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Original Research

FECAL COLIFORM BACTERIA AND FACTORS RELATED TO ITS GROWTH AT THE SEKOTONG SHALLOW WELLS, WEST NUSA TENGGARA, INDONESIA

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ABSTRACT

Background: The poor sanitation and small numbers of households who own toilet in Sekotong regency may relate to the diarrheal events due to the fecal coliform contamination in drinking water.

Aim: This paper aims to provide the concentrations of fecal coliform bacteria in shallow well waters and the factors associated to its growth.

Method: Fifteen groundwater samples were collected from 5 shallow wells to provide the concentrations of total fecal coliform bacteria (FC), mercury concentration, inorganic nitrogen compounds (represent as ammonia, nitrate, and nitrite), total phosphorus (TP), dissolved oxygen (D), pH, and salinity. The concentration of the parameters was then compared to the safe limit set by World Health Organization (WHO).

Results: The results indicated that the drinking water resources at the Sekotong regency were contaminated by coliform and mercury. One location with low mercury concentration was recorded with *E. coli* contamination. Residence, agriculture, and animal livestock were subjected as the sources of coliform contamination. Mercury concentrations may inverse the growth of FC. No apparent relationship was found between total phosphorous and inorganic nitrogen compounds to FC growth. However, we recognized the FC growth responded positively to the level of phosphorous in waters, but associated negatively to nitrate concentration. An inverse correlation was also found between coliform survival and salinity in this study. The pH range at 6.05 – 6.50 supported FC survival.

Conclusion: The drinking water resources at the Sekotong shallow wells were contaminated by coliform and mercury. It is important for local government to inform drinking water protection and treatment.

Key Words: Fecal coliform bacteria, nutrient load, physicochemical properties

INTRODUCTION

Worldwide, in 2012, around 21 of 100,000 people die of diarrheal disease.[1] In 2013, this infectious disease contributed to 6% of mortality among children under-5 in Indonesia.[2] As consent of Ministry of Health of Indonesia, diarrheal prevalence in West Nusa Tenggara exceed the national prevalence, reached to 13.2%.[3] Study found poor sanitation was recognized as the cause of diarrhea in developing country.[4] With only 49,10% of the total households in Sekotong regency owns toilet, it is not surprising the District Health Office estimated 1,046 of 25,450 population in Sekotong suffered from diarrhea in 2013, or 10.8% increased than the previous year.[5,6]

The diarrheal episodes in Sekotong regency are perceived to be associated with fecal coliform bacteria. As it has been found in other developing countries, the infectious diarrhea was significantly related with contamination of fecal coliform bacteria in drinking waters.[7-9] Land use and livestock-related management practices, such as grazing and manure applications, may relate to fecal coliform indicator concentrations in waters.[10] This paper aims to measure the concentration of total coliform bacteria in drinking water resources and to find out the factors associated to its growth.

METHODS

Groundwater samples

There were 15 groundwater samples collected from 5 shallow wells at villages in Sekotong regency (S 08º 45-46’ 51.1-2” and E 115º 56’ 39.0-41.7”), as shown in Figure 1 with detail description available in previous study.[11] At the sampling locations, the land may be used for residence, agriculture, or animal live stocks as shown in Table 1. The elevation at subjected areas was noted arranged from 2 to 26.5 m asl. During sample collection, the temperature of shallow well waters was recorded ranged 28.75 – 29.65˚C. The samples were collected during rainy season in December 2014 with precipitation falls about 1,557 mm. The shallow well waters which drawn manually using an acid-washed plastic were preserved to a corning®50mL poly ethylene terephthalate (PET) centrifuge tube and stored in an insulated ice box, as the previous study.[12] Single-use glove was used during sample collection.

