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DEVELOPMENT OF THE WATER QUALITY INDEX (WQI) AND HYDROGEN SULFIDE (H_2S) FOR ASSESSMENTS AROUND THE SUWUNG LANDFILL, BALI ISLAND

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Abstract: The byproducts of anaerobic processes at municipal solid waste landfills are leachates and gas emissions. One of the landfills operating in the coastal area of Bali Island is the Suwung landfill. The objectives of this research is to identify the water quality index (WQI) and hydrogen sulfide (H_2S) parameters, as well as the health complaints by the local community around the Suwung landfill. A total of 12 samples were taken from wells, and surface and coastal water bodies. The parameters measured in this study are TSS, DO, COD, BOD, and NO_3-N. The comparison of the parameters were in accordance with PP No. 82 of 2001 for the second-class water quality standards. Each sample for the TSS and DO parameters meets only eight and five quality standards, respectively. Meanwhile the COD parameters are only met by one sample. For the BOD, all samples did not meet the second-class water quality standards. The WQI analysis showed that seven samples were slightly polluted and two samples were polluted moderately. The average WQI value per water quality is 4.12, which means that the water quality around the landfill is slightly polluted. The H_2S parameters mention concentrations at four points do not meet air quality standards. Respondents felt uncomfortable with the odour caused by the H_2S. The future implication of this study is to know the indications of public health conditions.

Keywords: WQI, H_2S, health complaints, landfill.

Introduction

The growth of the population of Bali Island is causing an increase in the amount of production and consumption, which has led to the emergence of various kinds of municipal solid waste (MacRae & Rodic, 2015) and wastewater (Suryawan *et al.,* 2019a; Suryawan *et al.,* 2019c). Currently, municipal solid waste in Denpasar City is transported to the Suwung landfill. The Suwung landfill is a facility that was designed with the sanitary landfill method, but the operational implementation uses an open dumping system. The possible impacts are environmental quality decrease of ground water, river, sea water, and an increase in disease vectors, as well as negative effects on the health of the local community. The results of previous studies mentioned that the quality of waters in the Suwung Estuary were classified as slightly polluted (Saraswati *et al.,* 2018) and the well water was in the moderately polluted category (Jaya *et al.,* 2018).

The existence of a landfill can cause a decline in water quality and public health (Yodi *et al.,* 2020). Sustainable landfill management should be able to control the composition of waste that can be stockpiled (Suryawan *et al.,* 2019b). Infiltration of water into landfills will affect the quality of the leachate. This leachate infiltration can flow into the water surface, and it can also sink into deep aquifers. Open dumping landfills and the practice of placing landfills near coastal waters can have an impact on the water quality and bring harm to the marine ecosystem and cause degradation in biological functions (Tanjung *et al.,* 2019).

Besides the decreasing quality of water, landfills can also result in a decrease in ambient air quality. Solid waste decomposition usually occurs aerobically, continued facultative, and anaerobically when oxygen is depleted. In solid waste anaerobic degradation, one of the gases produced from this decomposition is H_2S (Yodi *et al.,* 2020). Sampling by Meirinda (2008) of all community houses around the landfill in Medan Marelan district showed that H_2S concentrations were above the maximum standard (Meiranda., 2008). Hartini and Kumalasari (2014), found that H_2S measurements in all Jatibarang Landfill zones in Semarang City were below the required quality standards (Hartini & Kumalasari, 2014). Other studies where H_2S levels were good enough in the waste sorting area meant that they were below the required quality standards (Putri, 2018).

Environmental pollution due to the operation of landfills can affect the health of the local community (Hartini & Kumalasari, 2014). The objectives of this research are to analyse the impact of the operation of the Suwung Landfill on water and air quality, and evaluating the health complaints of the local community. The development of water quality prediction models is an important step towards better water quality management of rivers (Ho *et al*., 2019).

