Public Health of Indonesia
E-ISSN: 2477-1570 | P-ISSN: 2528-1542

Original Research

Assessing seawater intrusion and chloride zones in residents' wells in selected coastal area of Indonesia: A GIS analysis

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DOI: https://doi.org/10.36685/phi.v9i2.661
Received: 21 December 2022 | Revised: 8 March 2023 | Accepted: 7 June 2023

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Abstract

Background: Seawater intrusion refers to the infiltration of seawater into groundwater, either naturally or artificially, due to the extraction of groundwater for domestic purposes. Seawater intrusion can have wide-ranging impacts on various aspects of life, including health issues, reduced soil fertility, structural damage, and groundwater contamination. In the Kendari District area, people rely on springs, dug wells, and drilled wells to fulfill their daily water needs, as well as for tourist and commercial activities. However, signs of seawater intrusion become evident when the water used by residents in the area becomes brackish or even saline.

Objective: This study was to determine the distribution pattern of seawater intrusion and chloride zones in the coastal area of Kendari District, specifically within Kendari City, Indonesia.

Methods: This study employed a descriptive research design and utilized purposive sampling to select the subjects. A total of 20 water samples were collected from residents in Kendari District, Kendari City. The research was conducted at various wells within the district. The collected data were then entered into a Geographic Information System (GIS) to analyze the distribution pattern of seawater intrusion and chloride zones in the coastal area of Kendari District, Kendari City.

Results: The findings revealed an average pH of 7.11 (ranging from 5 to 8.8), an average temperature of 29.4°C (ranging from 29.4 to 32.7°C), an average Total Dissolved Solid (TDS) level of 590.25 mg/L (ranging from 54 to 1,388 mg/L), and an average salinity of 3.05‰ (ranging from 1 to 5‰).

Conclusion: Based on these results, it can be concluded that seawater intrusion is classified as low and is not affecting the wells used by residents in the coastal area of Kendari District, Kendari City, Indonesia.

Keywords: salinity; seawater; groundwater; chloride zones; coastal area; GIS

Background

Coastal areas possess significant natural resource potential but are highly susceptible to changes in the surrounding land (Guo et al., 2021; Lestari et al., 2017). Economic activities that involve the conversion of coastal land, such as swamps and mangroves, into industrial, tourism, and residential areas can contribute to coastal environmental pollution (Seifollahi-Aghmiuni et al., 2022; Tosepu, 2019; Xu et al., 2019). Kendari City, located in Southeast Sulawesi Province, Indonesia, is one such coastal area, covering a land area of 271.76 km2, which accounts for 0.7% of the total land area of Southeast Sulawesi Province. As the capital of Southeast Sulawesi Province, the level of land utilization in Kendari City's coastal areas is relatively high. These coastal areas are utilized for various purposes, including residential settlements, fish pond farming, warehousing, shipyards, ports, and tourist attractions. The population density in Kendari City is approximately 1.70% and continues to increase, resulting in significant impacts on the environmental quality, particularly in aquatic environments such as groundwater, surface water, and seawater (Badan Pusat Statistik Kota Kendari, 2021b; Chen et al., 2020).

The rapid advancement of technology, coupled with population growth, has led to extensive groundwater extraction, resulting in groundwater levels dropping below sea level (Hounsinou, 2020). Uncontrolled groundwater extraction, without considering the environmental carrying capacity, can cause the groundwater level to exceed the recharge rate of the aquifer. This can have detrimental effects on underground water sources and lead to surface soil depletion (Shammi et al., 2019). Additionally, factors such as rising sea levels, land subsidence, and ongoing groundwater extraction contribute to the encroachment of seawater into land areas, particularly in deep aquifers, leading to seawater intrusion (Hounsinou, 2020). Excessive groundwater pumping creates voids within the aquifer, resulting in the groundwater level dropping below sea level. This height difference allows salt-containing elements like chloride (Cl) from seawater to infiltrate the groundwater, leading to groundwater pollution (Herlambang & Indriatmoko, 2005).

