Modeling the Spread of Infectious Diseases after Flood in the Rainy Season in South Bandung, Indonesia

Nuraeni, Shimaditya
Arai, Takeshi
Department of Industrial Administration, Faculty of Science and Technology
Tokyo University of Science
2641 Yamazaki, Noda-shi, Chiba-ken 278-8510
Tel : 04-7124-1501
shimaditya@sbm-itb.ac.id, tarai@rs.noda.tus.ac.jp

ABSTRACT

Flood is the most frequent natural disaster in Indonesia. However mitigation program is still not effective, especially the indirect impact related to human health. The limitation on clean water, sanitation facilities, cold temperature and the quality of health surveillance might trigger the outbreak of infectious disease and also ineffective the mitigation policy. Therefore in this paper we use System Dynamic that modeled the two diseases that mostly emerge during rainy season, diarrhea and acute-respiratory-infections (ARI) to give insight and feasible policy to mitigate and control the potential outbreak of infectious disease

Keywords : diarrhea, acute-respiratory-infection (ARI), system dynamics

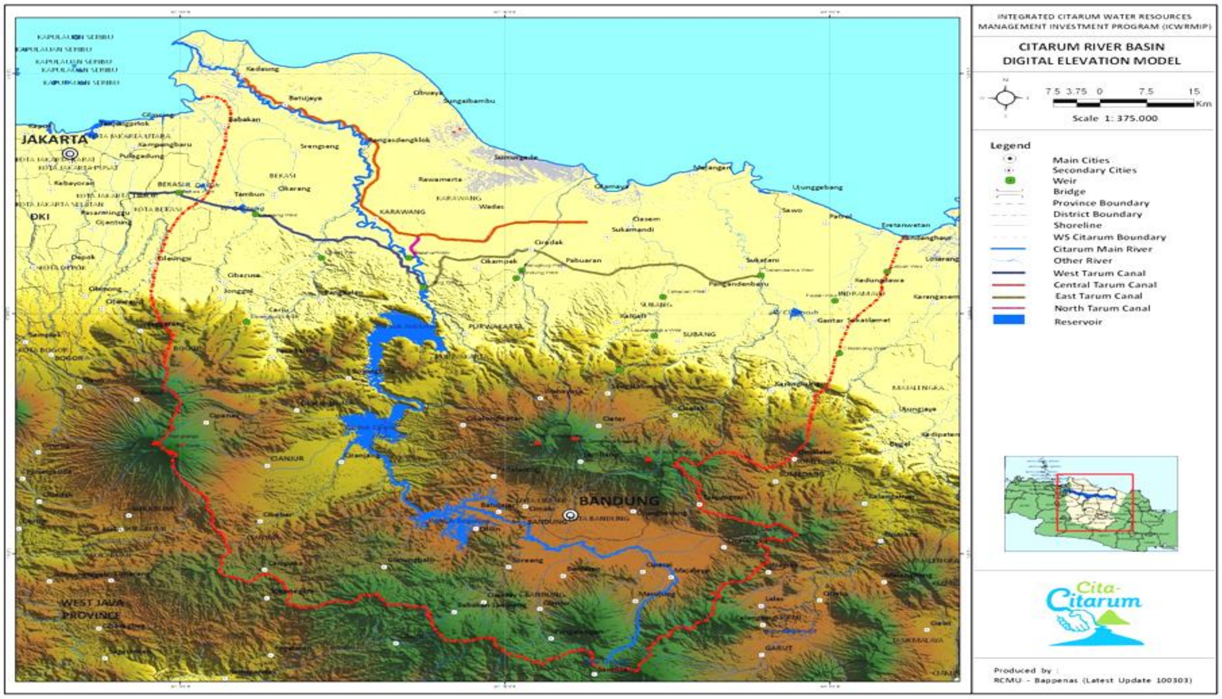
INTRODUCTION

Figure 1. Map of Indonesia

Indonesia, a country in Southeast Asia located in equatorial, has 5,590 main river with 600 of them are potentially prone to floods. The average precipitation is 147 mm per month. With the significant change of rain precipitation because of climate change, the number and frequency of rivers that potentially flood increase. Even though the rain consequently causes overflowing in the surface water, human activities and changes of land uses often make the situation worse.

More than 58% of Indonesian people live in Java Island with 43% of them stay in West Java and make it the most populous province in Indonesia. There is one main river in West Java Province, The Citarum River, flows through several cities (one of them is Bandung city). It runs three dynamos for hydropower electricity in three dams, provides water for industries and 21.3 million residents and irrigates 390,000 paddy fields.