A popular water quality index (WQI) is applied in order to attain freshwater quality information quickly and to monitor water quality. WQIs have proven to be a practical method that takes into account the critical environmental variables that show pollution conditions in a water body. When considered in terms of public health risks, the stream can be used as drinking and potable water and does not pose a potential hazard to adult and child health (Ustaoglu *et al*., 2020).

Health risk assessments are very important to ensure the groundwater quality assessments. Moreover, potential human health risk assessments are conducted to evaluate the possible adverse harmful human health impacts on infants, children and adults. The water quality index (WQI) was used to evaluate the status of groundwater quality for drinking purposes in the study area. According to the WQI, the water quality is classified as excellent if it is lower than 50 mg/L, good if it is between 50 mg/L and 100 mg/L, poor if it is between 100 mg/L and 200 mg/L, very poor if it ranges from 200 mg/L to 300 mg/L, and not suitable for drinking if it is larger than 300 mg/L (Adimala &Qian., 2019)

Determining the water quality index and health risk assessment is, therefore, important to assess the risk level. The risk for children is generally higher than adults and, consequently, children have higher risk of being adversely affected by pollutants (Njuguna, 2019). In addition, several numerical models have been used by different researchers in the evaluation of water quality for drinking purposes. Such models include water quality index (WQI), heavy metal pollution index (HPI), heavy metal evaluation index (HEI), and contamination index (CI). Furthermore, numerical models have also been widely employed in the estimationof both non-carcinogenic and carcinogenic health risks associated with the ingestion of poor quality water (Ezugwu *et al*., 2019).

Materials and Method

Water Quality Sampling

The determination of the location of water sampling was conducted by the purposive sampling method. The purposive sampling method is a sampling technique used to determine a sampling location that can describe the characteristics of the whole area (Sundra, 1997). Water samples were collected from some of the sampling point, such as wells, surface water, and estuaries. The total samples taken were 12 (Figure 1) from well, surface water, and estuary. The grab sampling method refers to representatives of a larger quantity that is taken at a specific time.

Samples were collected during the dry season of June 2019. This research was not conducted during the rainy season. According to Zhang (2007), sampling during the rainy season did not produce representative results of air quality. The rainy conditions can also lead to increased accumulation of pollutants in water bodies (US EPA, 2002). As much as 3000 ml per sample were taken from each sampling location. The samples were collected by inserting the mouth of the sample bottle from the surface of the water to half depth, and then the sample bottle is raised until the water is full, and the bottle is then closed. The sample bottles are put in a cool box that has been filled with ice cubes and then directly analysed in the laboratory. The parameters measured are total suspended solid (TSS), which was measured by gravimetric (Standard Method 2540D), dissolved oxygen (DO), which was measured by DO meters (ASTM D888), chemical oxygen demand (COD), which was measured by the closed reflux method (Standard Method 5220C), biological oxygen demand (BOD), which was measured by the Winkler method (Standard Methods: 5210B), and Nitrate-N (NO_3-N), which was measured using a spectrophotometer (Standard Method 4500-NO3).

Air Quality Sampling

Ambient quality collection was carried out by measuring hydrogen sulfide (H_2S) gas at locations around the landfill. There are six sampling points for data collection for H_2S (Figure 1). H_2S determination was done using the methylene blue method (APHA 4500-S2). To produce representative air quality, measurements are not taken during the rainy season as the desired water quality and air quality must provide related results and produce a unified representative data.

