Spatial Dynamic Model of Detergent Distribution in Well Water and Their Impact on Community Health in Small Island

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Article Info	Abstract
	BACKGROUND: Domestic activities of coastal and island communities are factors that affect the quality and quantity of groundwater availability, including the use of detergents. Chemicals used in detergents can have a negative impact, both on public health and the environment. The dynamic spatial model is a solution to overcome the problem of detergent contamination. AIM: This study aims to build a dynamic model of the distribution of detergent pollutants in well water and their impact on public health in small islands. METHODS: This research is observational research using spatial analysis approach with kriging interpolation method and dynamic modeling with stock flow. Simple random sampling (simple random sampling). RESULTS: The results of the spatial modeling show that the patternthe distribution of contamination is higher in the east to the center of the island. The dynamic modeling results show that the detergent concentration distribution pattern in well water with the lowest concentration is 0.0 mg/l and the highest is 0.16389 mg/l. The pessimistic scenario experienced the highest increase of 0.21 mg/l, while the optimistic scenario experienced the highest increase of 0.03 mg/l. An optimistic scenario is built with 75% off-island laundry activities and WWTP management. CONCLUSION: Based on the results of the analysis, laundry activities and WWTP management must be considered in order to minimize detergent contamination on small islands.

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INTRODUCTION

Domestic activities of communities in the coast and islands are one of the factors that can affect the quality and quantity of groundwater availability. For example, the use of detergents cannot be separated from people's daily lives such as washing activities that produce liquid waste. Chemicals used in detergents can have a negative impact, both on health and the environment. Liquid detergent in large quantities is at risk of contaminating the quality of groundwater and other water bodies in the vicinity if it is not treated and only seeped into the ground (1).

The majority of sources of drinking water and daily needs for coastal communities and small islands use well water. The physical condition of the clean water facilities used by respondents, especially dug wells, still does not meet the requirements, this means that the risk of pollution is still high. The survey results on the physical quality of clean water used by respondents that came from PAM all met the requirements, but some that came from dug wells did not meet the requirements. This makes clean water sources vulnerable to contamination by domestic waste such as bacteria and detergents (2).

Chemicals used in detergents can have a negative impact, both on health and the environment. Liquid detergent in large quantities is at risk of contaminating the quality of groundwater and other water bodies in the vicinity if it is not treated and only seeped into the ground. Detergents consist of several main components, namely surfactants (surface active agents), such as Linear Alkyl Benzene Sulfonate (LAS) and Alkyl Benzene Sulfonate (ABS). LAS belongs to the category of anionic surfactants which are more easily biodegradable than ABS. Detergents also contain other additives such as alkalis, preservatives, bleaching agents, and coloring agents, anti-corrosive agents and enzymes (3).

Spatial analysis and GIS have been widely applied by researchers in the field of environmental health, including air quality, water quality, pesticide exposure, vector control, and the built environment. One key question that frequently arises in environmental health research is how to relate health outcomes to exposure

data. As long as health outcome data includes multiple geographic references, GIS allows linking of outcome and exposure data through shared geography (4).

The distribution map of water pollution can be obtained based on the measurement of water quality samples, so that it can provide a spatial description of the condition of the level of water pollution in the specified location. This process is carried out using map interpolation. Interpolation is a menu provided by ArcToolbox in ArcGIS software. This menu has the ability to be able to search for known values at multiple data points. One of the interpolation methods is the Kringing method. Kriging can predict values that are close to the value of the interpolated data sample, even though the sample is enlarged to infinity (5).

Modeling is defined as illustrating, simplification, miniature, visualising or creating innovative predictions. The description of the environmental health process and the relationship between its components/variables uses logical representations and mathematical equations. Modeling is used to explain the physical, chemical, and biological phenomena that occur in the process. Modeling activities can include concept generation, organization, communication, understanding, testing, analysis, field measurement trials, predictions, early warnings, optimization of decision making (6,7). The distribution of detergents in well water on small islands is carried out to map and predict detergent concentrations and their impact on public health.

The purpose of this study was to determine the distribution of detergent contaminants with the spatial interpolation method in well water and estimating detergent concentrations in well water based on dynamic model simulation results for the next 20 years.