Figure 2. Citarum River Basin



Source : ICWMRIP

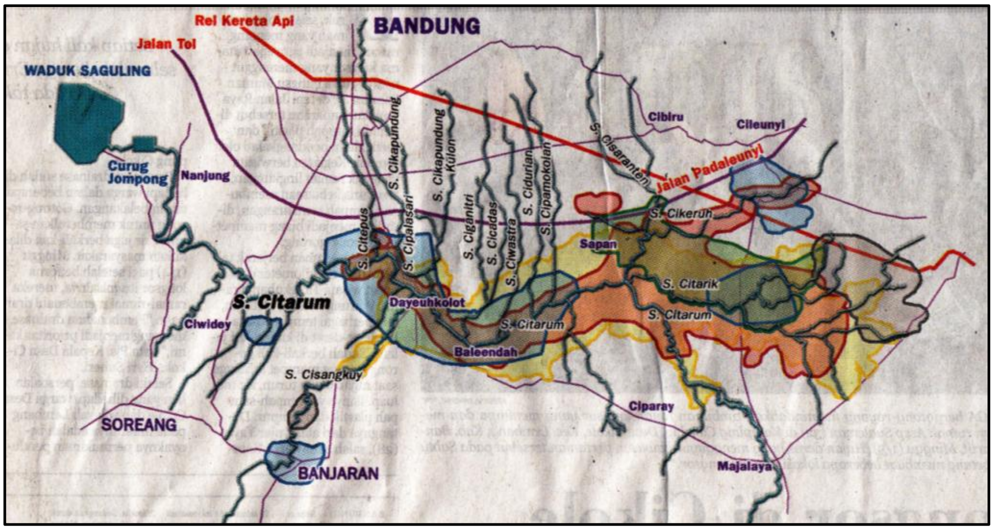
The Citarum River also is prone to flood. The flood history started in 1986 when there was land conversion for urban development[1]. At that time, the water inundated 7.450 ha area, sank almost 10 villages and 10 sub-district including Baleendah, Buahbatu, Dayeuhkolot, Majalaya, Rancaekek, Banjaran, Pameungpeuk subdistrict. Risking 68,635 people and forced 38,672 of them to evacuate. After the normalization process, in 1994 the inundation area was decrease to 5,100 ha, and continued to decrease until 3,200 ha in 2001. In 2003, after a long dry season, the inundation area caused by Citarum River was only 820 ha. But, in 2005 the inundation area then moved to Baleendah and Dayeuhkolot sub-district (Figure. 3).

At the beginning of 2010, the water from the Citarum River sank 4.474 houses in South Bandung and forces 2,915 people from Baleendah and Dayeuhkolot sub-district to evacuate[2]. This worst flood noted for the last two decades, also made the transportation to South Bandung and 17 textile industries temporarily paralyzed, risking 50,000 workers with potential loss of 20 billion rupiahs, and sank 3,109 ha paddy fields with potential loss 28 billion rupiahs. This situation continued almost three months.

Figure 3. Inundation Area of Citarum River

[1] In 1978, 65% of Bandung area was covered by buildings and residences. In 1981 the covered area increased to 85.6% and becoming 90% in 1986. The catchment area in north Bandung has been exploited for residences. So, less than 10% of open area that can absorb the water is left when the rainy season comes.

[2] This number is taken from Indonesian Red-Cross (recorded on19/02/ 2010) because there are several versions on the amount of houses and refugees. ANTARA (24/3/ 2010) reported there are 1500 houses sank and 4000 people have to evacuate. Surya Online (25/3/2010) reported there are 7960 houses sank and 16037 people have to evacuate. But for the simulation, the amount of affected population is taken from Department of Health in South Bandung regency.



Inundate area in 1986	Inundate area in 2003
Inundate area in 1994	Inundate area in 2005
Inundate area in 2001	

Source : *Pikiran Rakyat* Newspaper. Sunday, 8th May 2011

Although there was no victims, many workers were not able to go to work, the school-aged children could not go to school, and limited access to clean both water and food as well as cold-temperature might trigger the several potential infectious diseases as the surveillance on the evacuation site reported there are many of the refugees get diarrhea, acute respiratory infection (ARI) and experiencing skin itches.

According to Smith K et al (1998), there are direct and indirect losses caused by the flood, one of the direct intangible aspect are ill-health and water-borne disease. At short term, the impact of floods on the transmission of communicable diseases is limited, but an increased risk for water, vector-borne diseases, and diseases associated with crowding definitely exists (WHO, 2006). Diarrhea, hepatitis A and E, and leptospirosis are diseases related with contaminated water. Measles and acute respiratory infection (ARI) are diseases associated with crowding. Even flood water may wash away existing breeding site of mosquitoes, but the standing-water caused by it can create new breeding sites. That situation may trigger the vector-borne diseases such as malaria and dengue.