Seawater intrusion refers to the infiltration of seawater into groundwater, either naturally or due to human activities, such as extracting groundwater for domestic purposes (Muhardi et al., 2020). While seawater intrusion is a natural phenomenon commonly observed in coastal areas, it can become a significant issue in areas targeted for development as settlements and tourist destinations (Setiawan et al., 2017). The intrusion of seawater can hinder the extraction of freshwater for domestic and industrial water supply. In coastal areas, clean water is primarily obtained from springs, dug wells, and drilled wells, which are used for daily activities like bathing, washing, and tourism. Therefore, the demand for clean water in coastal areas becomes even more critical. Seawater intrusion can have far-reaching consequences on various aspects of life, including health problems, reduced soil fertility, damage to structures, and contamination of groundwater (Putri et al., 2016).

Kendari Subdistrict, located within Kendari City, is one of the coastal areas that experienced rapid population growth. As of 2020, it had a population of 28,580, with a growth rate of 1.09% (Badan Pusat Statistik Kota Kendari, 2021a). This area not only caters to domestic water needs but also serves as a tourist destination, resulting in high water demands. In order to fulfill these needs, residents rely on springs, dug wells, and drilled wells for their daily water requirements, including those related to tourism and trade activities. However, residents have reported signs of seawater intrusion, indicated by the brackish or even salty taste of the water they use. This issue deserves significant attention, as seawater intrusion can have direct and long-term detrimental effects on human health and groundwater quality. Therefore, conducting research to determine the potential distribution of seawater intrusion becomes crucial in preventing extensive groundwater pollution and ensuring that water quality remains suitable for its intended use.

Methods

Study Design

This study utilized a descriptive research design conducted in October 2022. It involved collecting and analyzing 20 water samples from wells owned by residents in Kendari District, Kendari City.

Samples

The selected well water samples met specific criteria, including being sourced from dug wells or drilled wells located along the coast and used for daily water needs.

Data Collection

The research process consisted of several stages. Firstly, a literature review was conducted to gather information on seawater intrusion, as well as obtain geological maps and understand the morphology of the research area, Kendari City. Secondly, the locations of wells along the coast of Kendari City were determined. Thirdly, well water samples were collected from residents using the grab sampling method. Parameters such as taste, color, rock type, temperature, pH, Total Dissolved Solids (TDS), and salinity were measured in the collected water samples. The tools used for this study included leads, buckets, sample bottles, label paper, pH meters, TDS meters, thermometers, and salinity measuring devices. The precise locations of each measurement point were recorded using Global Positioning System (GPS) technology. The distance from the shoreline to the sampled well points was measured, and the well depths were recorded to assess any potential relationship between distance and circulation in estimating the likelihood of seawater intrusion. Subsequently, the collected data were processed using Geographic Information System (GIS) software, Microsoft Office tools, and Google Earth. The final stage involved creating a distribution map illustrating the occurrence of seawater intrusion in the research area.

Data Analysis

The collected data from the water samples were analyzed using Geographic Information System (GIS) to identify the distribution patterns of seawater intrusion and chloride zones in the coastal area of Kendari District, Kendari City. GIS technology allows for the spatial analysis and visualization of data, enabling researchers to understand the extent and patterns of seawater intrusion in coastal area of the study.

Ethical Considerations

The ethical considerations have been addressed and secured by the Faculty of Public Health at Halu Oleo University in Kendari, Indonesia. It is ensured that proper ethical guidelines were followed throughout the study. Informed consent was obtained from each respondent, ensuring that they were fully informed about the study and its objectives before participating. Respecting and protecting the rights and well-being of the participants is essential in conducting research.

Results

Kendari Subdistrict is one of the subdistricts located within Kendari City, situated between 3°56'27" to 3°58'44" South Latitude and 122°34'40" to 122°37'37" East Longitude. Geographically, Kendari District shares its boundaries with Konawe Regency to the north, Kendari Bay to the south, Konawe Regency to the east, and West Kendari District to the west. The subdistrict comprises nine villages: Kandai, Gunung Jati, Kendari Caddi, Kessilampe, Kampung Salo, Mangga Dua, Mata, Purirano, and Jati Mekar. Among these villages, Mangga Dua Village has the largest area, accounting for 30.46% of the total subdistrict area. Gunung Jati Village has the highest population in Kendari District, with a population of 5,186 individuals, consisting of 2,643 men and 2,543 women (Badan Pusat Statistik Kota Kendari, 2021a).

