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Spatial distribution and vulnerability of Sea Water Intrusion in Makassar City

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ABSTRACT

Seawater intrusion is defined as the degradation of ground water both in quality and quantity. Sea water intrusion can occur due to high groundwater uptake in an area. Likewise in the Untia area, Makassar City. This study aims to determine the spatial distribution and vulnerability of sea water intrusion that occurred in Untia Sub-District, Makassar City. The type of data used is primary data and secondary data. Data collection methods used in the study of seawater intrusion vulnerability in the Untia of Makassar City are the sampling method and the literature study (desk study). Data analysis method used is a laboratory analysis method, and SVI (Szlafstein Vurnerability Index). The results of the analysis were obtained; 1) that the study sites were generally saltwater-intrusive in the medium category (69.10%), 2) The total area of Untia Sub-District which was intruded in saltwater in the medium and high category was 267.0 ha or 89.30% and the remaining 9.03% are areas that are slightly intrused (low) and 5.0 Ha or 1.67% are not intrused. Generally the study areas are categorized as vulnerable and very vulnerable, reaching 1,295.53 ha or 80.79%.

***Key words**: Vulnerability, Sea water, Intrusion, Makassar City.*

Introduction

Human activities in coastal and coastal areas have caused problems such as seawater intrusion due to uncontrolled use of groundwater in coastal areas (Abarca, 2006), as happened in Jakarta, Semarang, Surabaya and Makassar and various other coastal cities. On the other hand, mangrove degradation, coastal abrasion, siltation, damage to coral reefs, coastal pollution also occur gradually (Bambang, 2016). Therefore, efforts to restructure this region need to be carried out in an integrated manner with the physical continuity of the region regardless of administrative boundaries, and require special treatment for areas that have certain characteristics (Diposaptono *et al*., 2009).

According to Adrian *et al*. (2013) that seawater intrusion is one of the groundwater pollutions which results in an increase in groundwater salt content, which is identified by the value of Chloride concentration (Cl) originating from seawater through mass transportation of Chloride (Cl) in groundwater so that the availability of quantity and quality of water land that meets quality standards becomes limited. Water resource management is important in environmental sustainability. The potential of fresh water in coastal aquifers is very vulnerable to degradation, especially to the possibility of seawater intrusion (Pratiknyo, 2008). Furthermore Putranto and Kusuma (2009) stated that sea water intrusion is caused by prolonged and periodic changes in the ground water level contained in coastal aquifers, which are caused by excessive pumping, changes in land use, climate variations, or sea level fluctuations. Sea water intrusion will lead to a reduction in the availability of fresh water reserves and the contamination of existing production wells. Seawater intrusion is also related to the movement of seawater below ground level through surface water (rivers, canals and wetlands) Abdelmadjid and Omar (2019). Coastal aquifers are usually complex environments, characterized by instant sea levels, salinity variability, density distribution and heterogeneity of rock layers hydraulic properties. Climate variations, groundwater pumping and sea level fluctuations are the dynamics of hydrological conditions, which link the relationship between the distribution of dissolved salts through the relationship between density and salinity (Adrian *et al.,* 2013).

Various studies have been conducted in anticipating and controlling the impacts that can result from seawater intrusion, including; Marfai and King, 2008; Eltigani and Bushara (2018; ElSayed, 2018; Galindo *et al*. 2018; Mohamed, 2018; Nasr Hekal, 2018; Koosha *et al.* 2019; Leketa, 2019; Manoj *et al.,* 2019; Riina *et al.,* 2019; Salman *et al*., 2019. For this reason, so that management and impacts can be prevented early, an analysis of the vulnerability level of seawater intrusion is needed. This study aims to determine the spatial distribution and vulnerability level of seawater intrusion that occurred in Untia Sub-District, Makassar City.