METHOD

This type of research is observational using a spatial analysis approach with the kriging interpolation method and dynamic modeling with stock flow. Spatial analysis is used to show patterns distribution of detergent contamination on small islands. Dynamic system modeling to estimate the concentration of detergent pollution in shallow groundwater over the next 20 years. The dynamic model can also determine scenarios to control the occurrence of detergent pollution in shallow groundwater in small islands.

The sampling location is Barrang Lompo Island which is one of the small islands in the Spermonde Archipelago. Environmental sampling to estimate the concentration of detergent in ground water was carried out by simple random sampling. Sampling with this method is because the conditions of the sampling location are assumed to be homogeneous and the variability of the chemical composition of the soil is homogeneous, which is an island type of atoll. The number of well water samples studied were 45 wells, obtained based on sample calculations from a total of 132 dug wells and drilled wells on Barrang Lompo Island. Barrang Lompo Island is divided into four community pillars. Determination of the distribution of detergent in well water was determined by the interpolation method from all sampling points.

Analysis of dynamic system data using the STELLA program

The prediction time is 20 years. The number of simulation models is 3 (three) types of model scenarios, namely as follows:

1) The Pessimistic Model Scenario (scenario I) is a model scenario carried out to estimate the concentration of detergent for 20 years without any policy restrictions and interventions.
2) The Moderate Model Scenario (scenario II and III) is a scenario carried out to estimate detergent concentrations for 20 years with a policy of increasing IPAL coverage and laundry activities outside the island.
3) Optimistic Model Scenario (scenario IV is a scenario carried out to estimate the concentration of detergent for 20 years with a policy of increasing the coverage of WWTP for pollution control by 100% and combined with laundry activities outside the island by 75%.

Model flow chart

The assumptions underlying the variable relationship to detergent concentration in well water are explained as follows:

The population that increases from year to year can increase the use of detergents each year through residents' domestic activities (washing) and have an impact on increasing the volume of liquid waste produced by the population.

1) The detergent content (anionic surfactant) consists of two types, namely LAS and non-LAS (eg ABS).
2) The use of detergents in the process of washing clothes and household appliances produces liquid waste that still contains high detergent if not treated.

3) The concentration of detergent contained in wastewater can increase the concentration of detergent residue in shallow groundwater if it is directly applied to the soil or dug holes without being treated.

4) The distance of the well to the pollutant source or WWTP that does not meet the requirements will also increase the concentration of detergent residue in shallow groundwater.

5) Rainfall can affect the decrease and increase in the concentration of detergent residues in groundwater. The decrease in the concentration of detergent residue due to dilution due to the addition of groundwater volume and the increase in the concentration of detergent residue due to the dynamics of the pollutant following the groundwater baseflow.

RESULTS AND DISCUSSION

Distribution of Detergent Pollutants in Shallow Groundwater on Barrang Lompo Island

Barrang Lompo Island has a fresh water supply from shallow groundwater. This water source is utilized by the community through extraction from drilled and dug wells. The presence of detergent concentrations in shallow groundwater indicates contamination by domestic waste from washing activities. The distribution of detergent concentration in shallow groundwater on Barrang Lompo Island can be seen in the following figure.
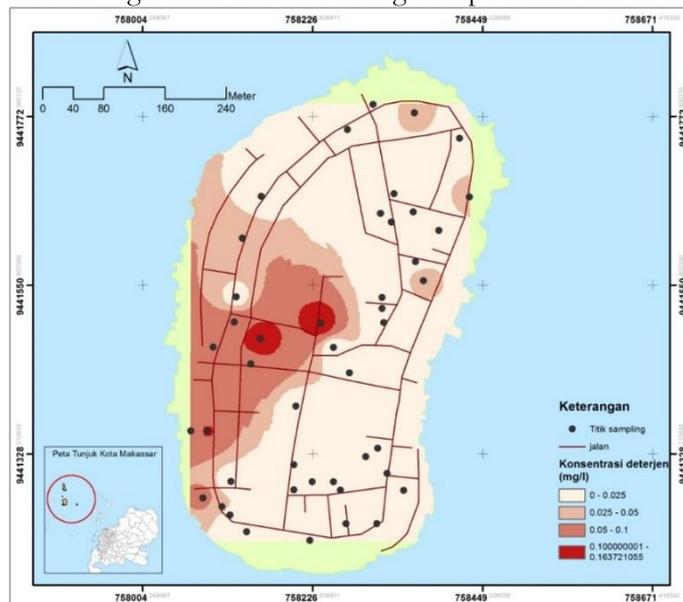

