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Purely Spatial Scan Statistics using Ordinal Model on Diarrhea Determinant Factors in Tanah Bumbu District, South Kalimantan (Indonesia)

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Abstract: Diarrhea was a deadliest disease for children-under five years. In Indonesia, prevalence of diarrhea reaches 3,5% while its incidence in South Kalimantan was 3,3%. Purpose of this research was to determine spatially the correlation between causal factors with diarrhea cases in the working area of several public health center in Tanah Bumbu District. Its result should be useful as a tool for evaluation and determination of accurate and efficient planning based on geographical area. Ordinal data of diarrhea determinant factors was analyzed using SaTScan™ v9.4.4 in purely spatial analysis function with ordinal data model. *P* value was defined from Relative Risk value, and result from SaTScan™ was then visualized on map using QGIS NODEBO 2.16.3 to obtain the distribution pattern of cluster at risk. Data showed specific geographic distribution pattern of risked cluster and have a tendency to correlate cluster pattern with the distribution plot and strong density of diarrhea incidence. Result suggested that clusters with moderate to poor determinant quality have the same tendency with high case density in the area. Local-specific intervention related to improvement of water quality and sanitation along with continual education about clean and healthy living behavior, should be able to decrease the burden of diarrhea in the community.

Keywords: Diarrhea, SaTScan, Spatial Scan Statistic, Sanitation, Clean Water, Clean-living Behavior

1. Introduction

Diarrhea contribute to at least 20,1% of children-under five years mortality [1]. Children in developing country such as Indonesia can suffer from diarrhea 10 times a year [2]. Based on data from Basic Health Research (RISKESDAS; Riset Kesehatan Dasar) 2013, diarrhea prevalence of Indonesia was 3,5%, while diarrhea incidence of South Kalimantan Province was 3,3% [3]. Acute diarrhea on South Ethiopians children were significantly associated to the absence of toilet in family, untreated drinking water, improper disposal of baby waste, and poor quality of domestic clean water [4].

Quality and accessibility of clean water, clean-living behavior and quality of sanitation were important factors in improving the quality of general health and avoiding various diseases including diarrhea. Control of those factors was substantial for planning and determining the focus of intervention in the community so that diarrhea cases of can be reduced as much as possible in areas that were prone for outbreak. Consistent interventions by campaigning hand washing with soap, improving water quality, and fecal-waste management can significantly reduce the risk of diarrhea [5].

Analyzing the pattern of disease distribution and some risk factors spatially were decent and inexpensive approach to detect concentrations or groups of disease impact for prevention action planning and to measure the success of an intervention [6,7]. A number of studies have conducted spatial cluster analysis to find the correlation of diarrhea risk factors in order to determine diarrhea epidemic clusters pattern of an area and consequently planning and intervention will become priority for high-risk areas [8–10]. It is important for Tanah Bumbu District to determine upfront management of areas and efficient control of diarrhea in the areas. This study focused on water quality by the types of pollutant bacteria detected, access to clean water, hygiene behavior, and community sanitation access.

This paper was sought to find the distribution of diarrhea on different environmental conditions and behaviors that contribute to the incidence of diarrhea epidemic on an area. This study aimed to determine the relevance of various factors mentioned above with diarrhea cases in several working areas of public health center (Puskesmas) in Tanah Bumbu District as the tool for evaluation and determination of accurate and efficient planning based on geographical area.

2. Method

This paper was an advance analysis of preceding research on analysis of diarrhea factors in Tanah Bumbu District using GIS approach [11,12]. We emphasized this paper on water quality by calculated types of pollutant bacteria as the degree of water quality and other diarrhea risk factors that were processed into ordinal data. These data were analyzed for cluster scanning using software SaTScan™ v9.4.4 in purely spatial analysis function with ordinal data model [9,13].

Head of the family from diarrhea patients in six public health center (Puskesmas) in Tanah Bumbu District were sampled within categories: diarrhea and gastroenteritis from certain infection [Code A09]; diarrhea from other intestinal bacteria infection [Code A04]; diarrhea from Salmonella infection [Code A02], and; diarrhea from Shigella infection [A03]. As much as 501 samples chosen were randomly selected based on proportion and total number of population in the sampling area.