Materials and Method

Data types and sources

The type of data used in this study are primary and secondary data. Primary data, including; ground water samples at 20 sampling points (wells), and secondary data is the map of administrative area of Makassar City. Primary data is obtained from the field by taking ground water samples which are then analyzed in accredited laboratories (KAN accreditation). Measured parameters include; pH, temperature, salinity, $CaCO_3$ and electrical conductivity (DHL). According to Yusuf and Daris (2018) that primary data is data obtained directly from the field /object of research, whether in the form of measurements, observations or interviews and then processed to answer the research objectives. Whereas secondary data is regional administrative maps which obtained from Bappeda. According to Nasution (2009) secondary data is data obtained or collected by researchers from various existing sources (researchers as second hand).

Data collecting method

Data collection methods are techniques or methods used to collect data (Sugiyono, 2011). Data collection methods used in the study of spatial distribution and vulnerability level of seawater intrusion in the Untia Sub-District of Makassar City are the sampling method and desk study. Sampling is the process of taking or selecting n elements from a population of size-n (Lohr, 1999). Sampling in this research is sampling (taking) a certain volume of water from community wells, for further analysis in the laboratory. While the desk study or literature study method is an activity to collect information relevant to the topic or problem that is the object of research. Such information can be obtained from books, scientific papers, theses, dissertations, encyclopedias, the internet, and other sources (Arikunto, 2010).

Data analysis method

The method of data analysis is a technique or method of processing data into information that can give results to the problems studied (Arikunto, 2010). Data analysis method used in the study of spatial distribution and vulnerability level of seawater intrusion in Untia, Makassar City is the laboratory analysis method, and the SVI (Szlafstein Vurnerability Index). Laboratory analysis is intended to determine the level (concentration) of water quality parameters including; pH, temperature, salinity, $CaCO_3$ and electrical conductivity (DHL). While the SVI analysis is intended to find out areas that are vulnerable to seawater intrusion.

SVI analysis is used to modify/adjust parameters of the determinants of the level of vulnerability of coastal areas to the threat of seawater intrusion, in terms of physical and socio-economic disaster factors. Physical factors include; roads, ports and strategic areas, while socio-economic factors, including; population density, productive land and urban systems. The formula for calculating annual SVI in each region / city (Ramieri *et al*., 2011) is:

$$SVI = \left(\frac{1}{n}\prod_{i-1}^{N} Vi\right)^{1/2}$$

Where;

SVI = Szlafstein Vurnerability Index

N = physical and social economic parameters; V1 (road), V2 (port), V3 (strategic area), V4 (density population), V5 (productive land), dan V6 (urban system).

n = number of samples

Factors that are indicators of vulnerability (physical and socioeconomic), require the identification of various parameters which mostly affect the vulnerability of each part of the coast. This is key information that will help to outline appropriate adaptation measures for the risk of reducing relative vulnerability for each region. Following are the criteria and weight of the region's vulnerability to saltwater intrusion at the study site.

Results and Discussion

Spatial Distribution of Saltwater Intrusion

The spatial distribution of sea water intrusion in the study area will greatly affect various community activities and development, both of which have a direct impact on the physical environment and also have a direct impact on the socio-economic environment of the community. Spaial studies related to seawater intrusion and conservation has been conducted by Abhay *et al*. (2019) found that spatially seawater intrusion would continue to have an impact on the coastal environment if conservation efforts were not made. Raju *et al*. (2018) conducted a sensitivity analysis study and mapping of potential groundwater vulnerability zones in the Birbhum District, India.

Vulnerability to socio-economic aspects in this study is illustrated in the form of impacts on productive land. The potential is obtained from overlay (overlapping) seawater intrusion maps with land use maps, which are divided into agricultural land, residential land, ponds and unproductive land. Potential agricultural land in the study area identified includes; mixed gardens, rice fields and fields. Whereas unproductive land was identified including; mangrove areas, green open spaces (RTH), vacant land, and protected areas.