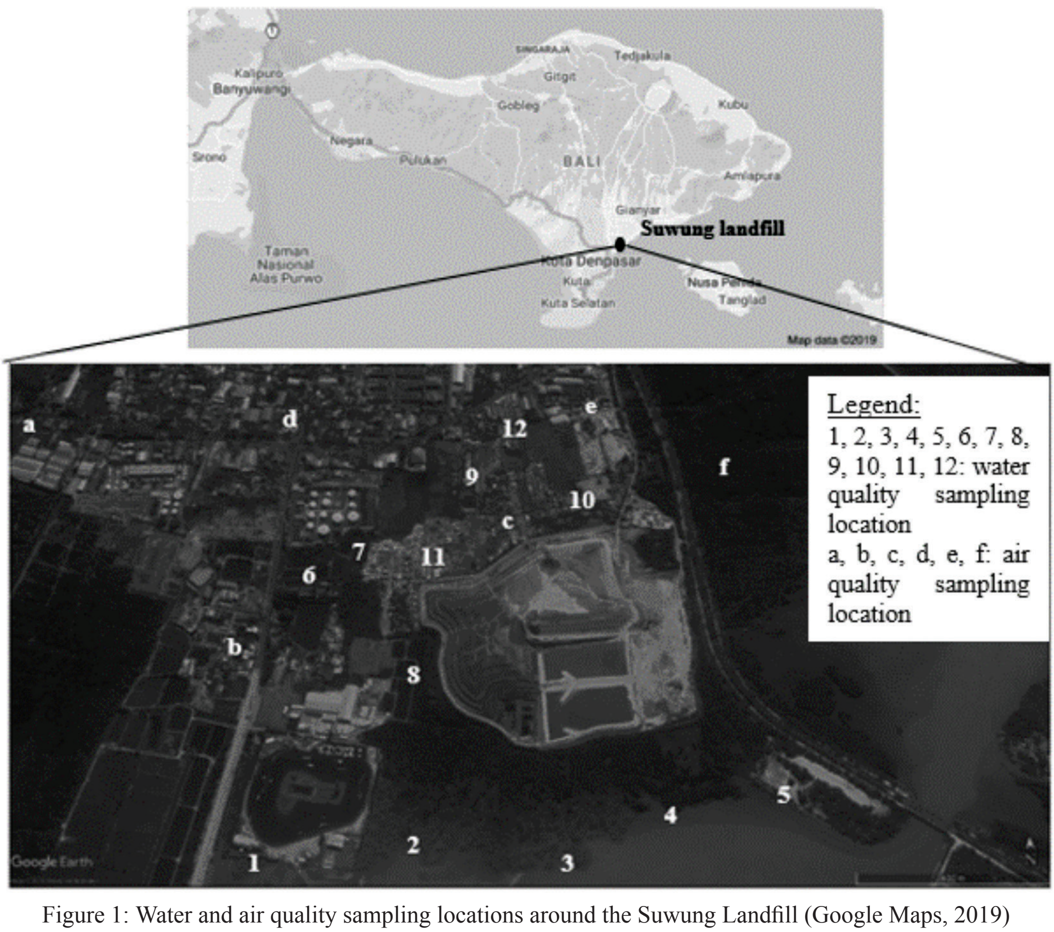

Figure 1: Water and air quality sampling locations around the Suwung Landfill (Google Maps, 2019)

Water Quality Index

The results obtained from the analysis were compared in a comparative descriptive analysis and the Water Quality Index (WQI) was calculated. Water quality standards were determined according to PP No. 82 of 2001 for second-class water quality standards. Determination of shallow ground water quality status using the WQI method was according to the Decree of the State Minister for the Environment No. 115 of 2003 (Table 1**)**. Data on water quality around the Suwung Landfill were calculated by the WQI using equation 1*:*

$$\mathbf{WOI} = \sqrt{\frac{(C_i/L_{ij})_M^2 + (C_i/L_{ij})_R^2}{2}} \qquad (1)$$

Notation description:
Lij = Concentration of water quality parameters stated in the water allotment standard
Cij = Concentration of water quality parameters obtained from the analysis results
WQI = WQI (Water Quality Index)
(Ci/Lij)M = The value of the maximum Ci/Lij calculation
(Ci/Lij)R = The value of the average Ci/Lij calculation

Table 1: Evaluation of water quality against IP values

WQI	Condition
0 ≤ WQI ≤ 1	Meet quality standards (good condition)
1≤ WQI ≤ 5	Slightly polluted
5 ≤ WQI_j ≤ 10	Moderately polluted
WQI j > 10	Heavily polluted

(Decree of the State Minister for the Environment No. 115 of 2003)

Data collection for Public Health

Sampling was done using the random sampling method with a questionnaire. A total of 62 respondents who live around Suwung Landfill were involved in this study. The questionnaire included items on public satisfaction with the environmental conditions, especially the quality of water bodies and ambient air. This study also summarised the number of public complaints on health and opportunities for disease.

