Evaluation of Rainwater Harvesting System On Skin-Deo Factory Cikarang

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Abstract. The purpose of this study is to determine the effectiveness of the construction of rain water harvesting buildings or rain water harvesting with a reservoir system or the construction of a ground water tank related to the distribution system of the raw water network itself, the operation and maintenance of the water and to test the quality of the water collected in the building ground water tank. Research conducted using quantitative descriptive methods by collecting data related to the dimensions of Rainwater Harvesting (PAH), data on the roof area of water catching the whole section that captures water to the ground water tank, rainfall data from 2007 to 2017 as its inflow value, and raw water needs of usage in the factory area. From the results of this study it was found that the potential for groundwater savings in a period of 3 years was 45.3%, the water quality from the results of laboratory tests, and physical tests of rainwater were included in the first class criteria of water quality whose designation could be used for raw water drink, the water distribution system used is the down feed system, the water treatment used (filtering of solid material, siltation, absorption). However, in the factory area itself the water is only limited to being used for production operations, including bathroom needs, gardening, cooling tower and certainly to reduce runoff caused by rainwater itself. The conclusion of this study is that the expected design criteria are in accordance with current needs and can meet existing needs and are able to accommodate rainfall runoff.

Keywords: Evaluation, Rainwater Harvesting, Skin-Deo

1 Introduction

Water is one of the main needs for humans and healthy plant growth.. Water supply security has become a major concern worldwide due to ever-increasing water demand resulting from population growth, rapid urbanisation and industrial development. Moreover availbility of water resources is decreasing due to water pollution around the world as consequence of increasing urbanisation and industrialisation [1].

Good water sources from springs, rivers, wells, lakes, seas and rainwater are owned by so many and extensive in Indonesia. In general, abundant water in Indonesia, especially those sourced from rain water with an average rainfall of 2000 - 4000 mm / year means that if rain water is "collected" for one year it will be as high as 2-4 meters. Therefore, there are several efforts that can be done, namely by carrying out a rain harvesting system. Even in the international world is now an important part of the global agenda of environmental water resources management in order to tackle water inequality in the rainy and dry season (lack of water), a source of shortages of clean water supply to the world's population, and prevention of floods and droughts.

In general, risk of water inadequacy is lesser in developed countries than developing countries [2]. But supplying adequate water to the cities requires a notable amount of other

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resources such as energy and infrastructure. Hence even countries with good water balance conditions between demand and available water resources are continuously evaluating alternatives (e.g. reduction in water consumption and identification of new sources to supply water) to optimise water management. One of the most common and adaptable alternative sources is the rainwater for use in the buildings, in particular residential buildings [3],[4], [5].

Rainwater is used as either the principal or a supplementary source of water to the main water supply system in a residential building [6]. One of the existing water conservation methods that already exist for households or other needs is rainwater harvesting, which is a source of collecting, storing rainwater and utilizing existing runoff water. Rainwater harvesting is a method of catching or collecting and utilizing rainwater optimally. Rain harvesting can be defined as an effort to collect rain water for clean water needs and or absorb rainwater into the ground to cope with floods and drought. Most techniques for collecting water usually use large water sources such as rivers and groundwater (eg wells and irrigation systems), and require large-scale investment. But in many countries of the world, various small-scale and simple methods have been developed to capture and collect runoff water used for a variety of productive purposes both for households or for other needs such as industry. If this surface runoff is left alone it can cause soil erosion, and this run-off flood / standing water can be harvested and utilized.

2 Literatur Review

2.1 Rainwater Harvesting

Rainwater harvesting is an activity to collect rainwater locally and store it through various technologies, for future use to meet the demands of human consumption or human activities [7]. Another definition of rainwater harvesting is the collection, storage and distribution of rainwater from the roof, for use inside and outside the home or business. Sustainable drainage system is a technique used in managing rainwater that falls on the surface of roofs and other surfaces through a series of actions, whose main purpose is to control the flow rate and volume of surface runoff to reduce the risk of flooding and water pollution and in order to reduce pressure on the drainage network (sewerage network) and in order to improve biodiversity and local convenience (localamenity). The basic concept of developing sustainable drainage is to improve water use, minimize losses and improve and conserve the environment. Thus, the main priority of activities must still be aimed at managing runoff [7].