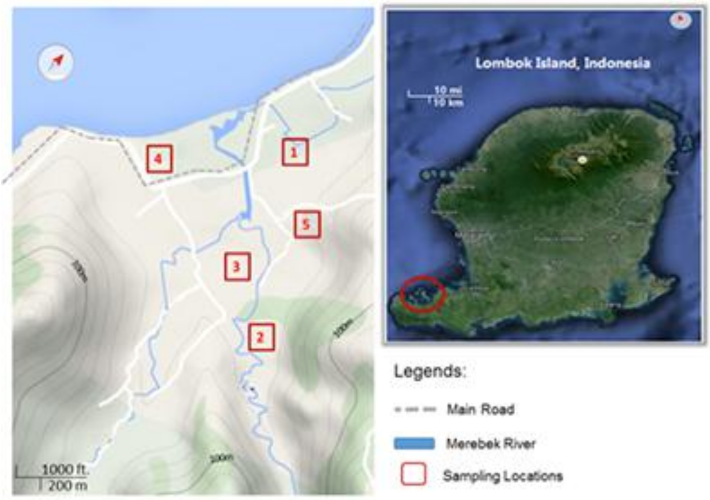
Mercury measurement

Digestion procedure for waters as the Standard National Indonesia (SNI) 6989.78:2011 regarding to mercury determination in water samples.[13,14] Mercury concentration was measured at Laboratorium Penelitian dan Pengujian Terpadu (LPPT) – Universitas Gadjah Mada (UGM), Yogyakarta, Indonesia, and the inter and intra-observer variations, and the quality control (QC) were controlled following the SNI 06-6992.2-2004 method, accredited to IKU/5- 4//MA-01. The laboratory has been assessed and accredited by SNI ISO/IEC 17025:2005 for conducting calibration and analytical test. The limit of detection (LOD) and the limit of quantification (LOQ) calculated in was 0.03 and 0.10 ppb, respectively, while the recovery of mercury concentration determination in water samples (with 6 replications) was 103%.[11]

Water property measurement

Groundwater samples were transferred to Balai Budidaya Laut Lombok Laboratory for measurement of total organic matter (TOM), total phosphorous (TP) and total inorganic nitrogen by following the national standard of measurement SNI 06-6989: 2005. The pH, dissolved oxygen (DO), and salinity of the freshly collected non-filtered samples were measured *in-situ* using a pH/DO/Salinity meter, respectively. The device was calibrated 3 times before the measurement.

Figure 1. Sampling locations represent the 5 shallow wells in Sekotong regency, West Nusa Tenggara, Lombok, Indonesia (Google Earth).



Fecal coliform measurement

The fecal coliform bacteria were counted by plate count method at Tryptone Bile X-glucuronide agar 3 days after inoculation.

Data analysis

The data obtained from the field was analyzed using Microsoft Excel for calculation to obtain the mean value and standard error. The concentration of the observed parameters was represented as mean or mean ± SE.

RESULTS AND DISCUSSIONS

Fecal coliform bacteria: concentrations and sources

Results exhibited that during rainy season the fecal coliform (FC) was detected on all shallow wells at Sekotong's Gold Mining village and one of those five sampling locations for fecal *E. coli*. The colony forming unit (CFU) assessed in the shallow well water samples varied from 1 to 4,000 CFU/100 mL for coliform and measured at 300 CFU/100 mL for *E. coli*. Several numerous sources can be subjected as the sources of coliform bacteria contamination in water resources including fecal contamination either from humans or animals, or runoff from agricultural field, rainfall, or sewage. Table 1 confirmed that the fecal coliform may enter the drinking water system from the nearby residence, agriculture, and animal stocks; but, by the data, only residence contributed to *E. coli* contamination to the drinking water resources. The highlighted sources of fecal coliform bacteria at the subjected locations are animal grazing and open defecation. The depths of water surface in the observed well waters may reflect the accessibility of coliform bacteria to the shallow wells,[15] but it is not associated to the number of TC in the shallow wells.

There is no doubt that the shallow well water at Sekotong's Gold Mining village should be treated. The total coliform bacteria measured in the subjected areas above the safe level by WHO guidelines that recommend the drinking water should have no detectable amounts of coliform bacteria. From the previous study the authors highlighted that the local people drink the fresh water without boiling.[11] Drinking untreated water will impact to the diarrhea morbidity in Sekotong Lombok Barat.

Mercury roles to fecal coliform bacteria

This study shows a low concentration of fecal coliform bacteria was measured at location with mercury concentration above the safe limit for drinking water (2 ug/L), at the average (± SE) of 2.370 ± 0.653 ug/L. An increase of coliform concentration was found with a decreasing level of total mercury. The coliform may resist to the heavy metal,[16] but the growth can be deduced. Mercury contamination in Sekotong shallow wells was caused by the artisanal small-scale gold mining nearby as reported by the previous study.[11] The *E. coli* isolated at sampling location 5 resisted to elemental mercury at 10 ug/L (data not shown). Found at location 4, the concentration of mercury at the average of 0.115 ug/L may not relate to coliform suppression. We believe mercury should be existed in the water at certain level to inverse the growth of coliform bacteria.