Table 1 shows the quality of residents' drinking water in terms of temperature parameters, indicating an average value of 29.4°C. The water temperature was measured using a pH meter device. Water temperature plays a crucial role in regulating aquatic life, particularly in metabolic processes, as rising temperatures can lead to increased oxygen consumption. Examining the pH parameters, the average value is 7.11. The pH measurement of the water was conducted using a pH meter device. The Total Dissolved Solids (TDS) parameter exhibits an average value of 590.24, with a minimum value of 54 mg/L and a maximum value of 1,388 mg/L. The measurement of water pH was performed using a TDS meter and gravimetric device in the laboratory. The salinity parameter review reveals an average value of 3.05‰, with a minimum value of 1‰ and a maximum value of 5‰. The measurement of water pH salinity was carried out using a refractometer tool. In addition, the mapping results can be seen in **Figures 1**, **2** and **3**.

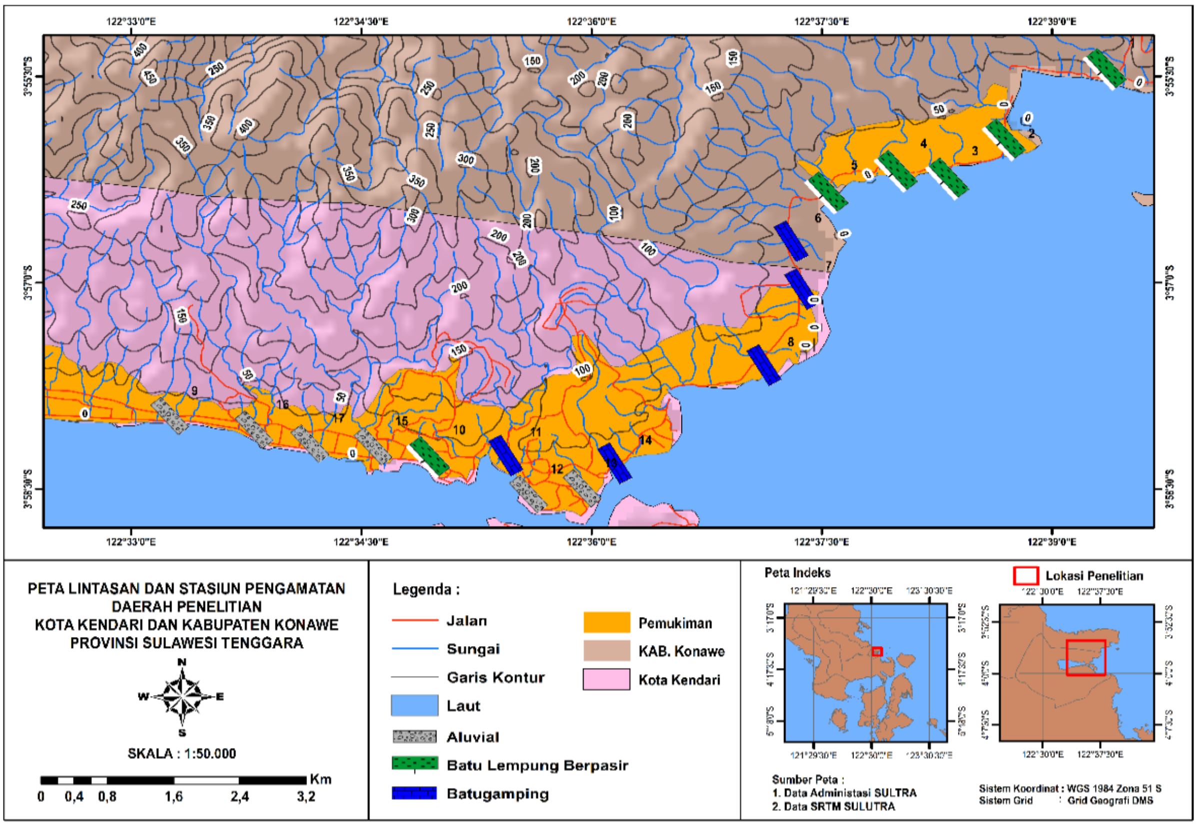

Figure 1 Research location map

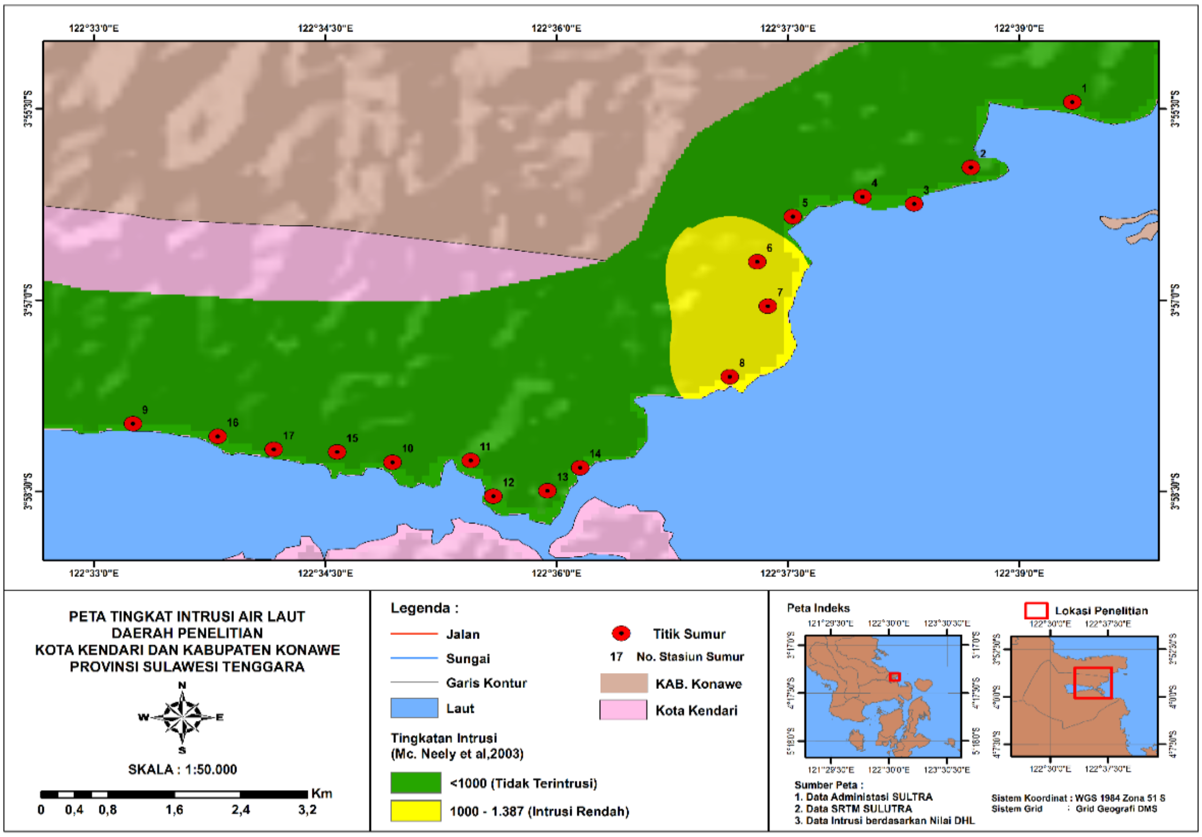

Figure 2 Distribution map of seawater intrusion in community wells in the coastal area of Kendari District, Kendari City