Rainfall is the main variabel of interest for a RWHS system [2], especially temporal variability of rainfall is the critical governing factor in its performance. Design of RWHS is generally concerned with determining the optimum tank size to ensure water supply for the anticipated use. An oversized tank is loss of resources (e.g. energy, time, and money); on the other hand and undersized tank will not be able to fulfil the required water de- mand. Therefore, needs of households and the characteristics of the geographical locations should be considered when designing a RWHS. Many studies are available in literature on the benefits, design, performance and feasibility analysis of a RWHS, for example in Germany [8], in China [9], in Brazil [10], in USA [11], [12], in Italy [13], in Virginia [14], in Mexico [15] and in Australia [16[, [17].

2.2 Inflow

The main equations used, including; surface runoff discharge using the Rational Method with equations. Inflow (input) is the volume of rainwater that falls on the roof of a building and is accommodated. The formula used to obtain inflow is a rational method based on the following equation:

$$Q = 0,287.C.I. \quad (1)$$

Q = runoff discharge plan ($m^{3/}s$) C= runoff coefficient
I = rain intensity at the same duration as the concentration time and a certain rain return period (mm/h)
A = area of drainage (hectare)

Runoff coefficient (C) is determined using the Weighted Runoff Coefficient formula or C equivalent, with the equation [18].

2.3 Calculation of Potential Amount of Water that Can be Harvested

The potential of the water harvesting potential from a roof building can be known through simple calculations [19], as follows:
harvestable water = Area x rainfall x runoff coefficient. In the illustration in the figure below for a 200 m^2 rain catchment area, 500 mm annual rainfall, the amount of water that can be harvested is determined as follows:

a) With an area of = 200 m^2 and the amount of annual rainfall = 500 mm, the volume of rain water that falls in the area is : 20.000 dm^2 x 5 dm = 100.000
b) Assuming that only 80% of the total rain can be harvested (20% is lost due to evaporation or leakage), then the volume that can be harvested: 100.000 x 0,8 = 80.000 l/y
   by using the following equation:

$$V = R \times A \times kV \quad (2)$$

V =the volume of water accommodated (m^3) R = rainfall (m)
A =catchment area (m^2)
k =water runoff coeficient

3 Research Method

This research method is a way to obtain relevant data to evaluate and also identify the concept of design criteria and the application of rainwater harvesting technology in the Skin Deo factory and also evaluating the system of rainwater harvesting, which already exists to accommodate rainwater and runoff discharge. In this study primary data collection will be sourced from surveys and also secondary data collected from literature studies and related agencies. The survey conducted in this study is obervasation conducted in the environment of Skin Deo Cikarang factory by observing the physical condition of the granary, the catchment area and the need for raw water. The analytical method used in this research is quantitative descriptive method. This method is in the form of data collection, data analysis, and interpretation of the results of the analysis to obtain information for conclusions.

4 Result And Discussion

From the research results of the rainwater harvesting system, this skin deo factory use a Cistern / Catchment system by utilizing the roof media to catch / harvest rainwater directly such as gutters, downspout pipes, first rainwater pouring channels (first flush diverters) and rainwater collection units (Figure.1).

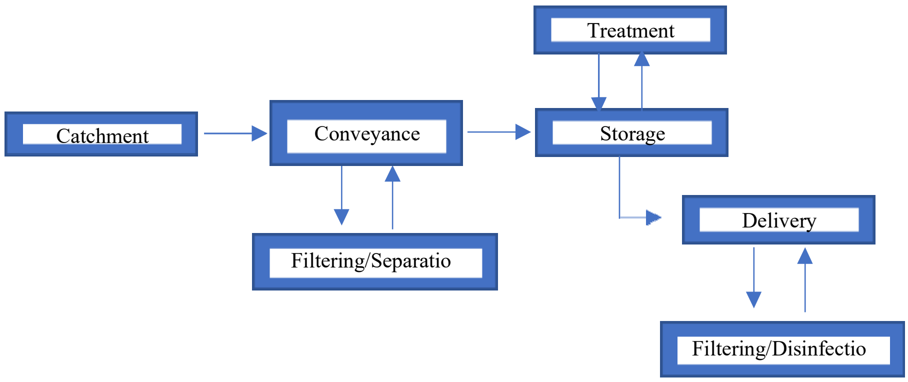


Fig.1. harvest rainwater directly

4.1 Calculation Analysis

Calculation analysis is done through the processing of raw data obtained from the Office of Public Spatial Planning (PUPR) of Bekasi City, Perum Jasa Tirta II of Bekasi City from monitoring rainfall data. By calculating or determining the average rainfall:

Table 1. Data on Maximum Rainfall of Bekasi Dam Station Rainfall Data for the Last 10 Years (2007-2017).

