Escalate groundwater potential for acquiring sustainability and resilience in Pekalongan City, Indonesia – a review

Asri Cahaya Hati*, *Thomas* Triadi Putranto, *Hadiyanto*, *Mochamad* Arief Budihardjo

Master Program of Environmental Science, School of Postgraduate, Diponegoro University, Semarang-Indonesia

Abstract. Groundwater in Pekalongan City suffered vulnerability. Water catchment quality in there is already at a critical threshold. The anthropogenic and natural factors which have fluctuating rainfall stressed groundwater. There are 4580 companies, 33 accommodation services, and 318 restaurants that exert clean water for their performance. The population of Pekalongan city in 2019 has reached 307,097 people, which has increased by almost 25% of the inhabitants in 1993. The local Health Department reported that there was an increase in the morbidity rate of 27.62% compared to 2018. The increase in flooding and land subsidence had triggered a diminish in land value and engender other economic losses. This study executed with a comprehensive literature review of (1)groundwater characteristics, (2)techniques for enhancing groundwater potential, and (3)alternatives of groundwater preservation that proper it. The assessment approach leads to accelerated groundwater infiltration through cutting material with low permeability by crossing less conductive aquifer layers through the installation infrastructure with large diameters. The unit provides the ability to carry out lateral infiltration and increase water storage in the soil to support sustainability and resilience.

Keywords. Groundwater potential, conservation, infiltration wells, flood prevention.

1. Introduction

Water blanket approximately 75% of the globe's surface. The study assesses that is 97% of it occurs in oceans. Around 3% of the water on Earth is freshwater that is physical shape varies presence a liquid, a gas, or a solid. it is sealed up in ice caps, glaciers, and permanent snow wrap around in the polar regions approximately 69%. Around 30.7% of freshwater is groundwater. Almost 0.3% of all freshwater gathered to be surface water [1]. Groundwater is a crucial resource for 54.76% of the inhabitant in Pekalongan City, Indonesia (Fig. 1). The rate of population and economic growth in line with water demand.

* Corresponding author: asricahayahati@students.undip.ac.id

The inhabitant in 2019 was increased by around 25% of the inhabitant in 1993 with population ratio has reached 6,729 person/km2. Actual data shows that there is the utilization of water resources for the economic operation of 4580 companies, 33 accommodation businesses, and 318 restaurants[2]. Local Water Supply Company only serves around 40% of the inhabitant. The company utilizes water resources from rivers and 32 deep wells [3].

The assessment with remote sensing application and geographic information system evince that 84% of the Pekalongan City water catchment areas are in the "started critical" category and 16% of the water catchment areas are already "rather critical" [4]. Besides, the dynamics of land-use change are unfavourable for groundwater conservation. The developed land areas increased by 23.29% that accumulated each year. Currently, the developed land areas reached out to 54.08% of the total area [5]. That stressor had triggered hydrometeorological disasters such as flooding [6].

This study executed with a comprehensive literature review of (1)Groundwater characteristics of Pekalongan City, (2)techniques for enhancing groundwater potential, and (3) alternative of groundwater preservation that proper it. The objective of the study is to delve groundwater potential in Pekalongan city and how to maximize it. The study is a prospect for realizing sustainable development with an environmental perspective and apply community resilience to face an increasingly uncertain and challenging era of climate change.

