Abstract

Background: Outbreaks of waterborne diseases caused by the contamination of water in the rural and tribal regions have become an area of prime concern in the research arena. The impact and intensity of waterborne diseases are expected to increase in these socioeconomic backward regions. Objective: The purpose of the study is to calculate the waterborne disease vulnerability index (DVI) for 13 blocks of the Kalahandi district of Odisha. Diarrhea and typhoid are two major diseases prevailing in each block of the district. Materials and Methods: Livelihood vulnerability index has been applied with some modifications to calculate the DVI for each block. In the DVI calculation, diseases are taken as an indicator for the exposure section. The sensitivity and adaptive capacity sections are categorized into two subcomponents to study the vulnerability of each block. Results: We have observed uneven distribution of diarrhea and typhoid among the blocks of Kalahandi. The result indicates that vulnerable populations and infrastructure play an important role in enhancing vulnerability whereas educational and health-care capacity reduces its impact. We have found that more than 50% of blocks in the district are categorized in moderate to high vulnerable zones. Conclusion: This study is done to understand the relationship between disease exposure, related vulnerability, and adaptive capacity. It is unique in the way the indicators have been chosen in the proposed method for the calculation of DVI and will have a higher degree of practical applicability.

Keywords: Adaptive capacity, disease vulnerability index, exposure, Kalahandi, sensitivity, waterborne diseases

Introduction

For centuries, water is considered life, but sadly nowadays, more than a billion of the world population do not have access to safe and clean water. Safe, reliable, and affordable water plays an important and crucial role in deciding the hygiene and health of a given population. Safe water is defined as “water that is free of dangerous microorganisms and does not have any significant impact on health after coming in contact with it.” Water gets easily contaminated due to agricultural runoff, industrial waste, sewage and animal waste, mining activities, and accidental oil leakage. Due to the unhygienic and poor quality of water, around 2.4 million deaths are recorded every year. It has been noted that drinking water is more contaminated, and is of poor quality in developing nations.

The burden of diseases constitutes a major public health concern globally. Availability of quality water has its direct and indirect impact on human health. In the present time, waterborne diseases coupled with increasing population pressure, industrialization, and environmental degradation have become a major challenge for both developed and developing countries. Many pioneer works have found a high correlation between contaminated drinking water and waterborne diseases such as typhoid and diarrhea. Diarrhea is the second highest contributor to the list of diseases, and alone kills more children than the combined number of three major diseases including tuberculosis, malaria, and HIV/AIDS. In addition to the degraded quality of water, poor infrastructure, low level of education, and nonavailability of health-care infrastructure play a very vital role in deciding the number of waterborne disease cases and their related deaths.

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Odisha is a state situated in the eastern part of India that constitutes nearly 4% of the land area and 3% of the country’s population.[11] In this study, we empirically try to calculate the disease vulnerability index (DVI) for the blocks of the Kalahandi district of Odisha. Among several kinds of waterborne diseases, acute diarrheal disease and typhoid are two major diseases having their impact on the majority population of the Kalahandi district. This district of Odisha is considered the most socioeconomically backward region of the country and is known as a symbol of poverty, disease, starvation, and death.[12] Keeping these issues in mind, this article focuses on understanding the level of exposure to diarrhea and typhoid, related vulnerabilities, and available adaptive capacity of each block through a range of indicators selected after a detailed study of the literature available on vulnerability index assessment.[13-16] Vulnerability is defined as a function of exposure, sensitivity, and adaptive capacity by the Intergovernmental Panel on Climate Change (IPCC).[17-19]

Materials and Methods

Study area

The study area, Kalahandi, is located between 19°N and 21.5°N latitudes and 82.20°E and 83.47°E longitudes. Physiography of the district includes undulating plains in the northeast and part of the Eastern Ghats.[20] In each block, the maximum amount of rainfall is received during the monsoon season. The temperature ranges between 4°C during winter to more than 45°C during the peak summer season. The district population is mainly dominated by the Scheduled Tribe (ST) and Scheduled Caste (SC) population.