Based on the previous experiences, the primary problem related to the flood disaster and probably many other natural disasters in Indonesia is lower performance of disaster management. Emphasis on only the post-disaster treatments instead of the prevention or mitigation plan, and unstandardize reports on the number of victims, refugees and their conditions might made the recovery process slow.

As mentioned in Indonesia’s Mitigation Plan 2010-2014, related to the direct intangible impact of natural disaster loss which is health aspect, there are 21 priority diseases which should be mitigated because they potentially become epidemic. The top five diseases are: acute diarrhea, malaria, dengue-fever suspect, pneumonia and bloody diarrhea.

The Government response related to the flood in South Bandung is try to normalize the river again, hopefully the inundation area is decrease and the flood will not as frequent as it used to be. However with the complicated procedures and bureaucracy, there is no assurance when the project will be started. Even if the normalization starts in 2011, the process needs at least two years of operation. So the houses in South Bandung in the next two year are going to be inundated by flood.

Therefore this paper tries to propose a decision support system for decision makers (DMs) related to the flood phenomena in South Bandung. System Dynamics (SD) as a tool is used to model the dynamic of diarrhea and ARI in both areas in South Bandung. Then, some scenario is developed to see the efficacy of the interventions.

TARGETED AREA – SOUTH BANDUNG

Bandung is the capital of West Java province that consist of four areas : North Bandung, Bandung city, East Bandung (Sumedang) and Bandung Selatan (Figure 4). Since 2007, West Bandung was established juridically and make South Bandung, now, consist of 31 sub-districts (Figure 5) with 3,172, 860 populations.

Figure 4. Map of Bandung

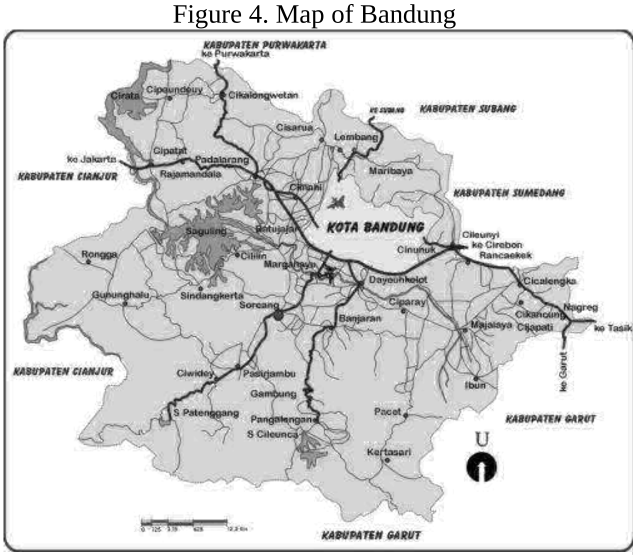
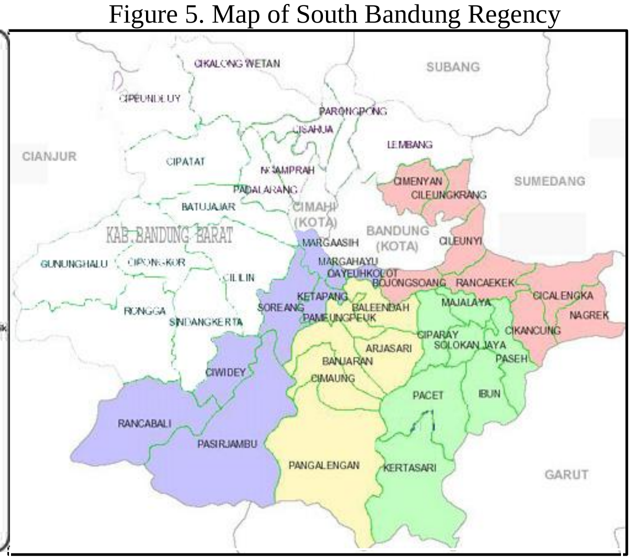


Figure 5. Map of South Bandung Regency



Source : www.bandungkab.go.id

When the flood hit South Bandung in 2010, there were six sub-districts that inundated and affected by it. The most houses inundated by flood are located in Baleendah and Dayeuhkolot. With the average person per house in Baleendah and Dayeuhkolot[3], then the amount of people that affected and should to evacuate are 76,410 and 23,308. Based on the interview with Regional Disaster Management Department (*Badan Penanggulangan Bencana Daerah-BPBD)*, the gap between the amount of people who evacuate and the one that should be evacuate because