Figure 1. Distribution of detergent concentration in well water on barrang lompo island

The distribution of detergent concentration using the kriging interpolation method from all sampling points above shows that the distribution of contamination is higher in the east to the center of the island. This is because Barrang Lompo Island has a sandy soil texture with a more dominant sand composition than silt and clay. This is in line with Rizza's research, which suggests that the source of chemical pollutants in dug wells can reach 30 – 60 meters because it is influenced by geographical conditions, soil type, soil permeability and porosity, seasons and groundwater movement (8).

Flowchart of Dynamic Model of Detergent Concentration in Well Water

Based on assumptions The underlying variable relationship to detergent concentration in well water is then transformed in the form of a Dynamic Model Flowchart using the STELLA program as follows.
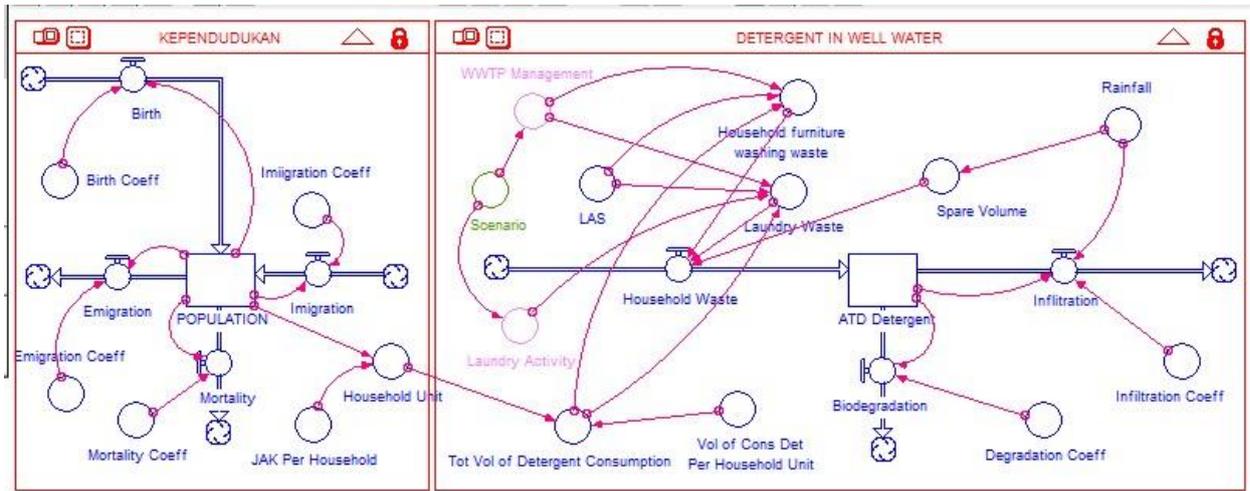
Figure 2. Flowchart of the dynamic model of detergent concentration in well water using the STELLA program

**Dynamic Model of Detergent Pollutants in Barrang Lompo Island Well Water**

  The model consists of two sub-models, namely the population sub-model and the shallow groundwater detergent sub-model. The simulation time in the planned model is for the next 20 years. The interventions used in the scenario to control the increase in detergent concentration in shallow groundwater are laundry activities outside the island and the management of Wastewater Treatment Plants (WWTP).

Dynamic Model Scenario

Table 1. Dynamic model scenario of detergent concentration in well water on barrang lompo island

No	Scenario	Laundry Activities Outside the Island	WWTP Management
I.	Pessimistic	There is not any	There is not any
II.	Moderate	75% increase	There is not any
III.	Moderate	There is not any	There is
IV.	Optimistic	75% increase	There is