Data analysis

The basic idea of the study is to calculate and compare the DVI value for each block and identify the blocks which are highly vulnerable in the context of exposure to diarrhea and typhoid, two major waterborne diseases found in each block. Data on diseases have been collected from the Government of India project on the Integrated Disease Surveillance Program (IDSP) office situated in the Kalahandi district of Odisha. Data on indicators are calculated separately for each block. For calculating DVI value, we have categorized multiple indicators into three broad concepts of exposure, sensitivity, and adaptive capacity [Table 1], given by the IPCC. In the present study, we have collected data from different secondary sources which include central and state government official publications.[21,22] DVI analysis is done to understand the exposure to diarrhea and typhoid which are major waterborne diseases and play an important role in deciding the morbidity and mortality in the blocks. Some modifications have been made in the livelihood vulnerability index methodology to construct the DVI, which will be fit for our specific case study. DVI constructs a weighted average approach, where each indicator shares equally to the overall index even though major components have several numbers of subindicators. The DVI analysis is constituted through four steps beginning with “indicators,” followed by “profile,” then “component,” and finally, the calculation of “vulnerability index.” The value of “indicator” is calculated using the “human development index” formula (step 1). The next step involves finding the “profile” value, for which an average of the already calculated standardized indicators/indicator index value is constituted under each profile (step 2). In the “component section,” we have taken exposure, sensitivity, and adaptive capacity. Calculated profile values under each component, i.e., exposure (disease factor), sensitivity (vulnerable population + infrastructural vulnerability), and adaptive capacity (educational capacity + health-care capacity), are weightage averaged using the formula mentioned in step 3 to obtain the value of each component.

The stepwise calculation of the DVI has been summarized below.

Steps to calculate the disease vulnerability index based on the livelihood vulnerability index formula

Step 1: Indicators

Values for all the indicators are to be standardized for all the blocks.

The steps can be broadly summarized as:

\[
(I_x) = \frac{I(d) - I(min)}{I(max) - I(min)}
\]

where \(I_x\) = Standardized value for the indicator

\(I(d)\) = Value for the indicator I for a particular block, d

\(I(min)\) = Minimum value for the indicator across all the blocks

\(I(max)\) = Maximum value for the indicator across all the blocks.

Step 2: Profiles

Indicator index values are combined to get the values for the profiles.

\[
(P) = \frac{\sum I_i}{n}
\]

where \(n\) – number of indicators in the profile

\(I_i\) – Index of the \(i^{th}\) indicator.

Step 3: Components

Once values for each profile under a component were calculated, they are combined to obtain the component value.

\[
(C) = \frac{\sum W_i P_i}{\sum W_i}
\]

where \(W_i\) is the weightage of the profile i

\(P_i\) are the profiles for block d

\(n\) is the number of profiles in each component.
Table 1: The broad categories and the indicators chosen to study disease vulnerability index analysis

| Component          | Profile            | Indicators                                                                 | Indicators values among the blocks |
|--------------------|--------------------|-----------------------------------------------------------------------------|-------------------------------------|
|                    |                    | Percentage diarrhea cases to total population (2015-2018)                   | Minimum 1 Maximum 7.9               |
| Exposure           | Disease factors    | Percentage typhoid cases to total population (2015-18)                      | Minimum 0 Maximum 3.8               |
|                    | Vulnerable population | Percentage population of SC and ST in total population                      | Minimum 31.52 Maximum 83.54        |
|                    | Infrastructural vulnerabilities | Percentage in the age group (0-6 years)                                     | Minimum 13.25 Maximum 17.37        |
|                    | Infrastructural vulnerabilities | Percentage families BPL                                                      | Minimum 8.08 Maximum 19.56         |
|                    | Distance on the road from district headquarter                   |                                                | Minimum 0 Maximum 93               |
|                    | Distance on the road from state headquarter                      |                                                | Minimum 369 Maximum 520           |
|                    | Percentage of villages covered with rural drinking water supply  |                                                | Minimum 19.35 Maximum 100          |
|                    | Percentage of Anganwadi centers with toilet facilities           |                                                | Minimum 2.56 Maximum 22.32         |
| Adaptive capacity  | Educational capacity | Literacy rate                                                                | Minimum 45.0 Maximum 67.9          |
|                    | Health-care capacity | Percentage availability community health centers                             | Minimum 0.0004 Maximum 0.003       |
|                    | Health-care capacity | Percentage availability primary health centers                               | Minimum 0.002 Maximum 0.005        |
|                    | Health-care capacity | Percentage availability of doctors (allopathic)                              | Minimum 0.01 Maximum 0.03          |
|                    | Health-care capacity | Percentage availability of functional beds                                   | Minimum 0.005 Maximum 0.08         |
|                    | Health-care capacity | Percentage availability of homeopathic dispensaries                          | Minimum 0 Maximum 0.003            |
|                    | Health-care capacity | Percentage availability of doctors (homeopathic)                             | Minimum 0 Maximum 0.002            |
|                    | Health-care capacity | Percentage availability of (Ayurvedic/Unani) dispensaries                    | Minimum 0.0004 Maximum 0.003       |
|                    | Health-care capacity | Percentage availability of doctors (Ayurvedic/Unani)                         | Minimum 0 Maximum 0.02             |

*Percentage availability of health-care capacity has been calculated separately for each block to their total population, *IDSP, district surveillance unit, Kalahandi, and the Government of Odisha, 2018. Data on different indicators have been taken from the state government reports. IDSP: Integrated Disease Surveillance Program, BPL: Below poverty line, SC: Scheduled caste, ST: Scheduled tribe

The values obtained for each block is then categorized into the low, medium, and high category.

