reminder letters are mailed to patients. Coronado et al. (2018) reviewed the literature and found a wide variation in the effectiveness of reminder letters on CRC screening from 22% to 45% depending on a wide variety of patient population variables (gender, race, socioeconomic status, etc.), Coronado's study increased CRC uptake by 13.9%. Baker et al. (2014) showed a 44.9% increase in CRC screening when multiple phone calls and reminder letters were used as interventions.

Methods

Environmental investigators for the State of Texas were required to undergo annual health-monitoring exams to detect undiagnosed work-related illnesses and fitness for duty. The full-time employees ranged in age from early 20's to mid-70's, were provided full health insurance with Blue Cross Blue Shield of Texas through the employer and had incomes in the $40,000 to $75,000 range. Exams included: complete work and personal health histories, vital signs, chest X ray, spirometry, electrocardiography, audiometry, laboratory work (complete blood count, 24 chemistries, lipids, hemoglobin A1c and lead levels), workplace appropriate immunizations (tetanus, hepatitis A&B), and a physical examination. Additionally, employees completed a brief CRC screening questionnaire (Figure 1) in 2023. The nurse practitioner (NP) provided brief counseling during the examinations directed at moving employees 45 years and older and/or with CRC risk factors to seek follow up with a primary care provider (PCP). The NP shared information with employees meeting the inclusion criteria and placed emphasis on types of screening and sensitivity of the tools available. Individuals with modifiable risk factors were encouraged to lose weight, exercise, follow a healthy diet, stop smoking and/or reduce alcohol consumption. Data were gathered over a two-year period (2023 & 2024) during the months of January through April.

Inclusion criteria for the intervention were participants at least 45 years of age, had never been screened or not screened in the past 10 years, had a family history of a first degree relative or multiple family members with a history of CRC, and individuals with a personal history of polyps.

In 2023, 552 health monitoring evaluations were conducted (52% male and 48% female). In 2024 562 evaluations were performed (53% male and 47% female). 128 investigators had CRC screening within the past 10 years while 74 met the inclusion criteria for screening. The 128 already screened for CRC represent a screening percentage of 63% which is below the national (75%) and state (73%) screening rates for eligible persons with insurance (see Table 1).

In 2023 a reminder follow-up letter (Figure 2) was sent to 41 of the 74 (55%) eligible participants two months following the initial screening. The letter reminded individuals about CRC risk factors and screening recommendations made during the screening.

Figure 2. *Follow-up Letter*

Dear May 4, 2023

You may remember during Health Monitoring this year I mentioned the need for you to discuss getting screened for colorectal cancer with your primary care provider. I recommended screening either because of your age or other risk factors related to colorectal cancer. I am writing to give you a follow-up reminder. Please go get screened! Below are a few important risk factors related to colorectal cancer.

Changeable risk factors: lifestyle issues

1. Overweight (BMI>25) or obese (BMI>30):
2. Sedentary lifestyle (<150 minutes of exercise weekly)
3. Diet consisting of heavy red meat and/or processed meats
4. Current or former smoker
5. Alcohol use (men >2 drinks/day & women >1 drink/day)

Unchangeable risk factors: personal/family history or other

6. Age between 45 & 75
7. Family history of colorectal cancer
8. Personal history of colorectal cancer
9. History of intestinal polyps
10. History of irritable bowel disease
11. Ethnicity: African American or Jewish
12. Diagnosis of diabetes mellitus

At next year's Health Monitoring exam, I will ask you about your screening experience. Please let me know if you have any questions.

In 2024, 62 of the eligible 74 workers needing screening returned for health monitoring. Twelve employees from 2023 no longer worked at the agency, had an internal job change, were sick or did not participate in the health monitoring and subsequently lost to follow up.