Year	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	CH Ma (Xi)
2007	290.00	732.00	152.00	361.00	97.00	92.00	2.00	13.00	6.00	88.00	202.00	279.00	732.00
2008	108.00	585.00	258.00	169.00	40.00	37.00	12.00	20.00	31.00	65.00	110.00	103.00	585.00
2009	198.00	302.00	144.00	2.00	89.00	65.00	5.00	22.50	54.00	22.00	164.00	227.00	302.00
2010	318.00	265.00	130.00	70.00	86.00	102.00	19.00	51.00	165.00	28.00	120.00	49.00	318.00
2011	74.00	52.00	35.00	81.00	155.00	29.00	3.00	6.00	6.00	25.00	38.00	186.00	186.00
2012	209.00	298.00	168.00	120.00	18.00	18.00	0.00	0.00	22.00	0.00	196.00	303.00	303.00
2013	447.00	256.00	124.00	60.00	219.00	87.00	272.00	32.00	64.00	99.00	116.00	440.00	447.00
2014	827.00	408.00	218.00	131.00	91.00	108.00	55.00	5.00	5.00	0.00	118.00	120.00	827.00
2015	197.00	332.00	139.00	101.00	47.00	8.00	0.00	0.00	5.00	0.00	53.00	115.00	332.00
2016	106.00	187.00	119.00	64.00	194.00	72.00	116.00	127.00	9.00	243.00	106.00	166.00	243.00
2017	151.00	103.00	30.00	55.00	90.00	40.00	0.00	0.00	0.00	39.00	82.00	193.00	193.00

Source: Division 1 of Perum Jasa Tirta II, Bekasi City

Table 2. Data on Maximum Rainfall of Setu Station Rainfall
Data for the Last 10 Years (2007-2017)

Year	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	CH Ma (Xi)
2007	89.00	555.00	120.00	263.00	168.00	77.00	16.00	0.00	8.00	71.00	112.00	319.00	555.00
2008	102.00	507.00	187.00	302.00	116.00	9.00	6.00	6.00	0.00	86.00	118.00	46.00	507.00
2009	198.00	128.00	183.00	26.00	45.00	84.00	35.00	56.00	63.00	0.00	150.00	226.00	226.00
2010	295.00	459.00	338.00	123.00	252.00	228.00	105.00	199.00	602.00	730.00	222.00	280.00	730.00
2011	172.00	202.00	84.00	374.00	189.00	20.50	9.50	19.00	19.00	130.00	150.00	258.00	374.00
2012	320.00	226.00	186.00	310.00	40.00	132.00	16.50	0.00	53.00	42.00	448.00	453.00	453.00
2013	449.00	247.00	305.00	58.00	230.00	50.00	259.00	37.00	0.00	123.00	178.00	392.00	449.00
2014	786.00	384.00	217.00	322.00	308.00	191.00	184.00	70.50	30.50	136.00	247.00	228.00	786.00
2015	248.00	354.00	139.00	101.00	47.00	8.00	0.00	0.00	9.00	0.00	53.00	116.00	354.00
2016	224.00	371.00	310.00	254.00	195.00	186.00	155.00	174.00	307.00	197.00	181.00	133.00	371.00
2017	197.00	332.00	139.00	101.00	47.00	8.00	0.00	0.00	5.00	0.00	53.00	115.00	332.00

Tabel 3. Data on Maximum Rainfall of Cibitung Station Rainfall
Data for the Last 10 Years (2007-2017)