Results and Discussion

Water Quality around the Suwung Landfill

The results of data analysis found that the overall water quality did not meet the second-class water quality standards according toRegulation PP No. 82 of 2001. Based on the TSS parameters, there were four sample points that did not meet the quality standards (Figure 1a). The two locations were surface water and estuary water areas. The quality standard for the value of TSS was 50 mg/L, and the average condition of the TSS quality was 39.5 mg/L. In certain areas, such as rivers and estuaries, wave energy is relatively small, so it does not affect the TSS distribution. Some hydro-oceanographic parameters were thought to influence the distribution of suspended material, such as waves, tides and currents (both ocean currents and arising from river flows). Anthropogenic factors from pollution also significantly affect changes in water quality (APHA, 1989).

From the results of measurements at the three observation points, it was found that the highest DO was at point 4, with a value of 5.9 mg/L, while the lowest DO was at point 1, with a value of 2.3 mg/L (Figure 2b**)**. The DO concentration within certain limits also indicated changes in water quality, as in the lower of DO concentration indicates a lower water quality. Decreased oxygen concentration will reduce the physiological activities of living things in water. DO saturation in sea water affects the respiration process of marine biota (Vuković *et al.,* 2019). Dissolved oxygen contained in seawater comes from air diffusion, phytoplankton photosynthesis processes and benthic plants. Its presence in seawater is essential for microorganisms that live in aerobic waters.