Table 1. Description of sampling locations and the level of the observed parameters including coliform bacteria, nutrient load, and physicochemical properties of the groundwater

Parameters	Unit	Sampling Locations					Safe Limit[a]
		Location 1	Location 2	Location 3	Location 4	Location 5	
Elevation	**m asl**	5	26.5	19.5	2	21	
Depth to water surface	**m**	1.38	5.10	3.10	1.63	2.5	
Land Uses							
Residence		Yes	Yes			Yes	
Agriculture		Yes		Yes	Yes		
Animal Livestock		Yes		Yes			
Total Fecal Coliform	**CFU/100 mL**	1	20	365	1,120	4,000	0
Fecal *E. coli*	**CFU/100 mL**	-	-	-	-	300	0
Mercury concentration	**ug/L**	2.370 ± 0.653	0.042 ± 0.012	0.054 ± 0.006	0.115 ± 0.085	0.070 ± 0.011	
Nutrient Load							
Nitrogen Compounds							
• Nitrate	**mg/L**	1.95 ± 0.071	2.75 ± 0.071	2.05 ± 0.071	1.70 ± 0	0.90 ± 0.141	10
• Nitrite	**mg/L**	0.02 ± 0	0.03 ± 0	0.02 ± 0	0.02 ± 0	0.02 ± 0	1
• Ammonia	**mg/L**	0.004 ± 0.001	0.045 ± 0.001	0.015 ± 0.001	0.049 ± 0.004	0.006 ± 0.001	1.5
• Total Nitrogen	**mg/L**	1.97	2.83	2.09	1.77	0.93	
Total Phosphorous	**mg/L**	0.060 ± 0.001	0.016 ± 0.001	0.011 ± 0.001	0.036 ± 0.001	0.037 ± 0.001	n.a
Total Organic Matter	**mg/L**	104.87 ± 0.06	51.87 ± 0.06	13.90 ± 0.01	7.86 ± 0.39	150.42 ± 0.01	n.a
Dissolved Oxygen	**mg/L**	1.43 ± 0.01	2.82 ± 0.01	2.51 ± 0.05	1.59 ± 0.01	1.66 ± 0.05	> 2.8
pH	**-**	7.25	7.55	6.05	6.50	7.35	6.5-8.5
Salinity	**%**	0.25 ± 0.029	0.05 ± 0	0.20 ± 0	0.18 ± 0.001	0.05 ± 0	0.1

[a] WHO's guidelines[17]

Concentrations of inorganic nitrogen compounds

During the sampling time, the concentrations of inorganic nitrogen compounds (represented as mg of nitrogen per liter in the nitrate, nitrite or ammonia) were very low varied from 0.926 to 2.825 mg/L in the shallow well water samples. The three assessed inorganic nitrogen species were found met the safe limit for drinking water by WHO. Nitrate concentrations were varied from 0.90 to 2.75 mg/L. The nitrite levels at the five sampling locations were almost similar ranged 0.02 – 0.03 mg/L. The peak level of nitrite was found at Location 2 where the nitrate was found at the highest level among the other sampling locations. Ammonia concentrations were reported between a low of 0.004 mg/L and a high of 0.049 mg/L.

In environment, ammonia originates from agricultural and industrial processes, and indicates the possible pollution of sewage and poultry. However, from the result, the ammonia concentration assessed in the shallow groundwater was modest. The contamination may be caused by the human activity, but seems the ammonia was oxidized while infiltrated to the groundwater to nitrate and nitrite.[18] Therefore, the level of ammonia in the groundwater system may indicate either nitrogen compounds contaminated the water or nitrification process existed in the system. The high levels of nitrate which following with low concentrations of ammonia and dissolved oxygen may indicate the nitrification process on the observed shallow wells. At location 5, used as residence, we found that the low level of ammonia, nitrate, and dissolved oxygen may indicate the presence of nitrification, but low ammonia input. Contrary to the data assessed in location 2, the residence may contribute to an increasing of ammonia flow at the water system. By the data, it is not clear which activity contributed the most in an increasing ammonia concentrations in the shallow groundwater system.

Total Phosphorus (TP), Total Organic Matter (TOM), Dissolved Oxygen, and pH

Phosphorus may be resulted from the decomposition of organophosphate pesticides, and it then runs off to the nearby water reservoirs.[19] The mean concentrations of total phosphorus (TP) load were between 0.11 and 0.60 mg/L. Referred to the criteria by OECD,[20] the trophic state index (TSI) of shallow well waters in Sekotong village fell into mesotrophic and eutrophic. It may explain the low DO of the shallow well waters. From the Table 1, only one of five sampling locations satisfied the DO level standard for drinking water (2.8-12.5 mg/L), and interestingly at the wells which categorized in eutrophic the DO levels were measured less than 2 mg/L. The study shows the conditions may lead to eutrophication and this condition will promote anaerobic process in the groundwater system. As review before, an excess contamination of phosphate to the receiving water will grow algal and aquatic plants greatly, and consumed large amounts of oxygen,[19] and it fosters a decreasing of pH.[21] However, the pH of groundwater was at a low of 6.05 and a high of 7.55, and this pH supported FC survival.