Year	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	CH Ma (Xi)
2007	500.00	724.00	156.00	289.00	89.90	104.00	0.00	19.90	1.20	104.00	110.00	321.00	724.00
2008	124.00	582.00	149.00	124.00	49.00	30.00	5.00	8.00	0.00	75.00	44.00	74.00	582.00
2009	304.00	233.00	101.00	75.00	48.00	80.40	0.00	32.20	3.00	0.00	96.50	177.00	304.00
2010	442.00	223.00	70.00	116.00	40.00	147.00	10.00	69.00	2002.00	349.00	150.00	118.00	2002.00
2011	151.00	103.00	30.00	55.00	90.00	40.00	0.00	0.00	0.00	39.00	82.00	193.00	193.00
2012	355.00	130.00	229.00	270.00	32.00	60.00	0.00	0.00	0.00	0.00	80.00	220.00	355.00
2013	637.00	232.00	89.00	168.00	224.00	70.00	89.00	14.00	7.00	58.00	0.00	88.00	637.00
2014	317.00	494.00	65.00	151.00	173.00	147.00	147.00	20.00	0.00	0.00	152.00	127.00	494.00
2015	257.00	263.00	100.00	114.00	26.00	17.00	0.00	0.00	0.00	0.00	35.00	86.00	263.00
2016	13.00	18.00	19.00	9.00	0.00	0.00	0.00	0.00	0.00	5.00	11.00	14.00	19.00
2017	169.00	394.00	79.00	111.00	103.00	82.00	138.00	164.00	221.00	256.00	292.00	14.00	394.00

Source: Division 1 of Perum Jasa Tirta II, Bekasi City

The comparison between raw water demand and rainwater supply is obtained from the merging of the calculated data with the Analysis data

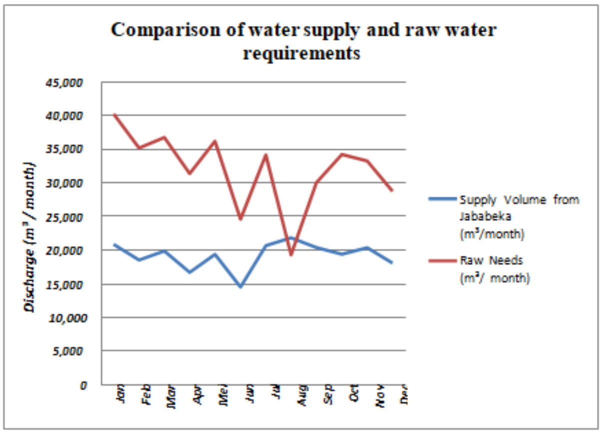


Fig.2. Comparison of water supply and raw water requirements

4.2 Hidrology

Rainfall data in this study uses monthly rainfall data from 3 rainfall recording stations with a period of 10 years from 2007 to 2017. These data were obtained from Division 1 of Perum Jasa Tirta II Bekasi City. The data of the three stations used are the closest rainfall stations to the location of the study, namely the Bekasi Dam Rainfall Station, Setu Rainfall Station and Cibitung Rainfall Station. The following is the rainfall data, which is: Calculation of the Rain Plan Logarithm. Rumus:

Log RT = logXi Rata2 + (K*STDEV logXi) (3)

r =(R24/24)*(24/t)^(2/3) (4)

RT =POWER(10;..) (5)

Table 4. Rainfall Analysis (Log Person)

Year	Xi	log Xi	log Xi-log X	(log Xi-log X)^2	(log Xi-log X)^3
2007	724	2.8597	0.3109	0.0967	0.0301
2008	582	2.7649	0.2161	0.0467	0.0101
2009	304	2.4829	-0.0659	0.0043	-0.0003
2010	2002	3.3015	0.7527	0.5665	0.4264
2011	193	2.2856	-0.2632	0.0693	-0.0182
2012	355	2.5502	0.0014	0	0
2013	637	2.8041	0.2553	0.0652	0.0166
2014	494	2.6937	0.1449	0.021	0.003
2015	263	2.42	-0.1288	0.0166	-0.0021
2016	19	1.2788	-1.2701	1.613	-2.0486
2017	394	2.5955	0.0467	0.0022	0.0001
TOTAL		**28.0369**			**-1.583**

4.3 Calculation of Rainwater Discharge That Can be Harvested

Layout map of Skin Deo Factory Cikarang is used to determine the type of building roof to determine runoff coefficient (A) and catchment area in the form of a roof. The coefficient (k), rainfall (R) and catchment area that are known are used to calculate the volume of collected rainwater, with the following equation.