Table 1 Measurement of multiple parameters

Station Symbol	Parameter												
	Water Source	**Temperature**	**pH**	**TDS**	**Salinity (‰)**	**Density**	**DO**	**BOD**	**NO_3**	**NO_2**	**Taste**	**Color**	**Type of rock**
SM 1	Dug well	30.5	7.3	93	3	1003	5.16	0.52	5.484	0.0108	Taste less	Clear	Siltstone–grained sandstone
SM 2	Drilled well	30.5	5	140	1	1001	5.85	0.81	5.048	0.0113	Taste less	Clear	Siltstone–grained sandstone
SM 3	Drilled well	32.1	6.3	600	3	1000	5.16	0.93	4.089	0.0092	Brackish	Clear	Siltstone–grained sandstone
SM 4	Dug well	29.5	8.8	54	1	1001	5.08	0.48	6.530	0.0071	Taste less	Clear	Siltstone–grained sandstone
SM 5	Dug wells	29.4	7.2	938	4	1004	5.85	0.69	5.745	0.0129	Taste less	Turbid	Siltstone–grained sandstone
SM 6 A	Drilled well	29.5	6.9	1388	4	1004	5.04	1.01	6.443	0.0045	Taste less	Clear	Limestone
SM 6 B	Dug well	32.7	7.2	615	2	1002	4.60	0.77	4.874	0,0024	Taste less	Clear	Limestone
SM 7	Drilled well	30.4	7	1112	3	1003	4.88	1.40	6.704	0.0045	Taste less	Clear	Limestone
SM 8 A	Drilled well	32.4	6.9	1249	2	1002	4.80	0.97	5.920	0.0035	Taste less	Clear	Limestone
SM 8 B	Dug well	30	6.9	832	3	1003	4.92	1.41	4.176	0.0071	Taste less	Clear	Siltstone–grained sandstone
SM 9	Drilled well	31	7.1	765	2	1002	5.56	0.69	4.786	0.0066	Taste less	Clear	Aluvial
SM 10	Drilled well	29.7	7.1	1014	4	1004	5.44	1,13	6.966	0.0030	Taste less	Clear	Siltstone–grained sandstone
SM 11 A	Drilled well	31.5	8.2	626	2	1002	4.96	1.09	6.443	0.0082	Taste less	Clear	Limestone
SM 11 B	Dug well	30.1	7.5	563	3	1003	4.52	0.56	6.094	0.0087	Brackish	Clear	Limestone
SM 12	Drilled well	29.9	6.9	330	5	1004	5.48	0.44	4.089	0.0061	Brackish	Clear	Aluvial
SM 13	Dug well	30.1	7.1	298	5	1004	4.52	1.90	4.961	0.0071	Brackish	Clear	Aluvial
SM 14	Dug well	30.9	7.2	274	3	1003	5.28	0.40	5.222	0.0118	Taste less	Clear	Limestone
SM 15	Drilled well	31	8	270	3	1003	5.44	0.73	6.269	0.0045	Brackish	Clear	Aluvial
SM 16	Dug well	29.9	6.5	326	3	1003	4.72	0.85	4.350	0.0082	Taste less	Clear	Aluvial
SM 17	Drilled well	29.7	7.1	318	5	1004	4.48	1.05	4.176	0.0056	Taste less	Clear	Aluvial

Discussion

The temperature measurements conducted at 20 locations revealed that, according to the Regulation of the Minister of Health No. 32 of 2017, which outlines the Environmental Health Quality Standards and Water Health Requirements for Sanitary Hygiene Purposes, Swimming Pools, Solus Per Aqua, and Public Baths, the water temperature remains within the acceptable range for water used in sanitary hygiene purposes (Menteri Kesehatan Republik Indonesia, 2017). This finding is consistent with a study conducted by Triawan et al. (2020) in Bengkulu City, where they employed the STORET Method to demonstrate that the water quality is still suitable for community use in terms of sanitary hygiene purposes.

The second parameter we examined was the pH level. pH is a measure used to determine the acidity or alkalinity of a substance. Changes in water pH have a significant impact on the physical, chemical, and biological processes of organisms living in the water. pH can influence chemical reactions occurring in water and can also affect the toxicity of harmful substances present in the water. Changes in water pH can greatly influence the physical, chemical, and biological processes of organisms inhabiting the water. pH values below 6.5 or above 9 indicate a high concentration of hydrogen ions in the water, which can cause chemical compounds in the human body to transform into toxins that may affect health.