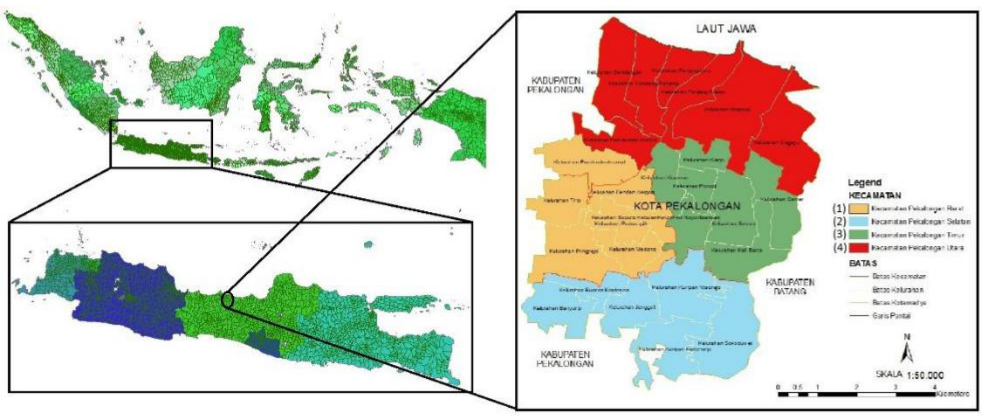

Fig. 1. Study area: Pekalongan City. 4 Sub-District : (1) Pekalongan Barat; (2) Pekalongan Selatan; (3) Pekalongan Timur; dan (4) Pekalongan Utara.

2. Groundwater characteristics

Pekalongan City has an area of 4,525 hectares. The location is in the Petalong Region joint with Pekalongan Regency and Batang Regency. Pekalongan City is included in the Pekalongan-Pemalang groundwater basin area [7]. Aquifer productivity is increasingly rising towards North Pekalongan [8]. Pekalongan City elevation has between 0-16 meters above sea level. It have a flat slope with range 0 - 1.893718% [4]. The topography is included in the lowland category (Fig.2) [7, 9-10]. Sea level rise occurred in the coastal city of Pekalongan. The analysis has been performed using parameters of sea waves and tides. The result confirmed that a wave height of 0.71 meters raises the sea level at 0.11 meters. Wave height of 1.93 meters raises sea level at 0.30 meters, while a wave height of 4.61 meters raises sea level at 0.66 meters [11]. Besides, Pekalongan City also experienced land subsidence of 4.8 - 10.5 cm/year which was analyzed through ALOS satellite [12].

Groundwater quality decreased in coastal areas due to seawater intrusion measured by the value of electrical conductivity. It occurred in 75% of the northern Pekalongan area. High salinity affected in 914.33 hectares [13]. The zone within a distance of 500-600m from the shoreline has 6.7 to 15.5% salinity, 800-900m has 2.9 to 6.6% salinity, and 1-1.5km has 1.4 to 2.8% salinity [14]. The study used a DRASTIC method showed that the Pekalongan City groundwater experienced vulnerability at moderate to high levels. DRASTIC Index between 101 to >180. The highest level of vulnerability has in shallow groundwater levels and unsaturated media zone [8]. Decreased water absorption capacity increases runoff water volume and decreases groundwater quality [4].

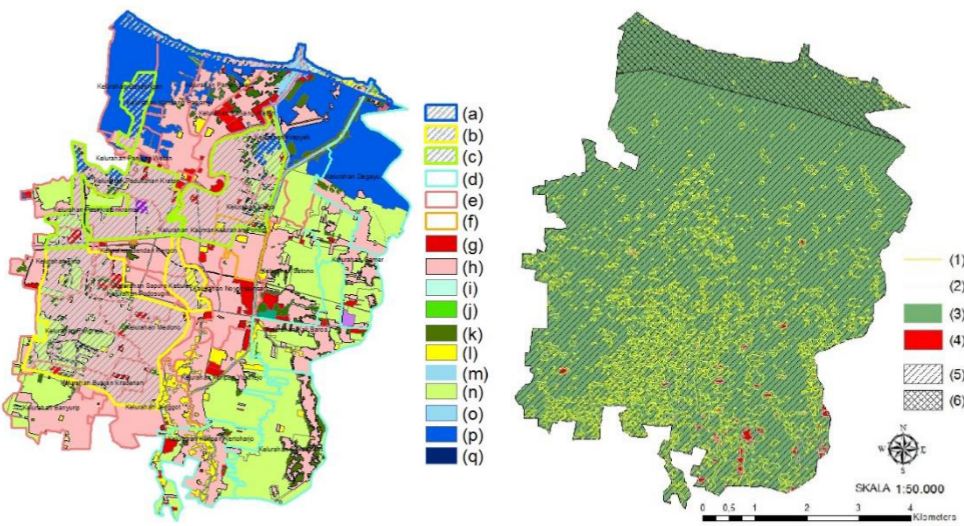

Fig. 2. Urban and land conditions : (a) abrasion-prone area; (b)flood-prone area; (c)rob-prone area; (d)low population density; (e)moderate population density; (f)high population density; (g)land developed area (non-settlement and industry); (h)settlement area; (i)coast; (j)forest; (k)mixed gardens, fields, dry fields; (l)meadows, shrubs and other open land; (m)fishing port; (n)paddy field; (o)river; (p)fish ponds; (q)other water reservoirs; (1)contour 10masl; (2)contour 20masl; (3)topography 10masl; (4)topography 20masl; (5)alluvial; and (6)alluvial-fan.