  The main scenarios in the dynamic model of detergent concentration in well water are categorized into pessimistic, moderate and optimistic scenarios. These scenarios are expected to be able to reduce the concentration of detergent in well water over the next 20 years. However, the significance of the decrease in concentration varies from each scenario. The optimistic scenario is the scenario that most significantly reduces the concentration of detergent in well water.
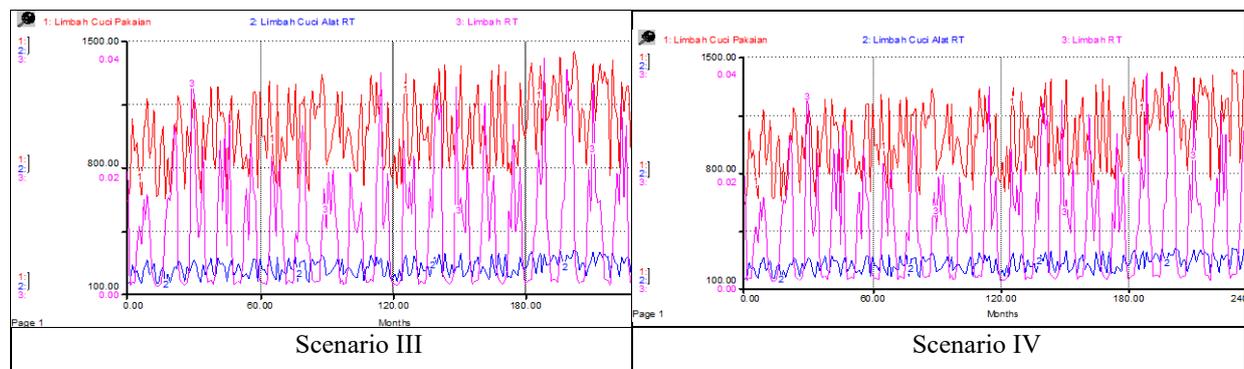

Scenario I	Scenario II

| Scenario III | Scenario IV |
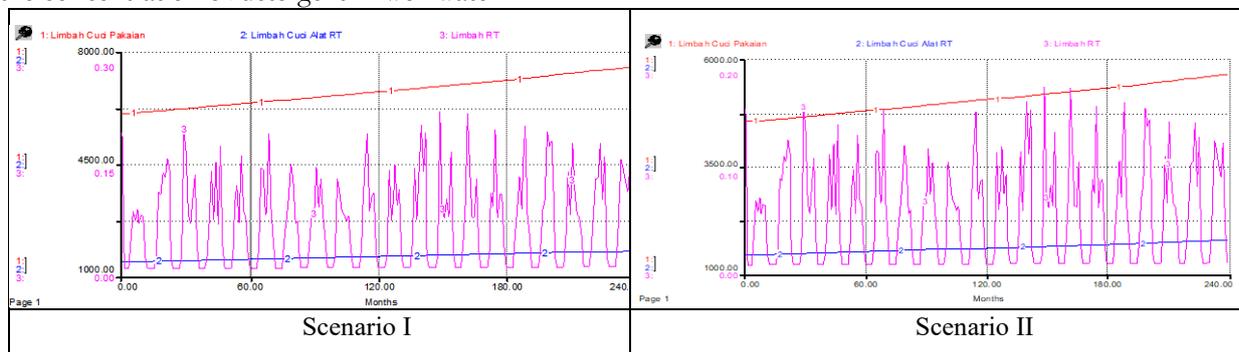
Figure 3. Estimated amount of detergent for washing clothes and household equipment washing and detergent concentration from total household waste for the next 20 years on Barrang Lompo Island

Shallow groundwater in Barrang Lompo Island based on the results of the examination of detergent concentrations indicated that it had been polluted by residents' domestic waste with varying detergent concentrations. This is evidenced by the minimum detergent concentration of 0 mg/l and the maximum detergent concentration of 0.163 mg/l. If based on the Regulation of the Minister of Health of the Republic of Indonesia Number 492 of 2010 concerning the requirements for the quality of drinking water, the requirement for the concentration of detergent in drinking water is 0.05 mg/l. This is in line with the research in Manokwari regency using the MBAS method which detects detergent concentrations that exceed the detergent concentration requirements according to the regulation (9).