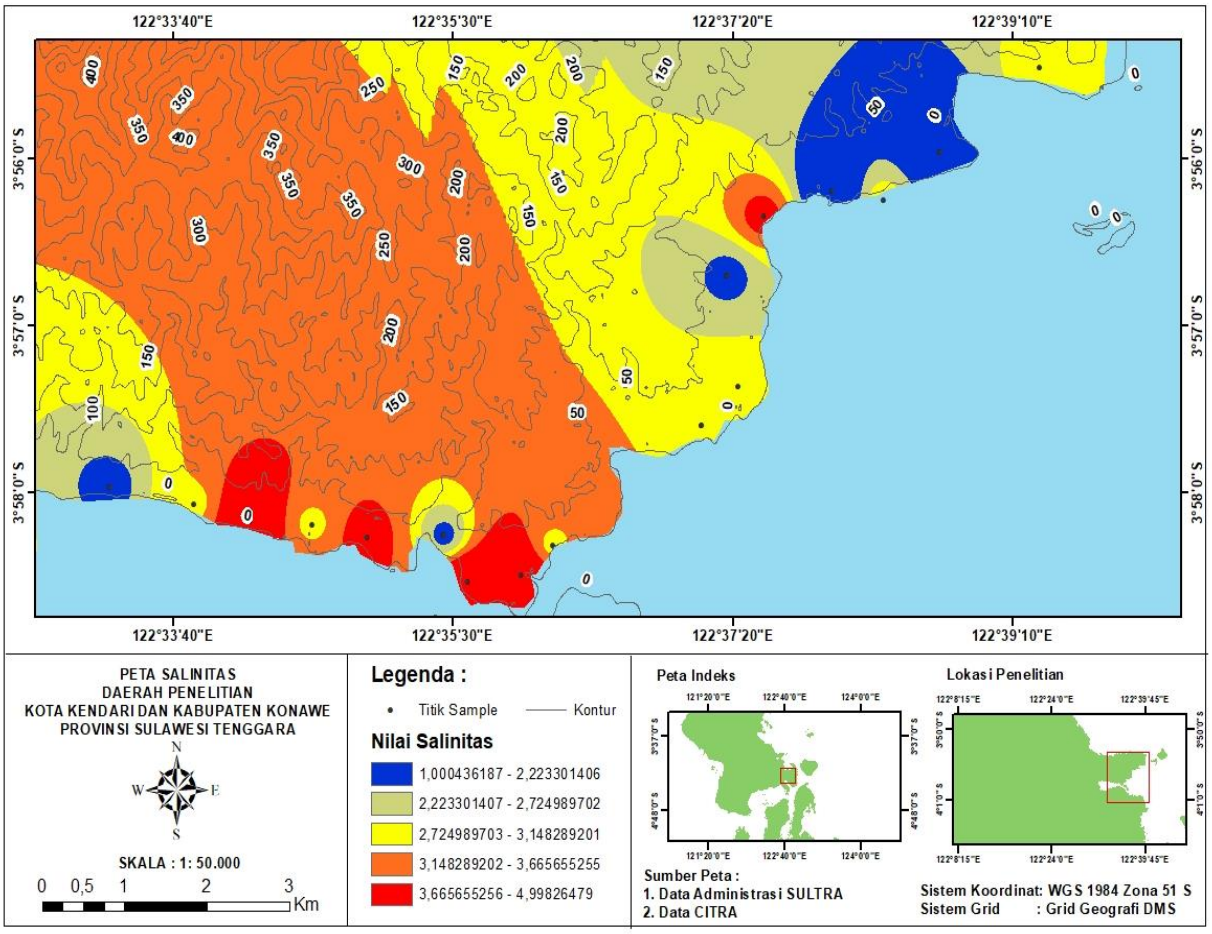

Figure 3 Salinity distribution map of coastal area of Kendari District

The results of pH measurements at 20 water source locations indicate that, according to the Government Regulation of the Republic of Indonesia Number 82 of 2001 concerning Water Quality Management and Water Pollution Control, the acceptable range for water pH in terms of sanitary hygiene needs is 6.5-8.5. The test results reveal that the majority of the water samples are still suitable for use, with an average pH value of 7.11. However, there is one point where the water is acidic with a pH of 5, and another point where the water is alkaline with a pH of 8.8. It is important to address water pH values that do not meet water quality standards, and water treatment processes can be implemented as a solution.

This finding aligns with the research conducted by Putri et al. (2016), which found that the overall quality of the pump water used by the Ketah Coastal community for daily needs is not suitable for direct consumption and requires processing or boiling due to exceeding the maximum allowable level. In their study, one point recorded a pH level of 8.73.

The third parameter we assessed is Total Dissolved Solids (TDS), which refers to dissolved solids with smaller particle size compared to suspended solids.