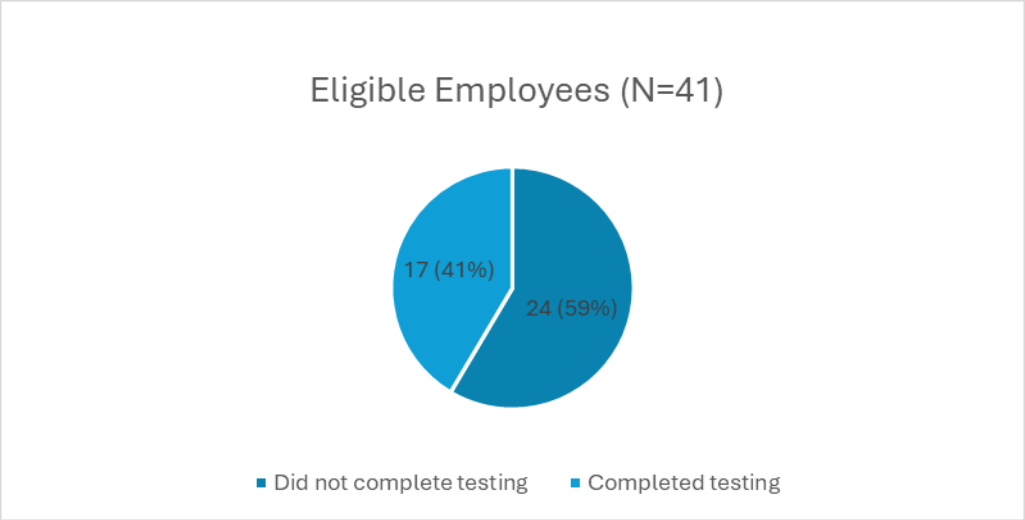
Returning workers (62) who received a CRC screening recommendation in 2023 were again questioned in 2024 to determine if they discussed screening with a PCP, if testing were recommended, and, if screened, what type of screening was performed (colonoscopy or stool-based test).

Results

A total of 552 workers completed the questionnaire (see Figure 1) in 2023. Two-hundred and two (202) met the inclusion criteria described above, 128 had already been screened within the past 10 years and 74 needed screening.

Of the 74 workers needing screening, 41 (55%) received letters encouraging further action related to getting CRC screening. Twelve workers (16%) were lost to follow up during the 2024 exams due to no longer being employed, sick, or had an internal job change not requiring health monitoring. Seven of the 12 lost to follow up had received reminder letters. Consequently, 62 workers were asked follow-up questions (see Table 2) and were included in the data analysis. 39 (63%) spoke with a PCP about getting screened for CRC, 37 (60%) received a recommendation to get tested, and 25 (40%) completed screening: 11 (44%) via stool testing and 14 (56%) via colonoscopy (see Table 2). 17 (41.5%) who received the reminder letter successfully completed screening. Figure 3 shows the impact of a reminder letter on CRC screening.

Figure 3. *Impact of Reminder Letters*



Reasons for not getting screened included scheduling issues, insurance denial, personal health problems, procrastination, and family turmoil. All stool-based testing was performed using Cologuard.

Table 2. *CRC Screening Questionnaire Follow-Up Results (N=62)*

Did you discuss CRC screening with your PCP?	39 (63)%
Did your PCP recommend CRC screening?	37 (60%)
Did you get CRC screening?	25 (40%)
Stool based screening	14 (56%)
Colonoscopy screening	11 (44%)

Discussion

Health monitoring exams provide an additional opportunity to remind employees to seek other health maintenance services such as CRC screening, mammograms, pap smear, adult immunizations (shingles, pneumonia, influenza, COVID, tetanus) and other CDC recommended screenings. Compared to other health monitoring programs the current program actualized CDC's idea of improving health behavior, reducing risks and enhancing overall health related to CRC[1] via a worksite screening.

Many eligible workers were unaware of the CRC recommended screening age of 45. Once educated about the recommendation for screening, workers were very receptive and expressed interest in pursuing follow up with a PCP. Future research and practice improvement projects might focus on ideas presented below which incorporate suggestions from other researchers cited above.

Workers who did not get screened provided excuses such as: "I forgot", "my insurance denied the request", or "my other medical issues prevented me from getting screened". Regardless of the excuse, some individuals have health beliefs that negate seeking and using preventive health services. Future projects/research would benefit by including both locus of control and health belief models incorporated into the screening/assessment tools.

While results on the study population are reported above there is only anecdotal information related to impact on family members of workers tested. The NP requested each eligible CRC screening candidate to inform family members about recommended screening guidelines. Three workers indicated relatives decided to seek testing once informed of the national CRC screening recommendations. The total trickle-down impact of the recommendation is unknown. Again, future research might focus on how family members influence CRC screening habits and behavior. Additionally, future research might center on the influence workplace CRC screening effects family members habits and beliefs.

Prompting workers participating in annual health monitoring examinations to seek CRC screening was moderately effective: 68% (n=25) who received a recommendation from a PCP to obtain screening did so. Future programs might include providing take-away health education information (written or electronic) as a reminder to pursue screening.