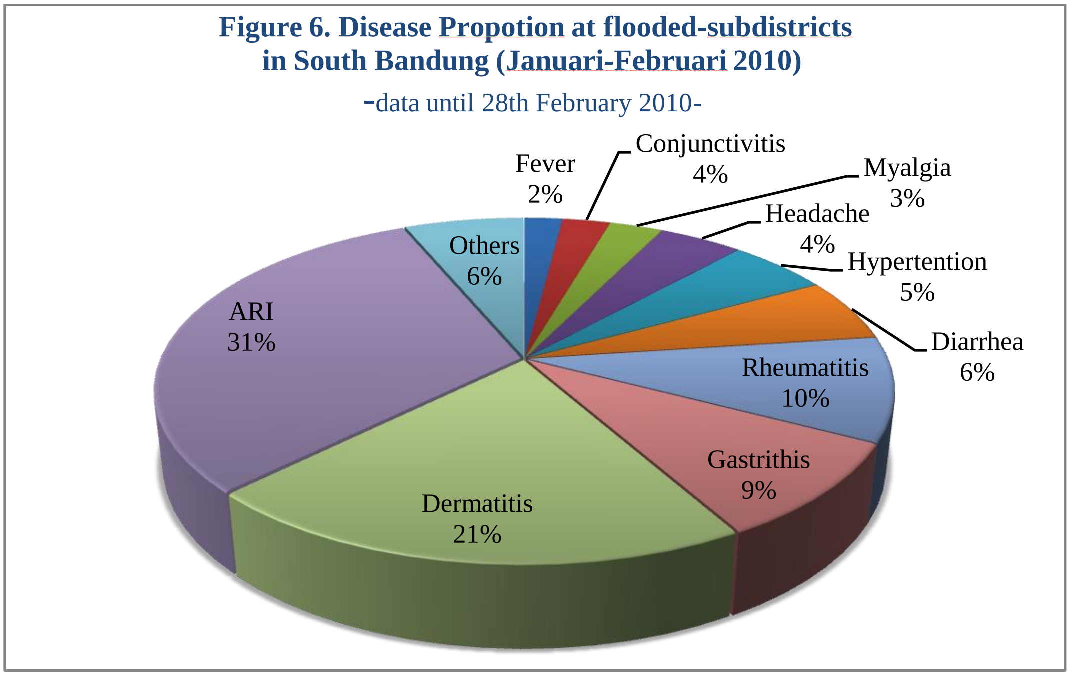
[3] Baleendah area is 4,155.54 ha with 192,480 populations. Total house is 17, 840 with average person per house is 10.8. Dayeuhkolot area is 1,102.91 ha with 121,224 populations. Total house is 36,384 with average person per house is 3.3 (Health Profile of South Bandung Regency 2009, Department of Health of South Bandung Regency)

most of the people who decide not to evacuate has two-level house. So, they prefer to temporarily do their activities in the second floor rather than move to the evacuation site.

Table 1. Number of Inundate House and People whose Evacuate

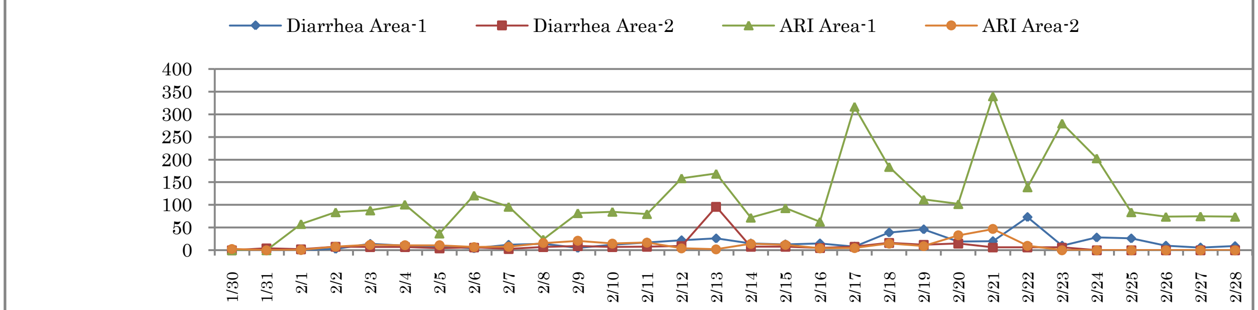
Subdistrict	Inundate House	Total House	%	Should Evacuate	Evacuate	%
Dayeuhkolot	7,063	36,384	19.4	23,308	8,849	37.97
Majalaya	2,492	15,872	15.7	25,418	3,233	12.72
Ciparay	41	22,080	0.2	283	283	100
Banjaran	1,646	16,512	10.0	11,357	4,896	43.11
Baleendah	7,075	17.840	39.7	76,410	4,450	5.82
Rancaekek	1,779	27,530	6.5	10,852	10,852	100