Vulnerability of socio-economic aspects, especially agricultural activities in the study area, was found that agricultural land which is productive land is spatially spread over 3 (three) intrusion categories namely; high intrusion area of 0.9 Ha, medium intrusion area of 36.4 Ha and low intrusion area of 11.7 Ha. Administratively, it is spread over 3 (three) Sub-District with the largest area located in Bira Sub-District.

The vulnerability of salt water intrusion will greatly affect various aspects of the socioeconomic life of the community, such as; groundwater extraction to meet daily needs, agricultural activities, business activities to industry (Sorensen, 2015). Efforts to reduce the negative effects of salt water intrusion, can be done with a map of the distribution of salt water intrusion which can be known areas that may

Table 8. Criteria and risk factor weights for vulnerability indicators

Factors (Variables)	Vulnerability Criteria and Weights				
	Very low (1)	Low (2)	Medium (3)	High(4)	Very High (5)
Road	Village	District	Connecting	Arterial	Highway
Port	No				Found
Strategic Region	No				Ada
Population density (ind./km²)	<100	100-200	200-400	400-600	>600
Land Use (productive land)	Fish Pond		Field	Gardens	Agriculture
Urban system	No			City Center Sub	City Center

Source: Modification of Szlafstein*(2005)*

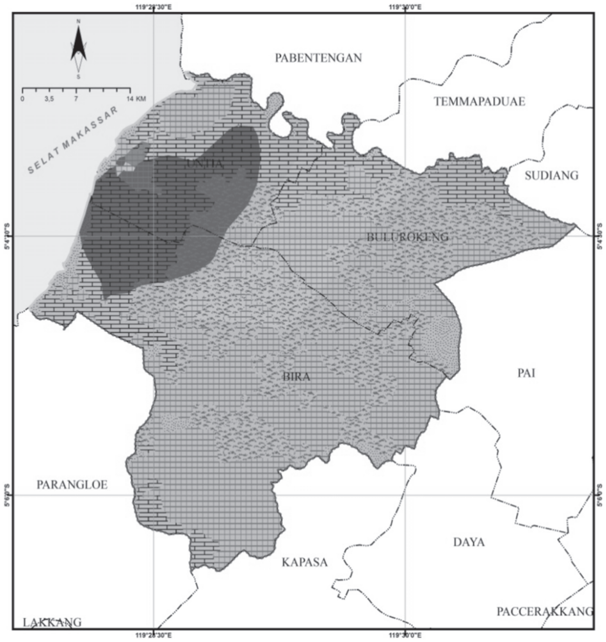

Fig. 1. Map of spatial distribution of saltwater intrusion on socio-economic aspects

be very vulnerable (Tano *et al.*, 2018). By knowing the potential vulnerability of salt water in an area such as in the Untia Sub-District, various losses or impacts can be minimized.

In addition to having an impact on the socio-economic aspects, the potential vulnerability of saltwater intrusion also impacts strategic areas and urban system areas. Strategic areas in the study area include, strategic areas for the benefit of environmental carrying capacity including mangrove ecosystem areas, green open spaces and protected areas. There is also a strategic area of economic importance and an urban system area. The strategic area of the city is a part of the city area whose spatial planning is prioritized, because it has a very important influence in the scope of the city in the economic, social, cultural and / or environmental fields.

The objectives of determining strategic areas are, among others, as consideration in preparing indications for the city's main RTRW program; and as a basis for the preparation of detailed spatial plans for urban areas. The compilation of strategic areas refers to the Minister of Public Works andof Infrastructure Degree No. 17/PRT/M/2009 concerning Guidelines for Preparation of City Spatial Planning as a follow-up to the implementation of the provisions of Article 18 paragraph (3) of Law Number 26 of 2007 concerning spatial planning. While the urban system area is an area that forms a unified urban center and in it there is a linkage of functions between urban areas in a metropolitan system.