Only 17 (41.5%) of eligible workers who received a follow up letter completed CRC screening. The data does not provide evidence the letters were instrumental in individuals completing the screening. Would any of the 17 (41.5%) have been screened if not prompted by a letter? Did the follow up letter make any difference? Future programs might include a second or third follow up letter or phone call to boost compliance.

41.5% of participants who received the reminder letter successfully completed screening. Other researchers (Coronado et al. 2018, Baker et al. 2014) have shown results as low as 13.9% and as high as 44.9% when multiple interventions were

[1]https://www.cdc.gov/workplace-health-promotion/php/model/index.html.

performed. The current project was successful by sending only one follow up letter as a reminder.

The current practice improvement project did not control for outside variables such as encouragement by other health care providers, family/significant others, or health department campaigns to obtain CRC screening. Locus of control and health beliefs drive preventive health behaviors, and the current project did not consider either. Finally, results of the current program may or may not be applicable to other population. To improve screening rates, future programs might include distributing education information (written or electronic) as a reminder to pursue screening.

Conclusions

Encouraging workers to seek CRC screening was moderately effective: 40% (n=25) who received a recommendation from a PCP to obtain screening did so while 41.5% who received a follow up letter completed screening. Associated screening costs are negligible and easily incorporated into any employee health care encounter.

Applications to Professional Practice

The current practice improvement project encouraged workers to seek colorectal cancer (CRC) screening and measured the behavioral effect one year later. Follow up reminder letters proved to be helpful in facilitating screening efforts. Workplace health monitoring and screening programs present an opportunistic moment for occupational health and environmental nurses to educate and encourage eligible workers to seek testing from a primary care provider (PCP). Incorporating USPSTF recommended screenings into mandated health monitoring programs requires minimal expense, effort, and time. Primary care and occupational health nurses have the knowledge, expertise, and access to workers to recommend and follow up on suggestions.

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Athens Journal of Health & Medical Sciences – Volume 12, Issue 1, March 2025 – Pages 49-84

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.[2]

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

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[2]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.

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*

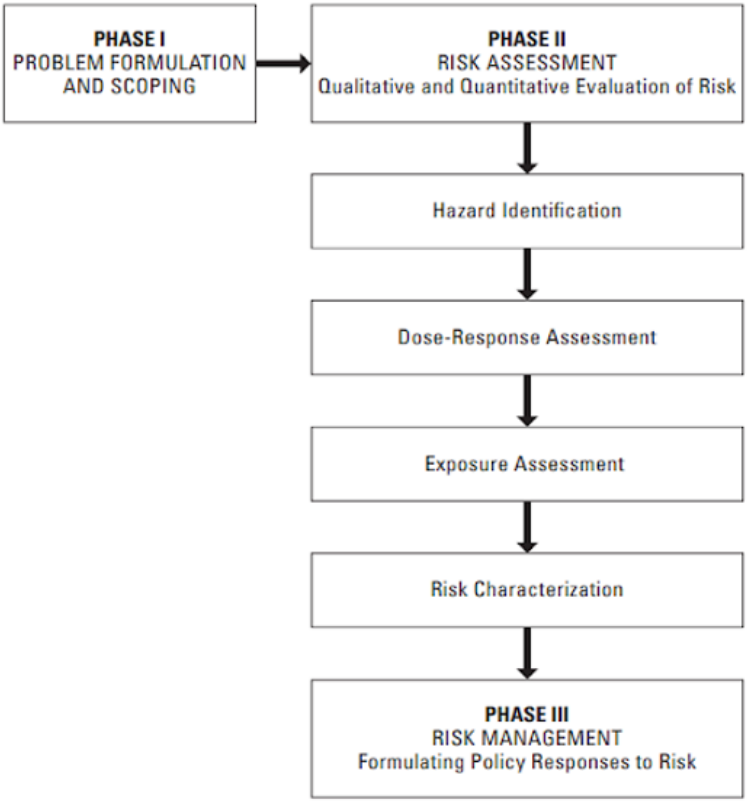
Relative Risk Ranking	Environmental Problem
High risk to human health	Ambient air pollutants Worker exposure to chemicals in industry and agriculture Indoor pollution Contamination of drinking water
High risk to natural ecology and human welfare	Habitat alteration and destruction Species extinction and 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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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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TEST REPORT

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

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TEST REPORT

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

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TEST REPORT

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

----------*END OF REPORT*----------

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