In the evacuation area for both sub-district, Baleendah and Dayeuhkolot, Department of Health of South Bandung Regency noted that there are several diseases suffered by the refugees. The top three diseases are ARI (31%), dermatitis (21%) and rheumatisms (10%), as shown in Figure 6. However, the Department of Health (DOH) of South Bandung Regency only recorded and focuses on two types of disease which are ARI and diarrhea. With different time for recorded the number of refugees who get diarrhea and ARI, generally, the number of people who get both diseases in Baleendah (as we later will be called **Area-1** for the simulation) is higher than in Dayeuhkolot (as we later will be called **Area-2** for the simulation). The daily records of the number of people who get diarrhea or ARI from both areas are shown in Figure 7. The accumulative data of the total people who get diarrhea or ARI from both areas are shown in Figure 8.



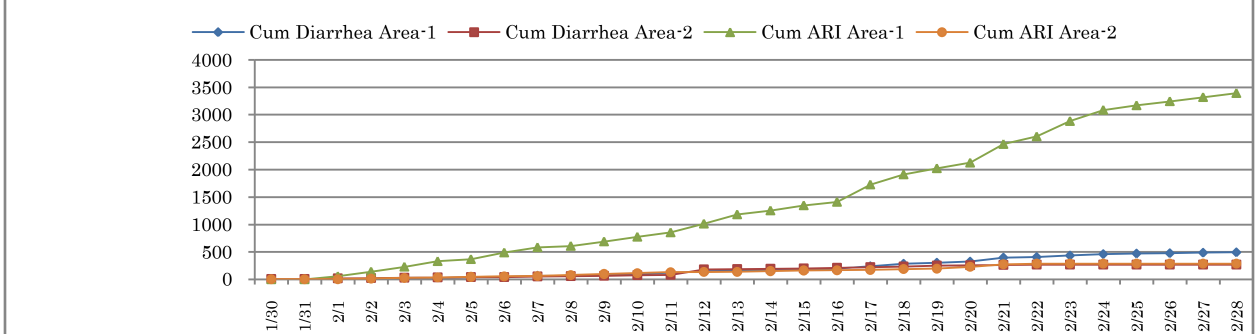
Source : DOH South Bandung Regency, 2010

Figure 7. Number of People in Area-1 and Area-2who get Diarrhea and ARI



	1/30	1/31	2/1	2/2	2/3	2/4	2/5	2/6	2/7	2/8	2/9	2/10	2/11	2/12	2/13	2/14	2/15	2/16	2/17	2/18	2/19	2/20	2/21	2/22	2/23	2/24	2/25	2/26	2/27	2/28
Diarrhea Area-1	0	0	0	3	14	10	8	4	12	14	5	12	17	22	26	15	13	15	8	39	46	19	20	73	10	28	26	10	6	9
Diarrhea Area-2	0	4	2	8	7	7	4	6	3	7	9	7	8	9	96	8	8	5	8	16	12	15	6	6	6	0	0	0	0	0
ARI Area-1	0	0	58	84	88	101	37	121	96	24	82	85	80	159	169	72	93	63	317	184	112	102	340	139	280	203	84	74	75	74
ARI Area-2	3	0	1	8	12	11	11	7	8	16	21	15	17	4	2	14	12	4	5	15	9	33	47	10	0	0	0	0	0	0

Figure 8. Cumulative Number of People in Area-1 and Area-2 who get Diarrhea and ARI



	1/30	1/31	2/1	2/2	2/3	2/4	2/5	2/6	2/7	2/8	2/9	2/10	2/11	2/12	2/13	2/14	2/15	2/16	2/17	2/18	2/19	2/20	2/21	2/22	2/23	2/24	2/25	2/26	2/27	2/28
Cum Diarrhea Area-1	0	0	3	17	27	35	39	51	65	70	82	99	121	147	162	175	190	198	237	283	302	322	395	405	433	459	469	475	484	491
Cum Diarrhea Area-2	4	6	14	21	28	32	38	41	48	57	64	72	81	177	185	193	198	206	222	234	249	255	261	267	267	267	267	267	267	267
Cum ARI Area-1	0	0	58	142	230	331	368	489	585	609	691	776	856	101	118	125	134	141	172	191	202	212	246	260	288	308	317	324	332	339
Cum ARI Area-2	3	3	4	12	24	35	46	53	61	77	98	113	130	134	136	150	162	166	171	186	195	228	275	285	285	285	285	285	285	285