TDS typically comprises organic substances, organic salts, and dissolved gases. The impact of TDS on health varies depending on the specific chemical species causing the concern. Solid particles present in water can originate from various organic sources such as leaves, sludge, plankton, industrial waste, sewage, household waste, pesticides, and more. Inorganic sources include minerals like calcium bicarbonate, nitrogen, iron, phosphorus, sulfur, and others originating from rocks and air.

The results of TDS measurements at 20 water source locations indicate that, in accordance with the Government Regulation of the Republic of Indonesia Number 82 of 2001 concerning Water Quality Management and Water Pollution Control, the established quality standard value for TDS in water used for sanitary hygiene purposes is 1.000 mg/L. The test results show that the majority of the water samples are still suitable for sanitary hygiene purposes, but there are 4 points where the TDS level exceeds the defined quality standard value. The findings of the seawater intrusion zoning assessment indicate a low level of intrusion in the residents' wells located in the coastal area of Kendari District, Kendari City.

The fourth parameter we examined is salinity, which refers to the total concentration of ions in water. Salinity indicates the total dissolved solids present in the water. During the conversion process, carbonates are transformed into oxides, bromides and other ions are replaced by chlorides, and organic matter is oxidized. Salinity is usually expressed in units of grams per kilogram (g/kg) or parts per thousand (‰). The results of salinity measurements at 20 water source locations reveal that most of the well water falls into the brackish category, but it is still suitable for sanitary hygiene purposes. This finding aligns with the research conducted by Putri et al. (2016), which highlights that the Ketah Coastal Area is one of the coastal areas in Situbondo Regency affected by seawater intrusion.

Conclusion

Low-level seawater intrusion occurs in the residential wells of coastal areas in the Kendari Subdistrict of Kendari City. In several coastal regions, seawater intrusion is a major concern, particularly in relation to residential wells. There are several factors that can influence the low-level seawater intrusion in residential wells. One significant factor is the distance of the wells from the coastline. The farther the wells are from the coastline, the smaller the likelihood of seawater intrusion. Additionally, geological characteristics play an important role. Thick and impermeable soil layers can act as a natural barrier against seawater intrusion, maintaining the quality of the well water. Moreover, a significant freshwater discharge in the aquifer can also reduce the likelihood of significant seawater ingress. Human intervention also plays a crucial role in minimizing low-level seawater intrusion in residential wells. Wise water resource management, including efficient water usage and regulated development in coastal areas, can help prevent damaging seawater intrusion.

Declaration Conflicting Interest

Authors declared no conflict of interest in this study.

Funding

This research was funded by the University Research and Community Service Institute through the Halu Oleo University DIPA Fund for the fiscal year 2022, under the reference number SP-DIPA-023.17.2.677510/2022, dated November 17, 2021. The research was conducted in accordance with the Work Implementation Agreement Letter NO. 3369/UN29.2.1/KU/2022, which was issued in Kendari in 2022.

Acknowledgment

We would like to express our gratitude to the Research and Community Service Institute of Halu Oleo University for providing financial support for this research, as well as to all the participants who actively took part in the study.

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References

Badan Pusat Statistik Kota Kendari. (2021a). *Kecamatan Kendari dalam angka.* Kendari: Badan Pusat Statistik Kota Kendari.

Badan Pusat Statistik Kota Kendari. (2021b). Kendari dalam angka. https://kendarikota.bps.go.id

Chen, H., Chen, C.-Y., & Shao, K.-T. (2020). Recovery and variation of the coastal fish community following a cold intrusion event in the Penghu Islands, Taiwan. *Plos One*, *15*(9), e0238550. https://doi.org/10.1371/Journal.Pone.0238550.

Guo, Q., Zhao, Y., Hu, Z., & Li, M. (2021). Contamination transport in the coastal unconfined aquifer under the influences of seawater intrusion and inland freshwater recharge—Laboratory experiments and numerical simulations. *International Journal of Environmental Research and Public Health*, *18*(2), 762. https://doi.org/10.3390/Ijerph18020762.

Herlambang, A., & Indriatmoko, R. H. (2005). Pengelolaan air tanah dan intrusi air laut. *Jurnal Air Indonesia*, *1*(2). https://doi.org/10.29122/Jai.V1i2.2348.