Selected respondents were home-visited based on the register from Puskesmas and asked for voluntary approval to contribute in the study by signing informed consent. Data collection was interview related to behavior, observation of house environment and access to clean water, marked the coordinates of house, and domestic water sampling. Water samples were analyzed in Balai Litbang Kesehatan Tanah Bumbu laboratory with standard bacteriological method to found the type of water pollutant bacteria [14,15].

Domestic water contamination was categorized into: 1 (very low); 2 (low); 3 (medium); 4 (High); 5 (very low). Whilst, access to clean water, clean and healthy living behavior (PHBS; Perilaku Hidup Bersih dan Sehat), and sanitation access were categorized into: 1 (good); 2 (moderate), and; 3 (poor). These ordinal data were then incorporated into SaTScan™ v9.4.4 software together with the coordinate data of village area and number of population per village obtained from the Demography and Civil Registration Office (DISDUKCAPIL; Dinas Kependudukan dan Catatan Sipil) of Tanah Bumbu District.

Purely spatial analysis using ordinal model was used to identify cluster distribution within a year study period (1 January to 31 December 2016). To reduce bias, study area measurement was set to default value (less than 50% of risky population) [16]. Area measurement with a high or low value setting was chosen to detect all clusters at risk by circular spatial window. The 95% Monte Carlo simulation (α = 0,05) was used with 999 replications to test for null hypothesis - there was no difference on relative risk (RR) between clusters. *P* value was defined from Log-Likely-hood Ratio (LLR) and RR value where cluster with highest LLR was used as “likely cluster” whereas cluster with lower LLR used as “secondary cluster” [13]. Result from SaTScan™ was visualized on the map using QGIS NODEBO 2.16.3 to obtain the distribution pattern of cluster at risk.

3. Results

Analysis of model involved 501 respondents with several types of ordinal data associated to the risk factors of the families likely-exposed to diarrhea. Result from the analysis was in the form of cluster consisting several villages detected. The village was the ID of the location used to determine the position of the cluster detected, therefore it was reasonable to be used as a support of an actual cluster position prediction. This result only represents the area under analysis which were working areas of six selected puskesmas in Tanah Bumbu so that the clusters detected cannot be used as an interpretation for other puskesmas.

Purely spatial cluster analysis detected 4 cluster of pollutant bacteria in domestic water samples (water quality) (Table 1). All clusters were not significant based on relative risk of all categories. However, clusters 1-3 showed water samples contaminated by 0-2 bacteria species (category 1-3) had enough impact on the cluster area between 2,17 to 19,18 km which involved a total of 33 villages detected.

Table 1. Purely Spatial Cluster Analysis for Number of Contaminating Bacteria in Water

Cluster	Categories	Observed	Expected	RR	p-value	Villages in cluster	Radius (km)
1	[1, 2], [3-5]	138, 2	128.54, 11.46	1.11, 0.13	0.064	24	19.18
2	[1, 2], [3, 4, 5]	142, 24	152.42, 13.58	0.90, 2.85	0.272	3	2.17
3	[1], [2, 3], [4], [5]	12, 98, 2, 4	13.89, 98.87, 1.85, 1.39	0.83, 0.99, 1.11, 6.64	0.996	6	8.73
4	[1, 2], [3, 4, 5]	0, 1	0.92, 0.082	0, 12.50	0.999	1	0

Categories: 1 = very low; 2 = low; 3 = medium; 4 = high, 5= very high; RR : relative risk

Access for clean water factor within category moderate and poor (category 2 and 3) detected 3 significant clusters which included 11 villages on radius between 0 to 8.77 km (Table 2). Cluster 1 and 3 showed significant difference in poor category, while cluster 2 significant in moderate category.