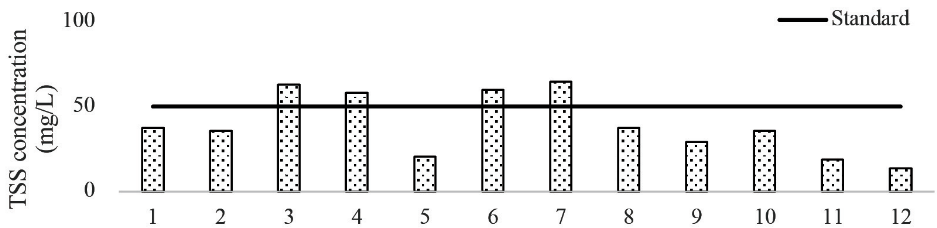

Figure 2a. Measurement results of TSS concentration

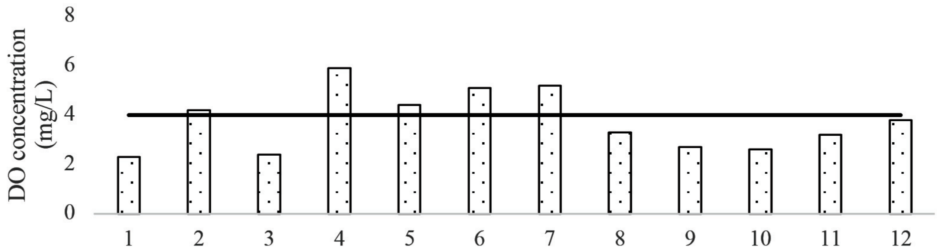

Figure 2b. Measurement results of DO concentration

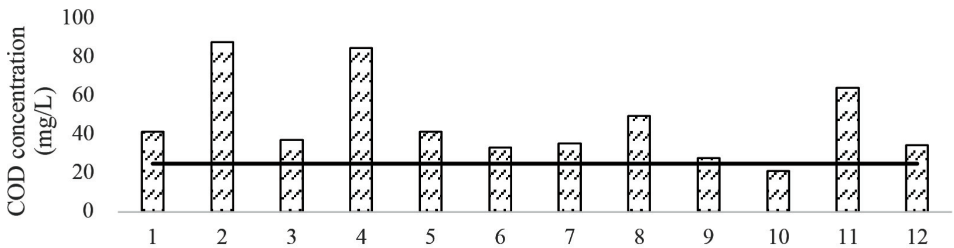

Figure 2c. Measurement results of COD concentration

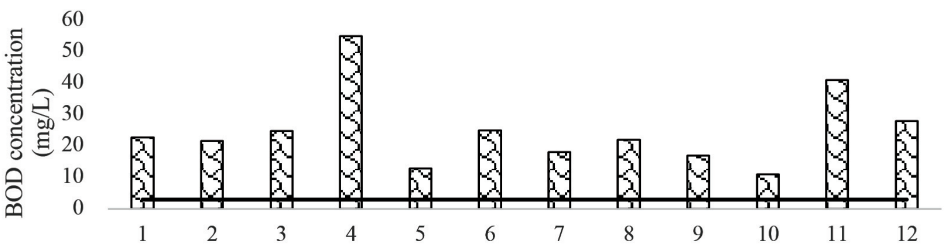

Figure 2d. Measurement results of BOD concentration

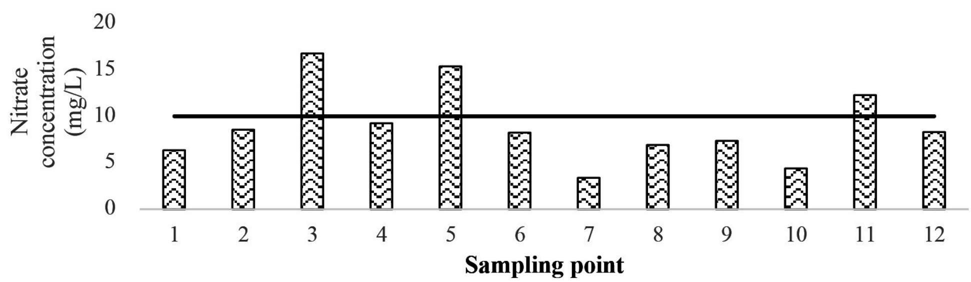

Figure 2e. Measurement results of Nitrate concentration

Figure 2: The measurement results of each pollutant concentration at the sampling points

The BOD and COD measurement results showed that almost no sampling points met the quality standard (Figure 2c and Figure 2d). The BOD provides information on fractions that are readily decomposed from organic matter that flows in water (Nguyen *et al.,* 2019). The BOD accumulation from pollutant sources will cause a pollutant burden on the ability of rivers to recover, thereby reducing the capacity of pollution loads (Jouanneau *et al.,* 2014). The COD concentration is an indicator of evaluating organic loading as pollutants in water quality.

The nutrient content in the form of nitrate indicates pollution that can potentially cause eutrophication (Nugraha, 2008; Suryawan *et al.,* 2020). Sampling points 3, 5, and 11 show nitrate parameters that did not meet quality standards (Figure 2e). This parameter also has the potential to cause an explosion of algae in the form of HAB (Harmful Algal Bloom) in the coastal area. Ambient and wastewater nutrient are also the primary important factors for algae bloom (Ali *et al.,* 2017; Apritama *et al*., 2020). Based on the results of calculations with equation 1, the WQI values are show that 10 samples are slightly polluted and two samples are moderately polluted (Table 2). However, the average for water quality around the Suwung landfill is slightly polluted.

The most important problem is managing landfill leachates with a good leachate collection system. The Ministry of Public Works' Regulation No. 03 of 2013 Appendix 3 states that the basis of landfills must be equipped with leachate collection pipes with a minimum slope of 2% towards the leachate collection and collection channels. The leachate collection pipeline system also functions as a rainwater flow collector when the land is not yet operational (still empty) to then flow into the river. Meanwhile, if the landfill is operational, the drainage pipeline to the river is closed, and the leachates are flowed to a leachate treatment plant (Mamun *et al.,* 2018).