V = R .A. K (6)

Rainwater Discharge, the method used to calculate rainwater discharge in a channels in this study is the rational method of USSCS (1973). The general form of this equation is as follows [18]:

Q = Qah. C. I. A. (7)

Q =flood discharge plan Qah = 0,00278 C I A m^3/s
C =run off coeficient (industrial weight area = 0,60-0,90) I = rain intensity for a constant time (mm/h)
A = catchment area of the roof (ha)

Q = Qah. C. I. A

= 0.00278 x 0,90 x 26,137 x 42,558

= 0,0042558 ha

= 0,0223 m^3/s (total runoff discharge)

Table 5. Calculation of PAH capacity for Cibitung Rain Station with a Total Raw Water Need of 70%

Month	Number of days	Average (mm)	Roof Area (m^2)	Total Water Needs (m^3/hr)	Koef Run off	Water supply Rain (m^3)	Total Water Needs 100% (m^3)	Total Water Needs 70% (m^3)	Deficiency (m^3)	Advantages (m^3)	Explanation
A	B	C	D	E	F	G	H	I	J	K	1
Jan	31	169	42.558	20.883	0.9	799.865	647.373	453.161	317.213	222.049	
Feb	28	394	42.558	18.542	0.9	710.199	519.176	363.423	254.396	178.077	
Mar	31	79	42.558	19.868	0.9	760.988	615.908	431.136	301.795	211.256	e = Obtained
Apr	30	111	42.558	16.704	0.9	639.8	501.12	350.784	245.549	171.884	from the
May	31	103	42.558	19.391	0.9	742.718	601.121	420.785	294.549	206.185	Table
Jun	30	82	42.558	14.52	0.9	556.148	435.6	304.92	213.444	149.411	g = c x d x f
Jul	31	138	42.558	20.656	0.9	791.17	640.336	448.235	313.765	219.635	h = b x e
Aug	31	164	42.558	21.844	0.9	836.673	677.164	474.015	331.81	232.267	j = h > g k =
Sep	30	221	42.558	20.395	0.9	781.173	611.85	428.295	299.807	209.865	g > h
Oct	31	256	42.558	19.411	0.9	743.484	601.741	421.219	294.853	206.397	
Nov	30	292	42.558	20.369	0.9	780.178	611.07	427.749	299.424	209.597	
Dec	31	14	42.558	18.092	0.9	692.963	560.852	392.596	274.817	192.372	

4.4 Storage Capacity Of Rainwater Harvesting

Tank Volume Calculation for Rainwater Harvesting, or Rainwater Harvesters in Skin Deo Factory Cikarang Factory Skin Deo Factory has a shape like Figure 4.3. The shape of the building Harvesting rainwater with the building volume in the form of a trapezoid, so here I use the trapezoid formula where the size is in accordance with the existing in the picture.

a = 6400 + 3500 + 3500 mm

= 13400 mm □ 13,4 m

b = 6400 mm □ 6,4 m t

= 3500 mm □ 3,5 m l = 20000 mm □ 20 m

V = 20 x 9,9 x 3

= 693 m^3

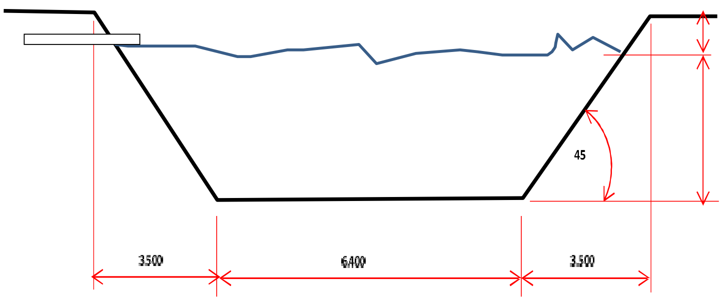


Fig. 3. Rainwater Harvesting Building Shape

$$V\ tank = \frac{V\ rainy\ season\ supply}{\square}$$

$$= \frac{500+724+156+289+104+110+321}{8}$$

$$= 288{,}3\ m^3 = 300\ m^3$$

After calculating the capacity of the rainwater harvesting tank, the monthly water balance can be calculated as in the following Table 10.