**Step 4: Vulnerability Index**

\[ \text{DVI} = (\text{exposure–adaptive capacity}) \times \text{sensitivity} \]

The final value of the DVI for each block is categorized between $-1$ (least vulnerable) and 1 (most vulnerable) and divided the value into three categories, namely low, moderate, and high vulnerable blocks.

**RESULTS**

The district has faced several major outbreaks of diarrhea and typhoid in the past few decades. This is happening again and again because of the factors related to the nonavailability of quality water, poor sanitation system, low level of education, and poor health-care capacity. The percentage of diarrhea and typhoid cases to the total population has been calculated separately for each block to understand the pattern of these diseases [Figure 1]. After the analysis of data, it has been found that there is a prevalence of variation among the blocks, and that is why we have considered these diseases as a major factor of exposure. According to the percentage, we have found that diarrhea is a more dominant disease than typhoid [Figure 1]. Interestingly, the maximum percentage of cases for both diseases is recorded in the Madanpur Rampur block of the district [Figure 1]. The final composite value ranges for the exposure section (0.03–1), sensitivity (0.32–0.71), and adaptive capacity (0.18–0.62) are divided into three equal parts on the basis of their score in the component section to classify them into low, moderate, and high zones [Figure 2a-c].

The final composite value for the exposure section shows that Madanpur Rampur (1.0) has the highest component value and hence is a highly exposed block. Bhawanipatna (0.49), Karlamunda (0.48), Jayapatna (0.40), and Kalampur (0.39) blocks have been categorized as moderately exposed [Figure 2a]. Blocks in the south, southwest, and southeastern part of the district are less exposed [Figure 2a].

Sensitivity related to diseases is defined as the degree to which people will be affected, which includes several subcomponents such as vulnerable population, environment, and available infrastructure. Diarrhea and typhoid have their maximum impact on the infant population; therefore, we have particularly taken the age group (0–6 years) of the population for the study. In the final composite value of sensitivity [Figure 2b], we have found that Thuamul Rampur (0.71), Jayapatna (0.68), Kokasara (0.65), and Golamunda (0.60) blocks of the district are highly sensitive. This is because of the high-profile value of these blocks [Table 2]. Lanjigarh block of the district is categorized as moderately sensitive block, and the remaining blocks are low sensitive based on the indicators.

Adaptive capacity plays an important role in understanding the vulnerability related to diseases. Better adaptive capacity enhances the chances of lower vulnerability. Here, in this
In the vulnerability index assessment, exposure and sensitivity play a positive role in increasing risk factor whereas adaptive capacity reduces it. Waterborne diseases such as diarrhea and typhoid have become a serious challenge and cause of concern for the district and state administration. During the field visit of the study area, it has been observed that there is no proper arrangement of drinking water supply in the whole district except for urban areas. People in the blocks are still dependent on the unprotected wells, hand pumps, and ponds for their everyday need for water. Open water sources are easily contaminated due to the free-roaming livestock.[24]

Poverty has always a negative impact on human health,[25] and it accelerates the rate of morbidity and mortality related to diarrhea and typhoid. We have observed that in the Madanpur Rampur (0.14) and Golamunda (0.08) blocks are categorized into high vulnerable blocks. Madanpur Rampur falls in the high vulnerable category concerning its exceptionally high exposure to both waterborne diseases [Figure 2d].

Interestingly, we have found that blocks such as Bhawanipatna, Junagarh, and Kesinga knew for their urbanization and development in the districts are in the moderately vulnerable category. Dharmagarh, Kokasara, Jaipatna Thuamul Rampur, Lanjigarh, and Narla are the least vulnerable blocks of the district [Figure 2d].

**Discussion**

DVI has been calculated by applying the formula: (exposure–adaptive capacity) x sensitivity. The values of the final DVI calculation lie between −1 and +1, and blocks of the district have been divided into three classes, i.e., high, moderate, and low. The blocks having high negative values are categorized as low vulnerable whereas the blocks near the positive values and above are categorized classes as moderate, and high positive values as high vulnerable blocks. The final value of the DVI for the blocks ranges between −0.19 and +0.14. Madanpur Rampur (0.14) and Golamunda (0.08) blocks are categorized into high vulnerable blocks. Madanpur Rampur falls in the high vulnerable category concerning its exceptionally high exposure to both waterborne diseases [Figure 2d].

Poverty has always a negative impact on human health,[25] and it accelerates the rate of morbidity and mortality related to diarrhea and typhoid. We have observed that in the Madanpur Rutupur (0.24) DVI value is calculated as moderate vulnerable blocks.

**Figure 1:** Locational distribution of diarrhea and typhoid cases in the blocks of Kalahandi. The bar diagram in the map represents percentage cases in total population for 4 consecutive years (2015–2018).