Based on the overlay result of saltwater intrusion map with a map of the strategic area and the urban system area, as in the picture above, it is known that the strategic area for the benefit of carrying capacity of the environment in the high-intrusion area is 4,09Ha, the area under moderate 57, 47 Ha and low intrusion area of 2.96 Ha. Administratively, it appears that strategic areas for the benefit of environmental carrying capacity are scattered in all three urban areas. In addition, it is also known that generally (89.07%) strategic areas for the benefit of environmental carrying capacity are in the area of moderate intrusion.

Whereas the strategic area for economic interests was obtained that most of the area was in Untia Village, especially the port area (PPI Untia). Strategic areas for economic purposes that are in the high intrusion area of 144.31 Ha, medium intrusion of 100.85 Ha, low intrusion of 11.53 Ha and non-intrusion is of 4.58 Ha. Based on this area, it is known that about is 55.23% of the strategic area for economic interests is in a high intrusion area.

The urban system area in the study area is a sub-downtown area that is administratively located in the Bira Village area. Sub-city center is an economic,

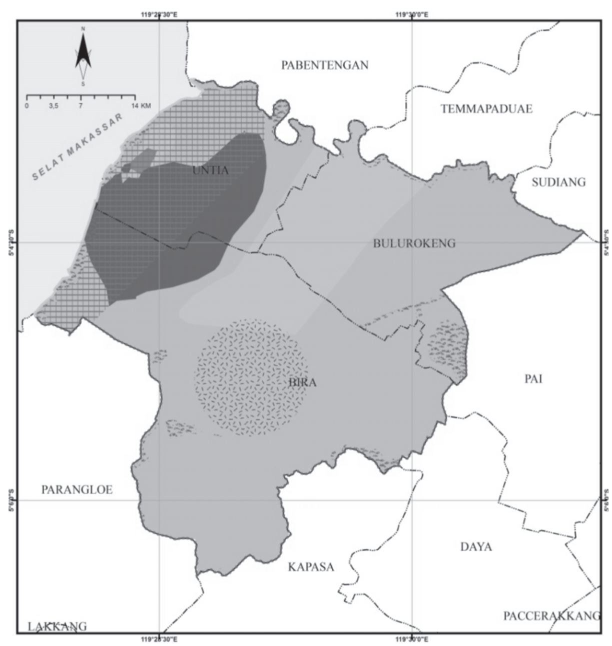

Fig. 2. Map of spatial distribution of saltwater intrusion vulnerability to strategic areas and urban system area

social, and/or administrative service center serving sub-regions of the city which was originally a CBD (Central Business District) or business center area, in this case is the region of Tamalanrea and power which also includes the Makassar industrial area (KIMA), the Daya integrated terminal area, Daya business area and Tamalanrea education area.

Regional Vulnerability

Groundwater vulnerability in coastal areas is one of the very important issues in the development of the current development (Weny, 2012). Anticipation and efforts to reduce the negative impact of groundwater quality in coastal areas due to anthropogenic factors and climate change, requires the determination of indications of areas that have high vulnerability (Yudo, 2018). Weighting efforts are needed based on the most important factors in understanding groundwater vulnerability in coastal areas.

Groundwater in coastal areas becomes very sensitive due to the threat of natural changes globally (global climate change) or anthropogenic (Lappas *et al.,* 2016). The accumulation of one or both of these pressures will cause groundwater in coastal areas to be vulnerable to an increase in the value of salinity caused by sea water intrusion, ancient salt washing and other causes. Groundwater vulnerability to changes in salinity value is defined as sensitivity of groundwater quality to the impact of excessive groundwater pumping, sea level rise or both along the coast, which is also determined by the characteristics of the aquifer (Bisri, 2009).

Based on physical factors (airports, ports, roads, protected areas) and socioeconomic factors (population density, land use / productive land), a map of the region's vulnerability to saltwater intrusion is obtained. Regional vulnerability figures are obtained from the Szlafstein index value (Szlafstein Vurnerability Index-SVI). SVI is intended to determine the level of vulnerability of the study area in terms of physical and socio-economic disaster factors. The vulnerability of physical factors is measured from the physical parameters of buildings such as; roads, ports and protected areas. While socio-economic factors are measured by parameters, population density and socioeconomic activities, especially agricultural.