Table 2. Purely Spatial Cluster Analysis for Access of Clean Water

Cluster	Categories	Observed	Expected	RR	p-value	Villages in cluster	Radius (km)
1	[1], [2], [3]	0, 8, 29	4.73, 28.14, 4.14	0, 0.27, 13.47	0.001	6	8.77
2	[1], [2], [3]	35, 153, 1	24.14, 143.73, 21.13	1.99, 1.11, 0.030	0.001	4	3.13
3	[1, 2], [3]	0, 7	6.22, 0.78	0, 10.08	0.001	1	0

Categories: 1 = good; 2 = moderate; 3 = poor; RR : relative risk

There were three significant clusters among four clusters detected from clean and healthy living behavior factor (Table 3). These three clusters geographically on radius between 2.49 to 9.27 km which included 25 villages. A noticeable result from clusters 2 and 3 was that the relative risk of behavior in the poor category was greater than 2 other categories.

Table 3. Purely Spatial Cluster Analysis for Clean and Healthy Life Behavior

Cluster	Categories	Observed	Expected	RR	p-value	Villages in cluster	Radius (km)
1	[1], [2], [3]	42, 57, 57	27.09, 42.35, 86.56	2.06, 1.60, 0.57	0.001	3	2.49
2	[1], [2], [3]	10, 26, 87	21.36, 33.39, 68.25	0.40, 0.73, 1.40	0.012	9	9.27
3	[1], [2], [3]	7, 18, 69	16.32, 25.52, 52.16	0.38, 0.66, 1.43	0.019	13	4.90
4	[1], [2], [3]	10, 12, 10	5.56, 8.69,	1.90, 1.42,	0.573	2	1.67

			17.76	0.55			

Categories: 1 = good; 2 = moderate; 3 = poor; RR : relative risk

Sanitation access factor detected four significant clusters within moderate to poor category (category 2 and 3) which impact 23 villages within 0.91 to 12.42 km range (Table 4). Highest relative risk was cluster 1 and 4 with poor category. Observed data in cluster 2 and 4 indicated that sanitation access on moderate category was higher compared to other category.

Table 4. Purely Spatial Cluster Analysis for Access of Sanitation

Cluster	Categories	Observed	Expected	RR	p-value	Villages in cluster	Radius (km)
1	[1], [2], [3]	0, 11, 26	1.03, 30.72, 5.24	0, 0.34, 7.25	0.001	6	9.04
2	[1], [2], [3]	7, 125, 1	3.72, 110.44, 18.85	2.77, 1.19, 0.040	0.001	2	2.17
3	[1], [2], [3]	6, 68, 1	2.10, 62.28, 10.63	4.26, 1.11, 0.081	0.002	7	0.91
4	[1], [2], [3]	1, 34, 21	1.56, 46.50, 7.94	0.61, 0.71, 3.34	0.003	8	12.42

Categories: 1 = good; 2 = moderate; 3 = poor; RR : relative risk

Results from analysis were visualized on following map. Map A showed position of cases compared to several cluster distribution patterns of detected risk factors. Map B showed four clusters of domestic water quality which concentrated in Mudalang, Kampung Baru Simpang Empat, Madu Retno, and Sumber Makmur Village. Map C picturized clusters distribution of clean water accessibility which concentrated in Satiung, Barokah, and Karya Bakti Village. Likewise, both Map D and E showed clusters distribution of sanitation access and clean and healthy-living behavior which concentrated in several villages. All maps showed distribution patterns that tend to correlate with the distribution and density of diarrhea cases.