Table 6. Water Balance Reservoir

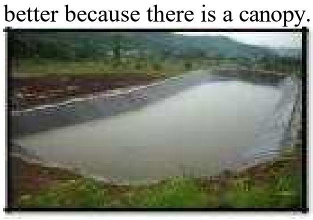
Month	Supply (m3)	Initial (m3)	First Annual Requirement (m3)	Final (m3)
Jan	169.0	143	250	62.0
Feb	394.0	430	250	574.0
Mar	79.0	362	250	191.0
Apr	111.0	261	250	122.0
May	103.0	327	250	180.0
Jun	82.0	263	250	95.0
Jul	138.0	151	250	39.0
Aug	164.0	904	250	818.0
Sept	221.0	474	250	445.0
Oct	256.0	589	250	595.0
Nov	292.0	519	250	561.0
Dec	14.0	346	250	110.0
	2023		3000	

4.4 Evaluation of Rainwater Harvesting Planning Results

Results of the evaluation of rainwater harvesting planning at Skin Deo Factory Cikarang, Tbk. with a 600 m³ capacity plan can be shown in Table 11.

Table 7. Rainwater Harvesting Planning At Skin Deo Factory Cikarang

Plan	Actual	Results
Design criteria capacity 600 m^3.	From the calculation data for the needs of this shelter is equal to $288.3\ m^3 = 300\ m^3$. Depending on the needs by looking at the actual conditions using calculations,	In accordance with the needs of the conditions in the area and enough to covered the needs.
	with the current actual condition 1⁄2 of the maximum capacity can still be covered.	

Plan	Actual	Results
Actual Conditions Shelter conditions use ponds covered with a roof. 	In accordance with the Subagyo (2012), related to the water utilization system by using a reservoir system but here it is better because there is a canopy. 	In accordance with the theory and the needs has planned.
In accordance with the initial purpose to reduce the occurrence of floods around the area of the Skin Deo Factory Cikarang, Tbk. due to rainwater runoff.	Conditions in the field are based on information from primary interview data and secondary data, the last 3 years of standing water in the area has been reduced and almost completely does not occur.	In accordance with initial planning.
The characteristics of rain water, rain water is one of the gray water that can be utilized for operational production needs. Rainwater has acidic properties based on the results of pH checking (pH: 6.0 -6.6).	For pH measurement results in the rainwater area in the Cikarang Skin Deo Factory, Tbk is : 6.0-6.7.	Still in accordance with the initial planning and after processing with RO3 the following pH data was obtained : 5.5-7.5.

5 Conclusion

There are several conclusions that we can draw from the results of "Rainwater Harvesting as an alternative in Water Resources Management as follows:

a) With a catchment area of 42,558 m^2 obtained Debit = 0.0223 m^3 / s with Effective Tank Volume = 288.3 m3 ≈ 300 m^3,

b) In the form of a trapezoidal reservoir with the design according to Figure 4.3, the volume of water collected in the reservoir is in accordance with the design criteria,

c) The amount of rainwater that can be collected on the roof of the factory with initial storage tank capacity of 600 m^3 with actual capacity, currently the holding tank only holds 288.3 m^3 = 300 m^3 which can meet the total needs of 61% per month and can save water use 39% monthly,

d) The initial criteria for collecting rainwater is 600 m^3 in design. Placement of underground rainwater harvesting reservoirs with a ground water system and with the help of pumps and temporary storage tanks, water can be channeled above and utilized for the needs of town water that was previously through the process of RO (Reverse

Osmosis),

e) Utilization of rainwater harvesting within factory very helpful in the operational process where is used to supply cooling towers in the packing hall and amenitis / bathroom areas,

f) In Harvesting rainwater in Skin Deo Factory Cikarang, Tbk., the water threat that is used is very simple, namely: Filtering of solid material, Sedimentation of mud, Absorption and then processed using the RO system.

g) rainwater obtained by filtering results in this designed technology, the pH value and parameters for the standard can even be used for drinking water and can be utilized without exceeding the permitted levels based on Group B / Category 1 standards set by the Ministry of Health.

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