Air Quality around the Suwung Landfill

Air quality sampling was carried out at six points in different types of areas. The direction of wind when sampling was conducted was to the north leaning to the west with an average speed of 21 km/h with a 22% humidity. The results of monitoring ambient air quality with H_2S parameters mention concentrations at four points did not meet quality standards (Table 3). H_2S can cause odour. Although H_2S levels are still below the quality standard, based on observations, these pollutants cause unpleasant odours and discomfort.

Table 2: Evaluation of water quality against WQI values

Area Sampling Type	Sampling point	WQI	Result
Coastal area	1	4,04	slightly polluted
	2	4,04	slightly polluted
	3	4,26	slightly polluted
	4	5,50	moderately polluted
	5	4,04	slightly polluted
Surface water	6	4,19	slightly polluted
	7	3,67	slightly polluted
	8	4,00	slightly polluted
	9	3,54	slightly polluted
	10	2,84	slightly polluted
Well	11	5,01	moderately polluted
	12	4,32	slightly polluted
Average		**4,12**	**slightly polluted**

Table 3: Evaluation of H_2S concentration against quality standard

Area Sampling Type	Sampling point	H_2S concentration (ppm)	Standard Deviation	H_2S quality standard (ppm)
Housing	a	0,007	**±0,004**	0,02
Housing	b	0,065	**±0,012**	
Housing	c	0,041	**±0,021**	
Roadway	d	0,056	**±0,018**	
Roadway	e	0,026	**±0,013**	
Vegetation	f	0,014	**±0,008**	

Health Complaints by the Community around the Suwung Landfill

The interviews results of community satisfaction with environmental quality can be seen in Figure 3. For water quality, 52% of the respondents said they were quite satisfied, and for air quality, 72% of respondents were dissatisfied. The immediate impact felt by the community was a decrease in ambient air quality mainly due to H_2S.

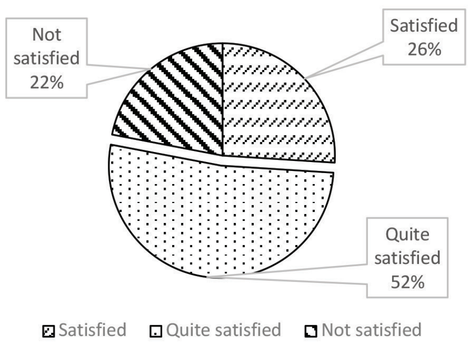

Figure 3a. Community response to water quality satisfaction

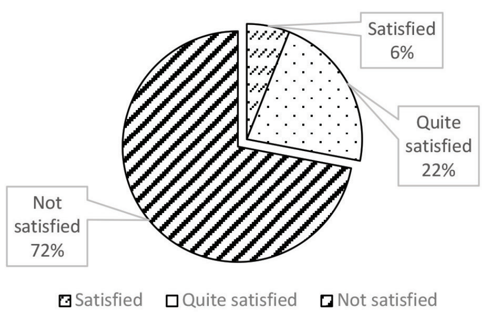

Figure 3b. Community response to air quality satisfaction

Figure 3. Diagram of community response to water and air quality satisfaction

In terms of water consumed by the community, the respondent's complaints were only focused on diarrhoeal diseases, where only 12% of the respondents complained about the disease and most of them were scavengers who work around the landfill. Diarrhoea is also one of the leading impacts, directly or indirectly, on child health (Tchobanoglous *et al.,* 1993). Toxicity tests from municipal landfill leachates have a potential impact on aquatic resources and demand (Shibata *et al.,* 2015).

In general, at concentrations of 0.0005 - 0.3 ppm, humans can easily recognise the smell of H_2S (Putri, 2018). If the concentration is found to be higher, it will cause a person to lose the ability to smell. H_2S is released from its source mainly as a gas and spreads in the air in the lower layers, close to humans. This gas can stay in the air for between 18 hours and 3 days on average (Putri, 2018). H_2S is more absorbed through inhalation than through oral exposure, and only in very small amounts through the skin (ATSDR, 2000). This gas is corrosive to metal and blackens various materials. H_2S is usually found with other toxic gases, such as methane (CH_4) and carbon dioxide (CO_2) in anaerobic solid waste degradation (Yodi *et al.,* 2020). Table 4 shows some of the complaints by the community. A total of 93.55% of the respondents felt uncomfortable with the odour caused by the operation of the Suwung landfill. Some respondents who work or become scavengers in landfills experience coughs (12.90%), throat pain (3.23%), and headaches (45.16%). The H_2S levels affect mood, daily activities, and physical symptoms of the local community around landfill areas (Heaney *et al*, 2011).