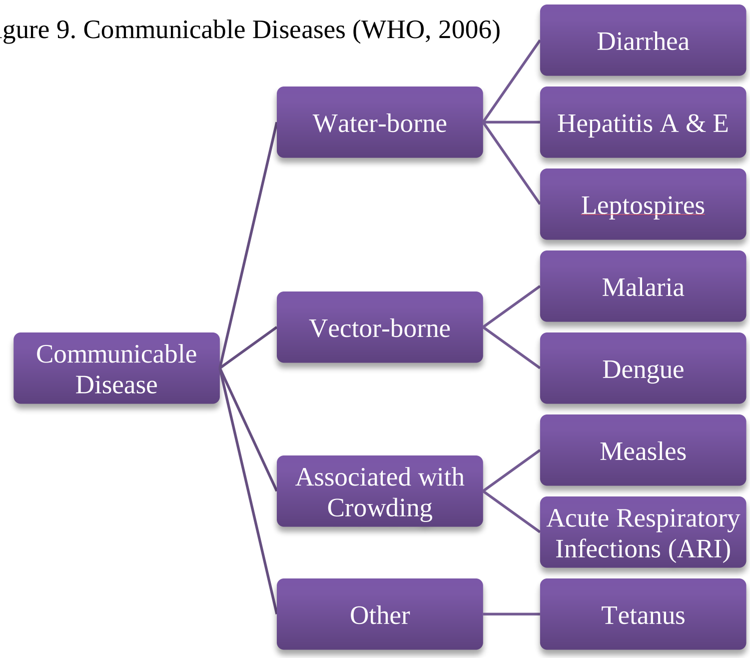
DIARRHEA and ACUTE RESPIRATORY INFECTIONS

According to WHO (2006), natural disaster are catastrophic events with atmospheric, geologic and hydrologic origins. They include earthquake, volcanic eruptions, landslides, tsunamis, floods and drought. From the past two decades, developing countries are disproportionately affected by natural disaster because of their lack of resources, infrastructure and preparedness systems.

The potential impact of communicable disease is often presumed to be very high in the chaos that follows natural disaster, because the risk of the outbreak is associated with the size, health status and living conditions of the population displaced by the natural disaster. Crowding,

inadequate water and sanitation, and poor access to health services, often characteristic of sudden population displacement, increase the risk of communicable disease transmission.
Although the overall risk of communicable disease outbreak is lower than often perceived, but the risk of transmission of certain endemic and epidemic-prone diseases can increase following natural disasters.
Several diseases related to water-borne, vector-borne, diseases that associated with crowding and diseases caused by corpse are summarize in Figure 9 below.

Figure 9. Communicable Diseases (WHO, 2006)



Diarrhea
Diarrhea is caused by infectious organism, including viruses, bacteria, protozoa, and helminthes that are transmitted from the stool of one individual to the mouth of another, termed *fecal-oral transmission*. Some are well known, others are recently discovered or emerging new agents, and presumably many remain to be identified[4].

According to Caimcross (2010) there are three factors that might reduce the risk of diarrhea. The risk reduction of diarrhea associated with hand washing using soap is 42%, risk reduction associated with improved water quality is 17% and 36% associated with sanitation/ excreta disposal.

Acute Respiratory Infections (ARI)
Acute respiratory infections (ARIs) are classified as upper respiratory tract infections (URIs) or lower respiratory tract infections (LRIs). The upper respiratory tract consists of the airways from the nostrils to the vocal cords in the larynx, including the paranasal sinuses and the middle ear. The lower respiratory tract covers the continuation of the airways from the trachea and bronchi to the bronchioles and the alveoli [5].
<u>Pneumonia</u>
Pneumonia can be categorized into lower respiratory tract infections. Both bacteria and viruses can cause pneumonia. Bacterial pneumonia is often caused by *Streptococcus pneumonia* (pneumococcus) or *Haemophilus influenzae*, mostly type b (Hib), and occasionally by *Staphylococcus aureus* or other streptococci. In the developing country, pneumonia is the second cause of death for children under 5 years old.

HEALTH PROFILE

Baleendah (Area-1) Health Profile

Area : 4,155.54 ha (16.82 km^2)
Population : 192,480 people
Household : 17,840 houses
Density : 46.32 per ha (11,443.52 per km^2)
Average person per household : 10.8

Table 2. Demographic of Area-1

	Male	Female	Total	%
1-4	7150	9438	16588	8.62
5-14	22308	20592	42900	22.29
15-44	45474	48048	93522	48.59
45-64	16588	15158	31746	16.49
>65	3147	4577	7724	4.01
Total	94667	97813	192480	100

From the all the house that monitored by DOH, 45.81% (8484 household) show the hygiene behavior such as hand wash with soap, 69.24% have clean water access, and 53.4% owned good sanitation in their house.