The quality of groundwater in community wells is affected by river water quality. Poor river water quality will adversely affect the nearest wells [15]. The research pointed that the lowest level of Cr(VI) dug well water in Banyurip Kelurahan is 0.07 mg/l, while the highest is 0.53 mg/l, and the average is 0.14 mg/l. The results of an inspection of dug wells showed that construction of dug wells 94.23% did not fulfil the requirements and 5.77% fulfil the requirements. The distance between the dug well and the river affected the level of Cr(VI). Chrome metal flowed from several batik dyes and the final washing process of batik [16]. Groundwater containing nitrite [17] and cadmium [3] surpassed the standard. Groundwater would be polluted by bacteriological parameters if it was closed to farm locations and waste disposal sites [18]. Implementation of Groundwater management encounters obstacles such as urban sprawl, intensive agriculture, globalized pharmaceutical, insufficient water as a renewable resource. Water depletion would continue then it survives to dependence on water reuse [19].

3. Groundwater potential

Infiltrated water will be a sub-surface run-off and some flows to the nearest surface water sources. Some percolates to become a groundwater flow, then flows in the aquifer, and some come out into springs [20]. Infiltration capacity is being decreased either due to a decrease in the quantity and quality of vegetation or water catchment areas. It will reduce the volume of groundwater while increasing the volume of runoff (floods) flowing in rivers, which will automatically shift the volume of water to the sea [21]. Groundwater extraction due to groundwater pumping in coastal areas will result intrusion of seawater. That will make groundwater in coastal areas no longer possible to be used directly [22].

The natural phenomena and lifestyles of modern society today need to be understood for raising awareness to make all communities participate in managing groundwater wisely with an environmental culture [20, 23]. Groundwater is a very valuable and vital source for fulfilling various social, cultural and economic needs for inhabitant in pekalongan city. The groundwater depletion not only would stress the future water resource of Pekalongan City but is a global issue. It studied by hydrological modelling using information from wells and GRACE satellites have been estimated to be around 95km^3/year [24-25]. The system of shallow urban groundwater could be escalated where it is not widely abstracted and little information exists for consequently. Protection and preservation of groundwater for the long term can be done by maximizing the potential of groundwater. Infiltration techniques have been used and developed to achieve the desired conditions for the sustainability of groundwater resources. Various forms of design used include trenches, galleries, shafts-Pits, and wells[26].

Infiltration trenches are a miniature surface footprint for bypass shallow impermeable level and suspend sediments on the bottom. Trenches supply substitute retention while water passes into soils. it is made water to be collected and percolated. Infiltration rates elevate with spacings that larger between parallel trenches. The favours of supplemented infiltration may be counteracted by the raised expenses of additional excavation, materials, and long-term maintenance. Galleries are wider than trenches. Infiltration galleries refer to systems are installed earlier the water table for recharging the underlying aquifer. Average infiltration rates ranged from 0.4 cfs (11.3 L/s) to 1.67 cfs (47.3 L/s). The next infiltration design is Infiltration shafts and pits. It is large-diameter shafts that are drilled to through lower permeability soils. The massive diameter initiates water retention and a more numerous parallel infiltration. Shafts are filled with cobbles or coarse gravel. It is equipped up the static water table that could be arduous to repair. An alternative is by placing a sheet of finer gravel and sand at the summit of the cobbles or coarse gravel to establish a converted filter for better supervise the clogging. The top sand cover would trap fine materials. That is eliminated and renewed periodically [26].