Complaints of respiratory tract irritation are similar to the research by Hartini and Kumalasari (2014) in the form of complaints of chest pain (16.2%), dry throat (10%), cough (6.7%) and shortness of breath (3.3%) in scavengers at the Semarang City Jatibarang landfill. The occurrence of respiratory tract complaints felt by officers of Super Depo Sutorejo depends on the length of time they were exposed and the level of pollutants. Other workers who were exposed to hydrogen sulfide gas experience nausea, vomiting, dizziness, dyspnea, eye and nose irritation. A worker died after several hours of exposure (Hartini and Kumalasari, 2014). Scavengers in a waste dumpsite in Pretoria, South Africa reported having back pain, headaches, diarrhoea, and shortness of breath (Nyath *et al*, 2018).

The Correlation of Public Health Results and WQI

The statistical data of the Denpasar City notes that most households already have access to clean and decent drinking water at a rate of 98.55%. The number of water supply service customers in Denpasar City is 85,136. or around 84.60% of domestic customers (BPS, 2019). The survey results mentioned that well water is the most widely used source of water in domestic activities. The quality of surface water and estuaries will indirectly cause bioaccumulation.

Based on the results, the WQI value show that 10 samples are slightly polluted and two samples are moderately polluted. The diagram of the community response in Figure 3 showed some of the complaints felt by the community. A research in 2008 revealed that the community

Table 4: Health respondent complaints around Suwung Landfill

Complaint	N	Number of respondents	%
Coughs	8		12,90
Throat pain	2		3,23
Headaches	28	62	45,16
Breathlessness	16		25,81
Uncomfortable when breathing	47		93,55

around the landfill was still using well water sources (Arbain *et al*., 2008). The Denpasar City Government study (2009) also mentioned that the community wells in the southern part of Denpasar City (including the landfill location) were already polluted. However, wells are still used as the main source of water for cooking, toiletries, and feeding livestock (Wahyutriani, 2018; Vidika *et al.,* 2017). Surface water and estuaries, which has high biodiversity and biota population, will be used by the surrounding community, especially by fishermen. The chance for biomagnification will be higher and can have an impact on public health complaints. Biomagnification occurs due to toxic substances, such as heavy metals, persistent, organic, micro pollutants, especially those attached to the suspended material (MM El-Feky *et al.,* 2019). Some respondents who work or become scavengers in landfills experience coughs (12.90%), throat pain (3.23%), and headaches (45.16%). The monitoring of water quality is important to meet the second-class water quality standards accordancing to with Regulation PP No. 82 of 2001 and to evaluate the health compliments by the local community.

Conclusions

The WQI analysis showed that three samples met the quality standard, seven samples were slightly polluted, and two samples were moderately polluted. The average WQI quality is 4.12, which means that the water quality around the landfill is slightly polluted. Landfill leachates must be well controlled in accordance with applicable regulations so that the water quality around the landfill is not polluted. A total of 93.55% of the respondents felt uncomfortable with the odour caused by the operation of the Suwung landfill. Some respondents who work or become scavengers in landfills experience coughs (12.90%), throat pain (3.23%), and headaches (45.16%). The health risks are associated with exposure to health hazards through water and he effectiveness of approaches. Based on the correlation between WQI and health complaints, it is found that all environmental quality index have a positive impact on the fulfillment of basic needs. This means that if there is an increase in air quality, water quality, biodiversity, public health, and environmental health, the fulfillment of basic needs will increase.

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