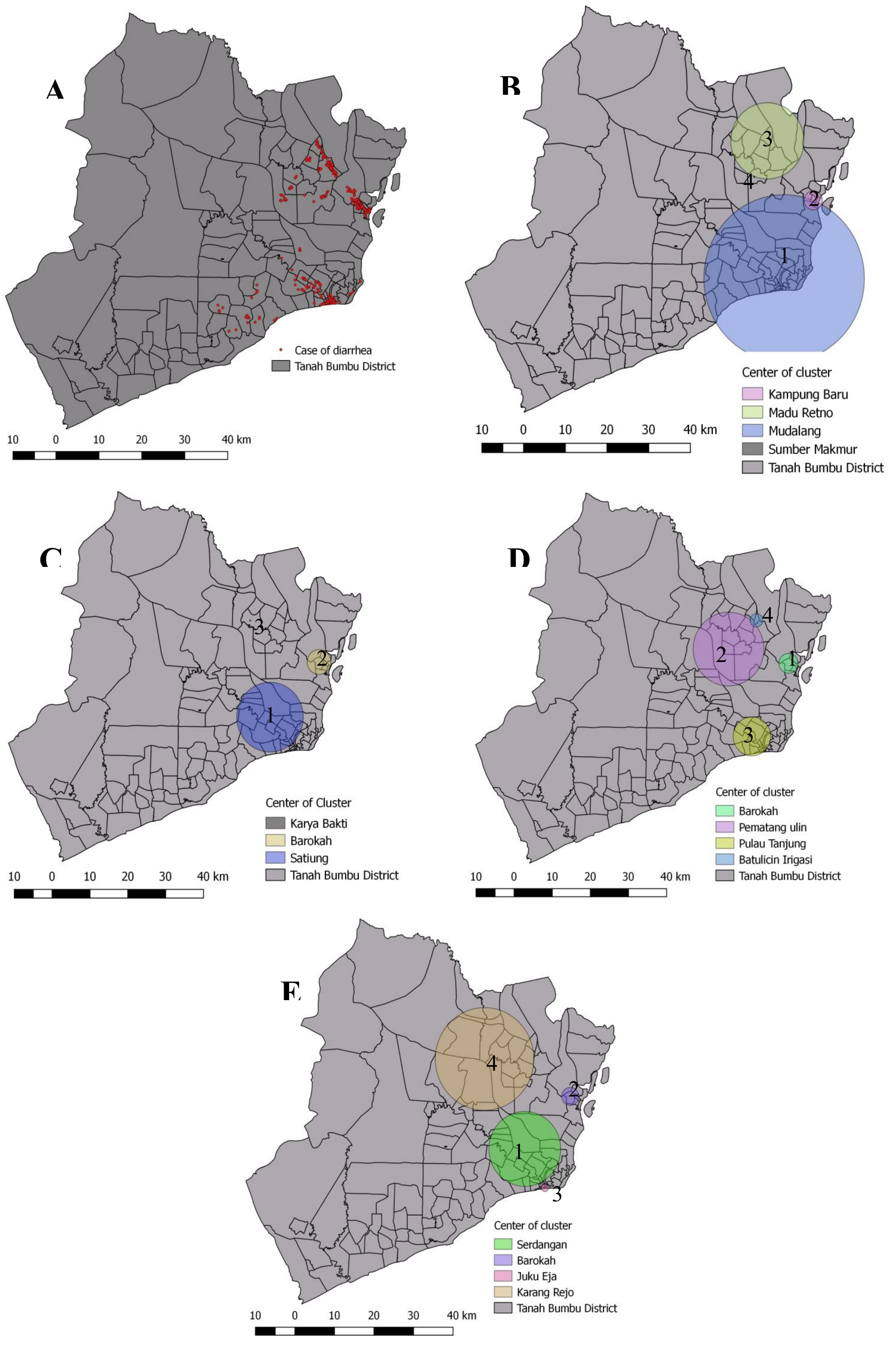
A
Case of diarrhea
Tanah Bumbu District
10 0 10 20 30 40 km
B
3
4
2
1
Center of cluster
Kampung Baru
Madu Retno
Mudalang
Sumber Makmur
Tanah Bumbu District
10 0 10 20 30 40 km
C
3
2
1
Center of Cluster
Karya Bakti
Barokah
Satiung
Tanah Bumbu District
10 0 10 20 30 40 km
D
4
2
1
3
Center of cluster
Barokah
Pematang ulin
Pulau Tanjung
Batulicin Irigasi
Tanah Bumbu District
10 0 10 20 30 40 km
E
4
2
1
3
Center of cluster
Serdangan
Barokah
Juku Eja
Karang Rejo
Tanah Bumbu District
10 0 10 20 30 40 km

Figure 1. Purely spatial cluster analysis using ordinal model depicted (A) Location of diarrhea patient who registered at local health care center and sampled; (B) Purely spatial scan statistic showing only statistically significant cluster for number of contaminating bacteria in water; (C) Purely spatial scan statistic showing only statistically significant cluster for access of clean water; (D) Purely spatial scan statistic showing only statistically significant cluster for clean and healthy life behavior; (E) Purely spatial scan statistic showing only statistically significant cluster for access of sanitation

4. Discussion

This analysis explicates that group concentration of potential impact from diarrhea risk factors can be detected geographically. This became very important in determining a targeted planning and intervention. Surveillance on public health requires a comprehensive yet specific statistical analysis to understand public health problem such as diarrhea. Spatial scan statistic was a tool to identify exactly where potential impacts can arise, therefore specific information about the size of the group and the magnitude of the risks can be made [6]. Spatial scan statistics with ordinal data not only detects the most risky areas, but also the clusters that most likely to raise the risk.