Dayeuhkolot (Area-2)

Area : 1,102.91 ha (4.46 km^2)
Population : 121,224 people
Household : 36,384 houses
Density : 109.91 per ha (27,180.27 per km^2)
Average person per household : 3.3

Table 3. Demographic of Area-2

	Male	Female	Total	%
1-4	2736	3010	5746	4.74
5-14	11766	11219	22985	18.96
15-44	33110	32291	65401	53.95
45-64	12313	12315	24628	20.32
>65	1918	546	2464	2.03
Total	61843	59381	121224	100

In Dayeuhkolot area, only 11,361 houses are monitored by DOH. Assuming this number represent the population, then it can be concluded that 57.21% household in Dayeuhkolot show the hygiene behavior. The number of house that have clean access is 83.82% and 86.89% owned good sanitation in their house.

MODEL DESCRIPTION AND SIMULATION

The basic structure of both diarrhea and ARI model are adapted from Kermack-McKendrick with some modification. The population is represented as stock and will be represent the health state but ***susceptible***. The initial populations modeled in the simulation are <u>4450</u> and <u>8849</u> for area-1 and area-2, respectively.

In diarrhea model, the probability of susceptible population being infected by diarrhea microbe depends on the incidence rate. The rate can be decrease through three factors such as the *access to safe drinking water*, *hygiene behavior rate* and *basic sanitation rate*. For the population that in the ***infected*** state can be recover immediately if they understand about the characteristic of the disease so necessary and immediate treatment can be done. Also depend on the time of infectivity which is in the period of 1-2 days diarrhea will reduce. For the people who don't have the knowledge about disease characteristic and how to overcome the primary symptom will get ***sick***, which is represented as conveyor stock. From that stock the number of people who recover will be depend on the *recovery rate*, which affected by the number of clean water and rehydration availability in the evacuation site. The dynamic model of diarrhea can be represented in Figure 10.

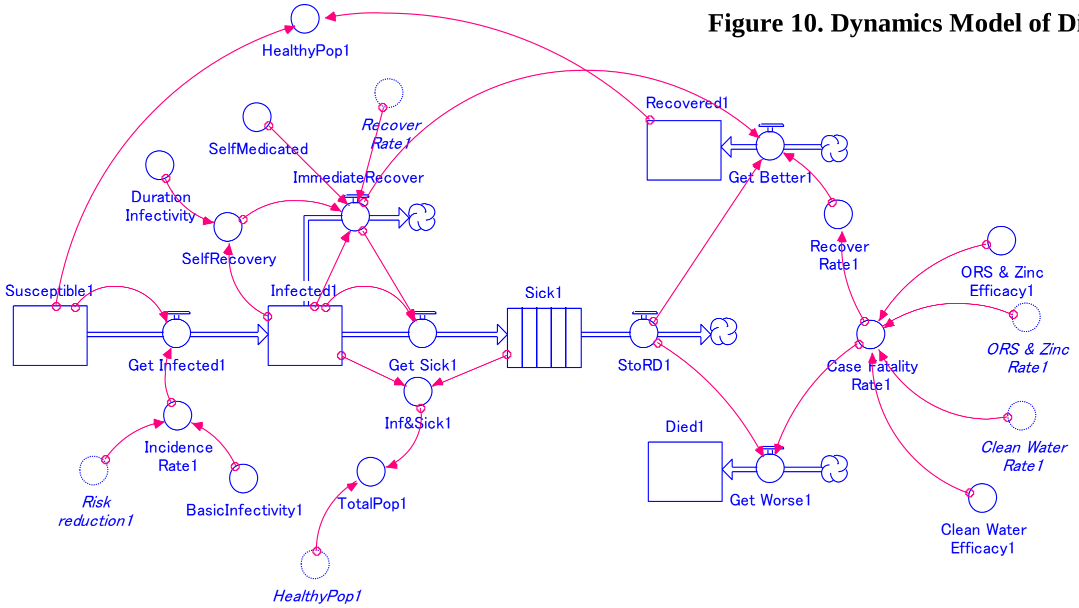


Figure 10. Dynamics Model of Diarrhea

Different characteristic with diarrhea, the probability of the population get infected by ARI microbe is depends on the *incidence rate* and *contact rate*. Since the disease of ARI is transmitted through droplet or air-transmission (Figure 11).