4. Groundwater preservation

Urban hydrology performs an influential role in a healthier ecosystem and enhances living statuses in urban landscapes with sustainability and resilience. Rainwater was considered as a resource. Water infiltration is a great activity not only in urban water management but also in agriculture and the construction field. That is a global issue, especially in the present with the circumstances of climate change. The earth is needed support to decrease runoff and increase percolation then extend the retention capability of the aquifer [27]. The efforts for sustaining sustainability of Water Resources so that will always available in sufficient quantity and quality to fulfil the necessity of humans and other living things, both present and future. The condition, nature and function of water will keep preserve. Groundwater preservation is carried out by assessing the distribution and characteristics of aquifers; hydrogeological conditions; groundwater conditions and environment; groundwater protected areas; water needs for the community and development. [28].

Government has established regulations and standards for rainwater infiltration. Infiltration could be done through the installation of shallow recharge wells, deep infiltration wells, catchment trenches and biopores [28-29]. The requirements that must be met are as follows: infiltration wells are placed on relatively flat land with a maximum slope of <2%; infiltration wells and rainwater catchment trenches can be made individually and communally; rainwater catchment wells are used for groundwater depths >2m, if groundwater depths <2 m can use rainwater catchment ditches; soil structure that can be used must have a soil permeability coefficient value >2cm/hour, and runoff coefficient is set at 0.95 [30].

5. Conclusion

Groundwater is a critical resource that must be managed with long-term and sustainable goals. infiltration is expected to be able to refill the ground space with clean water that can be utilized by the community. Regional governments, communities and the private sector are expected to immediately implement the central government regulation to carry out the construction of rainwater catchment infrastructure following the characteristics of the land and local hydrology. The installation of rainwater catchment wells in Pekalongan City is not only for groundwater preservation, but also as one of the strategies to deal with flooding, land subsidence, and seawater intrusion. In addition, community resilience to climate change will be realized.

References

1. A. du Plessis, *Global Water Availability, Distribution and Use*, in *Freshwater Challenges of South Africa and its Upper Vaal River*, Springer International Publishing, 3–11 (2017)
2. Badan Pusat Statistik Kota Pekalongan, *Kota Pekalongan Dalam Angka 2019*, Pekalongan, (2019)
3. A. Ginanjar, A. Rezagama, & D. S. Handayani, *Rencana Induk Sistem Penyediaan Air Minum Kota Pekalongan*, JTL, **4**(3), 1–8 (2015)
4. N. Adibah, S. Kahar, & B. Sasmito, *Aplikasi Penginderaan Jauh dan Sistem Informasi Geografis Untuk Analisis Daerah Resapan Air (Studi Kasus : Kota Pekalongan)*, J Geod Undip, **2**(2),141–153 (2013)
5. N. Bashit, Y. Prasetyo, A. Sukmono, & W. Wicaksono, *Kajian Perkembangan Lahan Terbangun Kota Pekalongan Menggunakan Metode Urban Index (Ui)*, **2**(2), 12–18 (2019)
6. M. B. Pratama, *Tidal Flood in Pekalongan: Utilizing and Operating Open Resources for Modelling*, in IOP Conference Series: Materials Science and Engineering PAPER, **676**(012029), 1–10 (2019)
7. Pemerintah Kota Pekalongan, *Rencana Tata Ruang Wilayah Kota Pekalongan Tahun 2009-2029*, Peraturan Daerah, 30 (2011)
8. T. T. Putranto, D. A. Widiarso, and F. Yuslihanu, *Studi Kerentanan Air Tanah Terhadap Kontaminan Menggunakan Metode Drastic di Kota Pekalongan*, Teknik, **37**(1), 26–31 (2016)