Hounsinou, S. P. (2020). Assessment of potential seawater intrusion in a coastal aquifer system at Abomey-Calavi, Benin. *Heliyon*, *6*(2), e03173. https://doi.org/10.1016/J.Heliyon.2020.E03173.

Lestari, H., Bahar, H., Asfian, P., & Ahmad, L. O. A. I. (2017). Environmental risk factors in coastal area of Wawatu Village, Moramo Sub District, North of South Konawe, Southeast Sulawesi. *Public Health of Indonesia*, *3*(3), 107-111. https://doi.org/10.36685/phi.v3i3.133

Menteri Kesehatan Republik Indonesia. (2017). Peraturan Menteri Kesehatan Republik Indonesia Nomor 32 Tahun 2017 Tentang Standar Baku Mutu Kesehatan Lingkungan Dan Persyaratan Kesehatan Air Untuk Keperluan Higiene Sanitasi, Kolam Renang, Solus Per Aqua, Dan Pemandian Umum. Jakarta: Menteri Kesehatan Republik Indonesia.

Muhardi, M., Faurizal, F., & Widodo, W. (2020). Analisis pengaruh intrusi air laut terhadap keberadaan air tanah di Desa Nusapati, Kabupaten Mempawah menggunakan metode geolistrik resistivitas. *Indonesian Journal of Applied Physics*, *10*(2), 89-96.

Putri, A. W., Suharto, B., & Susanawati, L. D. (2016). Identifikasi pencemaran air tanah akibat intrusi air laut (Studi kasus Pesisir Pantai Ketah Kabupaten Situbondo). *Jurnal Sumberdaya Alam dan Lingkungan*, *2*(3), 32-39.

Seifollahi-Aghmiuni, S., Kalantari, Z., Egidi, G., Gaburova, L., & Salvati, L. (2022). Urbanisation-driven land degradation and socioeconomic challenges in peri-urban areas: Insights from Southern Europe. *Ambio*, *51*(6), 1446-1458. https://doi.org/10.1007/s13280-022-01701-7

Setiawan, A., Juliani, H., & Sa'adah, N. (2017). Kajian yuridis terhadap pelaksanaan Peraturan Direktur Jenderal Perbendaharaan Nomor 22/Per/2013 Tentang Ketentuan Lebih Lanjut Pelaksanaan Perjalanan Dinas Dalam Negeri Bagi Pejabat Negara, Pegawai Negeri, Dan Pegawai Tidak Tetap (Studi pada Direktora). *Diponegoro Law Journal*, *6*(2), 1-14. https://doi.org/10.14203/Risetgeotam2017.V27.430.

Shammi, M., Rahman, M. M., Bondad, S. E., & Bodrud-Doza, M. (2019). Impacts of salinity intrusion in community health: a review of experiences on drinking water sodium from coastal areas of Bangladesh. Healthcare,

Tosepu, R. (2019). Public health significance of coastal communities. *Public Health of Indonesia*, *5*(4), 145-146. https://doi.org/10.36685/phi.v5i4.322

Triawan, D. A., Notriawan, D., & Ernis, G. (2020). Penentuan status mutu air tanah dangkal di sekitar Tempat Pembuangan Akhir Sampah (TPA) Air sebakul Kota Bengkulu menggunakan metode storet: A Cross-Sectional Study. *Jurnal Kimia Riset*, *5*(1), 22-28. https://doi.org/10.20473/Jkr.V5i1.17053.

Xu, Z., Ma, J., & Hu, Y. (2019). Saltwater intrusion function and preliminary application in the Yangtze River Estuary, China. *International Journal of Environmental Research and Public Health*, *16*(1), 118. https://doi.org/10.3390/Ijerph16010118.

Cite this article as: Nurmaladewi., Saktiansyah, L. O. A., Jayadisastra, Y., Sulfitrana, A., Kaimuddin, S. M., & Okto, A. (2023). Assessing seawater intrusion and chloride zones in residents' wells in selected coastal area of Indonesia: A GIS analysis. *Public Health of Indonesia, 9*(2), 74-81. https://doi.org/10.36685/phi.v9i2.661