At least three points that can be discussed from results above. First, the data show typical patterns of geographic distribution of risky clusters. Second, data tend to correlate cluster patterns with distribution plot and strong diarrhea cases density. Third, the results indicate clusters with moderate to poor quality risk factors seem to be consistent with the high density of cases in its area. The only limitation of this analysis was it cannot generalize the quality of cluster concentration and its impact to areas with different geographical characteristics. Nevertheless, this method was useful as a reasonable surveillance tool for identifying regional concentration to populations that share the same risk factors level. This method can accurately indicate the concentration with these risk factors so that the area could be a main focus in interventions planning.

Results showed that most cluster concentrations in category 2 and 3 were in areas where diarrhea commonly found. This was similar to study in Mauritania that showed quality of clean water and water contamination were the main trigger of diarrhea, and diarrhea often to be concentrated in areas with poor water quality [17]. Another study associated knowledge and pre-boiling water behavior of housewife with diarrhea cases in Tapin District (Indonesia) [18]. Data in Table 1 confirmed that water quality measured by the amount of bacterial contamination was at a low level that correlates significant clusters. This indicated that at the lowest water contamination level, it was sufficient to have significant impacts to diarrhea in the area. This may be caused by several situations including: a) low immune system that increases the susceptibility to bacterial; b) poor sanitation which increase persistent exposure that may increase the risk of diarrhea, and; c) families with infants and children can experience diarrhea several times a year [19].

The results clearly showed that clusters distribution was consistent with diarrhea cases distribution and cluster concentration that correlated with the diarrhea case density in the analysis area. Poor water quality, access to clean water, sanitation and clean-living behavior were the main risk factors of diarrhea in Tanah Bumbu District. From this study, we found several types of pollutant bacteria from water examined such as *Escherichia coli*, *Salmonella*, *Vibrio*, and some *enterococcus*. We did not continue the analysis of bacterial type to species level, however information on types of bacteria found was sufficient to clarify the poor quality of water, hygiene, and sanitation [10,20–24]. More types of pollutant bacteria in water will further exacerbate water quality in Tanah Bumbu community.

We found that most of the respondents in this study consumed drinking water bought from refill depots without pre-boiling (Data not shown). It was often seen that depots owner did not follow proper handling procedures and they move refill water into unsterilized containers to be delivered to customers. This becomes one of the possible determinants of the cause of diarrhea in this area [25,26].

The current standard in public health to treat diarrheal problems was mainly by oral rehydration to prevent more deaths [27]. However, diarrhea infections will remain happen in environment with poor sanitation and contamination [27]. Environmental restoration was important to reduce the burden of this disease. Individual hygiene behavior need to be promoted to the public as a preventive action and keeping personal health [28]. Routine monitoring of domestic water quality treatments, storage, installation and distribution of clean water should be encouraged by local governments to maintain healthy communities [29,30]. These efforts will be effective if applied locally depend on the main problem that affect the region most.

5. Conclusion

Purely spatial scan statistics method in this study showed spatial correlation between detected diarrhea determinants cluster and diarrhea cases distribution and density within the area of study. Water quality, access to clean water, sanitation, and clean-living behavior were main factors for diarrhea incidences in the community of Tanah Bumbu District.

6. Suggestion

Local-specific intervention related to improvement of water quality and sanitation along with continual education about clean and healthy living behavior, should be able to decrease the burden of diarrhea in the community.

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8. Author Contribution

DA provided concept and analysis of the script along with references collection. SH provided draft of the script whilst prepared logistic and materials in the research. DA provided references collection and data analysis.

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