The results of the analysis as in the fig. above it's known that in general the study area is categorized as vulnerable and very vulnerable, reaching 1,295.53 Ha or 80.79%. While areas that are categorized as low/less vulnerable are only 75.35 Ha or 4.70% and those that are categorized as medium is 232.64 Ha or 14.51%. This illustrates that the area of the study is currently experiencing high pressure and seawater intrusion. Regional vulnerability to saltwater intrusion will have an impact on all aspects of socio-economic and environmental including infrastructure. According to Hidir (2014) seawater intrusion can cause impacts on environmental and social aspects including; a) meeting the need for clean water is increasingly difficult, because groundwater is contaminated with sea water so that it feels salty, b) agriculture around the coast will suffer losses because the need for fresh water for irrigation decreases, c) the health of residents around the coast deteriorates because lack of clean water consumption. Furthermore according to Harnandi and Herawan (2009) that the impact of the occurrence of sea water intrusion, among others (1) Declining underground water level, (2) Hydrostatic balance will be disrupted, and (3) Land subsidence occurs due to excessive groundwater uptake. While the impacts on land use above include (1) Affected housing will not provide optimal functions for its inhabitants, (2) The level of comfort in occupancy will decrease, and (3) Losses for investors investing in the affected area. Groundwater, especially in

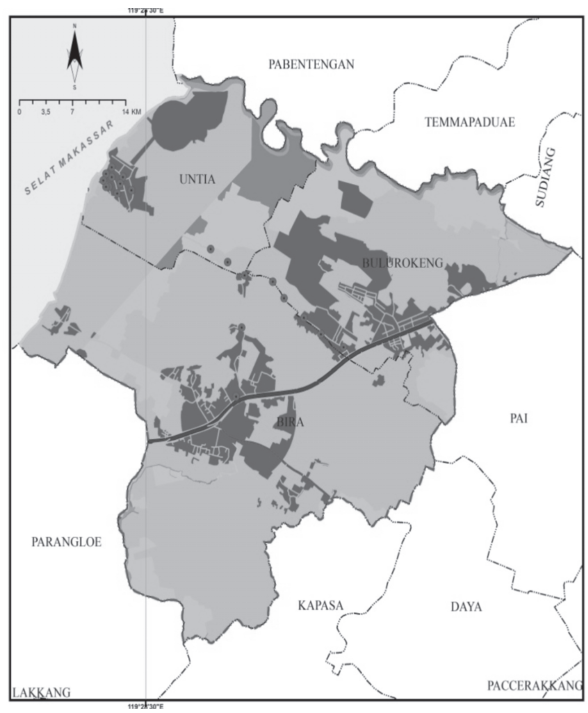

Fig. 3. Map of regional vulnerability levels

coastal areas, has a vital function for human and plant life. Sea water intrusion that occurs in ground water has several impacts that can harm humans both directly and in the long run (Khumaedi, 2016).

Conclusion

The results of the analysis and discussion obtained several conclusions as follows:

- The spatial distribution of saltwater intrusion is obtained that in general the study sites are saltwater intrusion with a moderate category (69.10%), and even in areas directly adjacent to the (sea) coast it appears that the location is highly intrused.
- The total area of Untia Village which is intrused by saltwater in the medium and high category is 267.0 ha or 89.30% and the remaining 9.03% is the area that is slightly intrused (low) and 5 ha or 1.67% is the area which is categorized as not intruded.
- Generally the study areas are categorized as vulnerable and very vulnerable, reaching 1,295.53 ha or 80.79%. While areas that are categorized as low/less vulnerable are only 75.35 ha 4.70% and those that are categorized as medium are 232.64 Ha or 14.51%.

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