The highest concentration of TP was found at location 1 where the combination of residence, agricultural activity, and animal livestock were taken place. The depth to water surface was also recognized to explain the high level of TP at the sampling locations, but not the dissolved oxygen and pH. Surprisingly, the results exhibited a negative correlation between DO and TP, as shown in location 2 and 3. It may indicate the low TP was a result of inadequate input of TP at those two locations. In addition, we found relatively low inputs of total organic at location 2 and 3, but high at location 1. By the data, there is weak evidence to show which activity increases or decreases the nutrient load to the shallow wells, but it is necessary to highlight an importance of direct access of contamination to the groundwater system through the wells.

Influence of inorganic nitrogen and phosphorus on total fecal coliform

During the observation, the lowest concentration of inorganic nitrogen compounds, measured at location 5, was followed by a very high number of total coliform. By the result, the level of ammonia and nitrite cannot show an apparent association to total coliform, as it shows the small number of TC at location 1 where ammonia found at the lowest level and nitrite found at the relatively similar level with the location 5. We recognized a negative association between nitrate concentration and total coliform in this study. The previous study also exhibited the same pattern revealing the wells contaminated by fecal coliform bacteria had measured with low nitrate concentrations.[22] However, in a close system as the septic-tank system, where the high concentrations of nitrate was recorded, there was no suppression of TC.[23]

Among the five shallow wells, no apparent relationship was found between total coliform and total phosphorous. However, we highlight a positive association between total coliform and total phosphate when the location used only for agriculture and livestock. Our study supports the previous experiment revealing the fecal coliform and phosphorus released from land-applied manure are transported similarly in surface runoff.[24] In this study we found that the correlation between phosphorus and total coliform in residential areas somehow unclear. The possible explanation perhaps was due to the difference of defecation behavior and sanitation of the residence.

Effects of salinity and pH on fecal coliform

The roles of salinity and pH have been considered by previous study to identify the causes of dynamic coliform growth in water.[25,26] Our study underlined a location measured with 0.25% salinity was assessed with very low number of total coliform. An inverse correlation was also found between coliform survival and salinity by other authors.[25] However, at location 3 and 4 measured respectively with 0.20% and 0.18% the total coliform was tremendously higher than the number in location 1. The pH of shallow well water at location 3 and 4, respectively measured at 6.05 and 6.50, are still in optimum range of coliform bacteria to grow.

CONCLUSION

The results conclude that the drinking water resources at the Sekotong shallow wells were contaminated by coliform and mercury. Animal grazing and open defecation are likely correlated to coliform contamination to the groundwater. For this reason, it is important for local government to inform drinking water protection and treatment. This research also presents the role of other contamination and physicochemical properties to the growth of fecal coliform bacteria in the shallow well system. An inverse growth of coliform may associate to mercury concentration and nitrate level in the groundwater. Should be realized that phosphorous will increase the concentration of fecal coliform in waters. The prevention actions of direct access of contaminants to the groundwater system through the wells are necessary.

REFERENCES

1. World Health Organization. Global Health Estimates (GHE) 2014: Deaths by age, sex and cause2014.
2. World Health Organization. Indonesia: WHO statistical profile2015.
3. Ministry of Health of Indonesia. Situasi Diare di Indonesia: Triwulan II, 2011 (Diarrhea Situation in Indonesia: Trimester II, 2011). Jakarta: Ministry of Health of Indonesia; 2011.
4. Fewtrell L, Kaufmann RB, Kay D, Enanoria W, Haller L, Colford JM. Water, sanitation, and hygiene

interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *The Lancet infectious diseases.* 2005;5(1):42-52.
5. Lombok Barat DHO. Profil Kesehatan Kabupaten Lombok Barat, Lombok Barat District Health Office (Dinas Kesehatan Kabupaten Lombok Barat). In: PL BD, ed2013.
6. Percepatan Pembangunan Sanitasi Permukiman. Buku Putih Sanitasi Kabupaten Lombok Barat2010.
7. Gruber JS, Ercumen A, Colford Jr JM. Coliform bacteria as indicators of diarrheal risk in household drinking water: systematic review and meta-analysis. *PloS one.* 2014;9(9):e107429.
8. Gundry S, Wright J, Conroy R. A systematic review of the health outcomes related to household water quality in developing countries. *Journal of water and Health.* 2004;2(1):1-13.
9. Vollaard AM, Ali S, Smet J, van Asten H. A survey of the supply and bacteriologic quality of drinking water and sanitation in Jakarta, Indonesia. *Southeast Asian journal of tropical medicine and public health.* 2005;36(6):1552.
10. Crowther J, Kay D, Wyer MD. Faecal-indicator concentrations in waters draining lowland pastoral catchments in the UK: relationships with land use and farming practices. *Water Research.* 2002;36(7):1725-1734.
11. Sinaga DM, Siriwong W, Gasong BT, Robson MG. Environmental impacts of mercury on soil and water resources in Sekotong's gold mining villages in Lombok, Indonesia. Paper presented at: The 1st International Conference on Environment, Livelihood, and Services (ICELS 2015) 2-5 November 20152015; Bangkok, Thailand.
12. Parker JL, Bloom NS. Preservation and storage techniques for low-level aqueous mercury speciation. *Science of the Total Environment.* 2005;337(1):253-263.
13. Suriansyah A, Gusrizal A. ALIBRASI DAN ADISI STANDAR PADA PENGUKURAN MERKURI DALAM AIR DENGAN KANDUNGAN SENYAWA ORGANIK TINGGI MENGGUNAKAN SPEKTROFOTOMETER SERAPAN ATOM. *Jurnal Kimia Khatulistiwa.* 2013;1(1).
14. Simange SM, Simbolon D, Jusadi D. *Analisis Kandungan Merkuri (Hg) Dan Sianida (Cn) Pada Beberapa Jenis Ikan Hasil Tangkapan Nelayan Di Teluk Kao, Halmahera Utara,* Tesis Sekolah Pasca Sarjana Institut Pertania Bogor.(http://repository. ipb. ac. id/bitstream/handle/123456789/46850/2011sms. pdf; 2010.
15. Kross B, Hallberg G, Bruner D, et al. *The Iowa State-wide Rural Well-water Survey: Water-quality Data: Initial Analysis*: Iowa Department of Natural Resources; 1990.
16. Bhattacherjee J, Pathak S, Gaur A. Antibiotic resistance and metal tolerance of coliform bacteria isolated from Gomati River water at Lucknow city. *The Journal of General and Applied Microbiology.* 1988;34(5):391-399.
17. World Health Organization. Guidelines for drinking-water quality: incorporating first and second addenda to third edition, Vol. 1, Recommendations2008: http://www.who.int/water_sanitation_health/dwq/fulltext.pdf.

18. Duijvenbooden Wv, Matthijsen A, Speijers G, Went Cv, Apeldoorn Mv. Integrated criteria document nitrate. *National Institute for Public Health and the Environment (RIVM), Report.* 1989(758473012).
19. Kumar M, Puri A. A review of permissible limits of drinking water. *Indian journal of occupational and environmental medicine.* 2012;16(1):40.
20. Vollenweider RA. *Eutrophication of waters: monitoring, assessment and control*: Organisation for Economic Co-operation and Development; 1982.
21. Johnson DB, Hallberg KB. The microbiology of acidic mine waters. *Research in microbiology.* 2003;154(7):466-473.
22. Gosselin DC, Headrick J, Tremblay R, Chen XH, Summerside S. Domestic Well Water Quality in Rural Nebraska: Focus on Nitrate-Nitrogen, Pesticides, and Coliform Bacteria. *Groundwater Monitoring & Remediation.* 1997;17(2):77-87.
23. Arnade LJ. Seasonal correlation of well contamination and septic tank distance. *Ground water.* 1999;37(6):920.
24. Stout W, Pachepsky Y, Shelton D, Sadeghi A, Saporito L, Sharpley A. Runoff transport of faecal coliforms and phosphorus released from manure in grass buffer conditions. *Letters in Applied Microbiology.* 2005;41(3):230-234.
25. Šolić M, Krstulović N. Separate and combined effects of solar radiation, temperature, salinity, and pH on the survival of faecal coliforms in seawater. *Marine Pollution Bulletin.* 1992;24(8):411-416.
26. Curtis T, Mara DD, Silva SA. The effect of sunlight on faecal coliforms in ponds: implications for research and design. *Water Science and Technology.* 1992;26(7-8):1729-1738.

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