9. F. N. Rochim and J. A. Syahbana, *Penetapan Fungsi dan Kesesuaian Vegetasi pada Taman Publik sebagai Ruang Terbuka Hijau (RTH) di Kota Pekalongan (Studi Kasus : Taman Monumen 45 Kota Pekalongan)*, Tek. PWK, **2**, (3), 314–327 (2013)
10. R. H. Sauda, A. L. Nugraha, and Hani'ah, *Kajian Pemetaan Kerentanan Banjir Rob Di Kabupaten Pekalongan*, J. Geod. Undip, **8**(1), 466–474 (2019)
11. H. Prihatno, *Variasi Kenaikan Muka Laut di Wilayah Pesisir Kota Pekalongan, dari Analisis Pasang Surut dan Angin*, J. Segara, **8**(1), 27–34 (2012)
12. E. Chaussard, F. Amelung, H. Abidin, and S. H. Hong, *Sinking cities in Indonesia: ALOS PALSAR detects rapid subsidence due to groundwater and gas extraction*, Remote Sens. Environ., **128**, 150–161 (2013)
13. M. R. Hidayat, *Pemetaan Intrusi Air Laut Kecamatan Pekalongan Utara Kota Pekalongan*, Universitas Negeri Semarang (2015)
14. E. Suharini, F. Hanafi, and W. Akhsin Budi Nur Sidiq, *Study of Population Growth and Land Use Change Impact of Intrusion on Pekalongan City*, in *Advances in Social Science, Education and Humanities Research*, **79**, 232–238 (2016)
15. Q. Guo, Z. Zhou, G. Huang, and Z. Dou, *Variations of groundwater quality in the multi-layered aquifer system near the Luanhe river, China*, Sustain., **11**(4), 1-19 (2019)
16. K. Izzatunnisa, S. Abdullah, and T. M. Mulyasari, *Pengaruh Kadar Cr (VI) Air Sungai dan Jarak Sumur Gali dengan Sungai Terhadap Kadar Cr (VI) Air Sumur Gali di Kelurahan Banyurip Kota Pekalongan*, Keslingmas, **38**(1), 57–66 (2019)
17. R. Rizza, *Hubungan Antara Kondisi Fisik Sumur Gali dengan Kadar Nitrit Air Sumur Gali di Sekitar Sungai Tempat Pembuangan Limbah Cair Batik (Studi di Kelurahan Podosugih Kecamatan Pekalongan Barat Kota Pekalongan)*, Universitas Negeri Semarang (2013)
18. S. Mawar, R. Saleh, and Supriyo, *Risiko Pencemaran Bakteriologis Sumur Galu dan Pamsimas di Wilayah Kerja Puskesmas Kusuma Bangsa Kota Pekalongan*, J. Keper Mersi, **4**(2), 11–14 (2013)
19. N. M. Burri, R. Weatherl, C. Moeck, and M. Schirmer, *A review of threats to groundwater quality in the anthropocene*, Sci. Total Environ., **684**, 136–154 (2019).
20. Darwis Panguriseng, *Pengelolaan Air Tanah*. Makasar: Pena Indis (2018)
21. A. Hossain Anni, S. Cohen, and S. Praskievicz, *Sensitivity of urban flood simulations to stormwater infrastructure and soil infiltration*, J. Hydrol., **588**(125028), 1–10 (2020)
22. X. Ren, N. Hong, L. Li, J. Kang, and J. Li, *Effect of infiltration rate changes in urban soils on stormwater runoff process*, Geoderma, **363**(114158), 1-11 (2019)
23. L. Freitas, M. J. Afonso, A. J. S. C. Pereira, C. Delerue-Matos, and H. I. Chaminé, *Assessment of sustainability of groundwater in urban areas (Porto, NW Portugal): a GIS mapping approach to evaluate vulnerability, infiltration and recharge*, Environ. Earth Sci., **78**(140), 2–17 (2019)
24. P. Doll, H. M. Schmied, C. Schuh, F. T. Portmann, and A. Eicker, *Global-scale assessment of groundwater depletion and related groundwater abstractions: Combining hydrological modeling with information from well observations and GRACE satellites*, Water Resour. Res., 5375–5377 (2014)
25. D. W. Vasco, T. G. Farr, P. Jeanne, C. Doughty, and P. Nico, *Satellite-based monitoring of groundwater depletion in California's Central Valley*, Sci. Rep., **9**(1), 1–14 (2019)
26. R. G. Maliva, *Vadose Zone Infiltration Systems*, in *Anthropogenic Aquifer Recharge*, Springer Nature Switzerland AG, 567–601(2020).
27. M. Zeleňáková, G. Hudáková, and A. Stec, *Rainwater Infiltration in Urban Areas*. Cham, Switzerland: Springer Nature Switzerland AG, 7–41 (2020).

28. Republik Indonesia, *Sumber Daya Air*, Undang-Undang, 17 (2019)
29. Republik Indonesia, *Pemanfaatan Air Hujan*. Peraturan Menteri Lingkungan Hidup, 12 (2009)
30. Republik Indonesia, *Sumur dan Parit Resapan Air Hujan*, SNI 8456 (2017)