Based on data from the Barrang Lompo Health Center, the achievement of WWTP that meets the requirements for households living on Barrang Lompo Island is still very low at 0%. So it is very possible residents' domestic waste can contaminate shallow ground water. In addition to the low WWTP achievement, shallow groundwater depth and the distance from the source of waste disposal/infiltration to resident wells are factors that cause detergent contamination in shallow groundwater. This is in line with Subhan's research, that wells that are less than 10 meters away contain a fairly high concentration of detergent (10).

The concentration of detergent in shallow groundwater on Barrang Lompo Island is strongly influenced by several factors including the number of people who consume detergent, concentration of detergent in household waste, rainfall, volume of groundwater reserves, biodegradation and infiltration capacity. The dynamic model aims to predict the rate of increase in detergent concentration in shallow groundwater on Barrang Lompo Island over the next 20 years. The control strategy to suppress the rate of increase in detergent concentration is the presence of laundry activities outside the island and the management of the Waste Water Treatment Plant (WWTP). The strategies are grouped into several scenarios, namely pessimistic, moderate and optimistic scenarios.

The results of the dynamic model prove that the combined scenario of off-island laundry activities with WWTP management (optimistic scenario) is very effective in reducing detergent concentrations in shallow groundwater on Barrang Lompo Island. The increase in the population that continues to increase from year to year for the next 20 years is directly proportional to the volume of detergent consumption for each household unit (RT), both for washing clothes and washing household appliances. The estimated annual population growth in Barrang Lompo Island is between 0.97% -1.31% for the next 20 years (11).

Based on the simulation results, the shallow groundwater detergent concentration (scenario I) is estimated over the next 20 years to increase to 0.21 mg/l or 6 times in 2015. This indicates that the detergent concentration has exceeded the quality standard for drinking water. This is because detergents cannot be completely degraded. Detergents fall into two categories, namely those containing anionic surfactants LAS and ABS. LAS has straight/unbranched alkyl groups which are easily decomposed by microorganisms while ABS is branched and difficult to decompose. LAS can be degraded up to 90%. However, the process is very slow and takes time because in breaking down the end of the chemical chain, especially the o-mega bonds, it must be broken and requires a beta oxidation process. Nature takes 9 days to decompose LAS, but only up to 50% (12,13).

The fourth (optimistic) scenario with the management policy of off-island laundry activities and WWTP management is very effective in reducing/limiting the increase in detergent concentration over the next 20 years. This is because the amount of detergent used by the community is reduced by the laundry activity and

the decreased concentration of detergent from RT waste that will enter shallow groundwater has been treated through WWTP.

The increasing concentration of detergent in well water is due to input from household/domestic waste from the washing process. This is in line with Lestari's research that the high pollution load in the waters of the Tanjung Unggat River is due to the high input of domestic waste originating from community activities as explained that the content of domestic waste generally consists of carbohydrates, fats and proteins. Decomposition by microorganisms will only break down complex compounds into simple ones or reduce residual pollutant concentrations (14,15).

The pessimistic scenario in general has an impact on the worsening/degrading of groundwater quality according to detergent parameters, so intervention/management is needed to prevent this. In the simulation results of an optimistic scenario, the average detergent concentration from shallow groundwater can be reduced to below the quality standard and meets the requirements for drinking water (16). This is in line with the research of Suwari that based on a pessimistic scenario, the water quality condition of the Surabaya River is getting worse where the assimilation capacity, public awareness, implementation of water pollution control regulations are decreasing from the existing conditions. While in the optimistic scenario, it is able to improve the condition of river water quality where the increasing population growth conditions also increase/improve assimilation capacity (17).

CONCLUSION

The distribution of detergent concentration in well water on Barrang Lompo Island with the lowest concentration of 0.0 mg/l and the highest concentration of 0.16389 mg/l. The distribution of contamination is higher in the east to the center of the island. The simulation results from the first scenario (pessimistic), the estimated detergent concentration in shallow groundwater has the highest increase reaching 0.21 mg/l or an increase of 9.5 times from the detergent concentration in shallow groundwater which is 0.02 mg/l . The simulation results for the fourth scenario (optimistic), the estimated detergent concentration in shallow groundwater has the highest increase reaching 0.03 mg/l or an increase of 0.5 times from the detergent concentration in shallow groundwater which is 0.02 mg/l. Based on the results of the analysis, laundry activities and WWTP management must be considered in order to minimize detergent contamination on small islands.

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