**Figure 2:** Choropleth maps showing (a) exposure, (b) sensitivity, (c) adaptive capacity, (d) disease vulnerability index distribution in different blocks of Kalahandi. Green, yellow, and red colors in the map represent low, medium, and high component values, respectively, for the exposure, sensitivity, and disease vulnerability index. The color combination is opposite for the adaptive capacity section.
Rampur block high percentage of infant age group (0–6 years), a large number of population from the marginalized class (SC and ST population), existence of poverty, less number of villages covered with rural drinking water, and unavailability of the proper toilet at the Anganwadi centers are the contributing factors for its very high vulnerability. Block like Golamunda is not highly exposed to both these diseases but still is placed in the high vulnerable zones [Figure 2d], due to its poor composite index value in the sensitivity and adaptive capacity section. It is important to note here that Bhawanipatna, the district founder, is also found in moderate vulnerable zone due to two combining factors of moderate exposure and adaptive capacity.

Lanijigarh block placed on the eastern side has a moderate composite value of exposure and sensitivity, but it is eroded by the high adaptive capacity value, and therefore, this block is placed under the category of low vulnerability. Dharmagarh and Kokasara blocks are among the low vulnerable blocks in the district due to their low level of exposure and moderate level adaptive capacity. Golamunda, Thumul Rampur, Jaiapatna, and Kokasara block sensitivity levels are high which may put them in a grave situation if an outbreak of any disease will happen in future. The overall DVI indicates that more than 50% of the blocks are placed under the high and moderate vulnerable zone.

This study is therefore helpful in finding those blocks which need proper attention from government officials to control diarrhea and typhoid. The merit of the study lies in the fact that the indicators used in this study are based on a detailed literature survey carried out on health vulnerabilities. After a span of 10 years, an analysis can be carried out to find the vulnerability situation of the blocks with the social, demographic, economic, and health-related infrastructure data, which can portray the significant changes occurring over a decade. The study here finds that these four factors play an important role in deciding the disease incidences and health vulnerabilities in blocks of the Kalahandi district. The increase and decrease of cases are highly dependent on these factors.

Table 2: Block-level calculation of profile values for exposure, sensitivity, and adaptive capacity section

| Blocks     | Exposure | Vulnerable population | Infrastructural vulnerability | Educational capacity | Health-care capacity |
|------------|----------|-----------------------|-------------------------------|----------------------|----------------------|
| Bhawanipatna | 0.49     | 0.42                  | 0.30                          | 0.66                 | 0.34                 |
| Kesinga    | 0.30     | 0.23                  | 0.39                          | 0.68                 | 0.35                 |
| Karlamunda | 0.48     | 0.04                  | 0.75                          | 0.69                 | 0.38                 |
| Madanpur Rampur | 1.00 | 0.56                  | 0.23                          | 0.61                 | 0.61                 |
| Narla      | 0.11     | 0.40                  | 0.39                          | 0.68                 | 0.27                 |
| Lanijigarh | 0.40     | 0.78                  | 0.42                          | 0.81                 | 0.52                 |
| Thumul Rampur | 0.26    | 0.89                  | 0.58                          | 0.80                 | 0.34                 |
| Dharmagarh | 0.03     | 0.38                  | 0.49                          | 0.55                 | 0.42                 |
| Junagarh   | 0.32     | 0.39                  | 0.31                          | 0.53                 | 0.26                 |
| Kalampur   | 0.39     | 0.07                  | 0.53                          | 0.46                 | 0.43                 |
| Jayapatna  | 0.16     | 0.38                  | 0.90                          | 0.60                 | 0.18                 |
| Kokasara   | 0.21     | 0.42                  | 0.82                          | 0.70                 | 0.35                 |
| Golamunda  | 0.32     | 0.44                  | 0.72                          | 0.28                 | 0.13                 |

CONCLUSION
This piece of research has depicted the vulnerabilities related to waterborne disease in a tribal and socioeconomically backward region like Kalahandi. Secondary data has been used in calculating DVI, thereby upholding a higher degree of practical applicability. The result of the study has identified blocks that are highly exposed to diarrhea and typhoid, indicating that they require urgent and special attention from the district administration and health authorities to scale up the control activities. Spatial understanding of the interrelation between disease exposure, the sensitivity of population, and available adaptive capacities will ultimately be helpful in the implementation of intervention strategies to control and eliminate these two deadly diseases from the blocks of one of the most vulnerable districts of the country. It could further be highlighted that coupled with the implementation of plans and policies, incessant assessment and monitoring of the implemented policies are also required. Finally, it can be said that this study could be of utmost help to public health researchers and policymakers to further explore the dynamics and disparities of vulnerability assessment of communities for ensuring the overall well-being of the community.

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Conflicts of interest
There are no conflicts of interest.

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