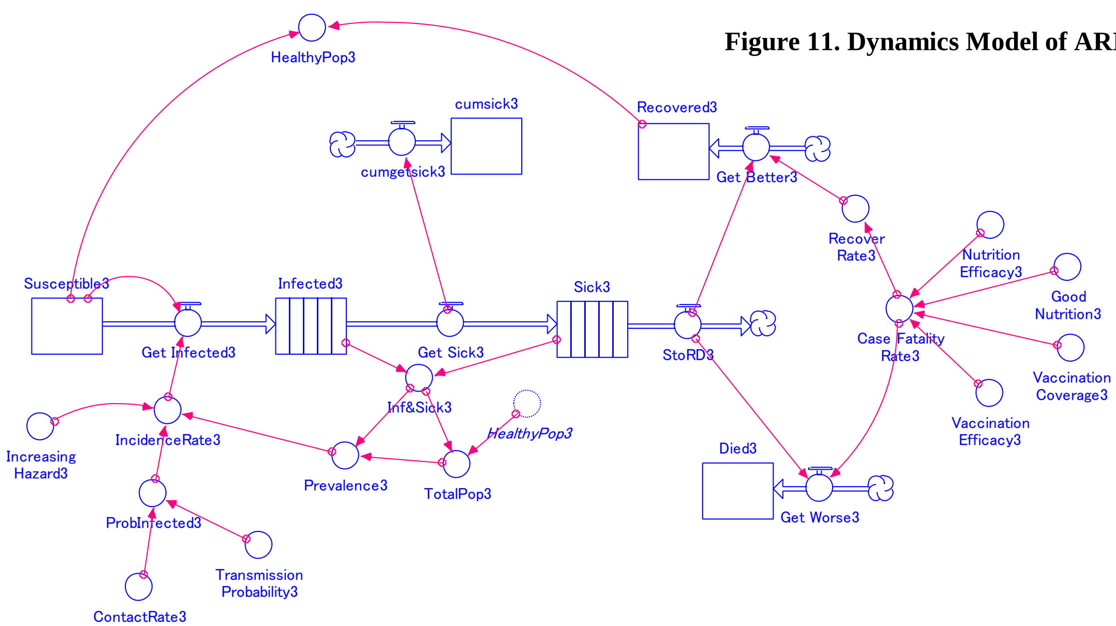


Figure 11. Dynamics Model of ARI

The recovery rate in ARI's model depends on the level of how good is the *nutrition of the population* and *vaccination coverage*. From both areas, area-1 is tends to have worse condition than area-2 in the level of risk-reduction for diarrhea. Even the vaccination coverage in area-1 is higher than area-2, but the number of people who get pneumonia in area-1 is higher than area-2.

The simulation was run on two conditions. First condition is status quo, which is represents the previous situation. The second condition of simulation is run after interventions are introduced in the model.

The intervention of both prevention and mitigation are applied on the model by increased the rate that related to prevention factors and mitigation factors. Since the aim of this paper is to propose decision support system, then it is necessary to have currency based. To calculate the currency on certain intervention, the reduction between targeted rate and basic rate (status quo) multiplied by a cost based on DALY. After that combining the total budget needed from the targeted rate with the budget allocation policy will give the *efficacy* of the interventions.

Table 4. Intervevntion for Diarrhea

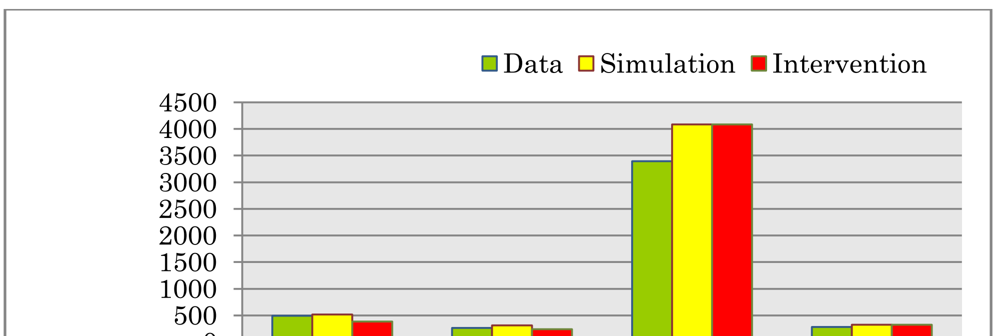
Area	Hygiene Behavior		Safe Drinking Water		Basic Sanitation	
	Current	Target	Current	Target	Current	Target
Area-1	45.81 %	90%	69.24 %	90%	53.4 %	75%
Area-2	57.21 %	90%	83.82 %	90%	86.9 %	75%

SIMULATION RESULT

With assumption of 2% budget allocation for both prevention and mitigation intervention, the efficacy of prevention program is 15% while the mitigation 2%. That efficacy shows only for diarrhea patients which reduce 25% from the basic situation. While for ARI, there is no different between the basic situation and after intervention. The not-significant result for ARI disease might be caused by the high-cost for intervention program, which mention before that the mitigation program for ARI is by introduce vaccination where most of the pneumococcal vaccination is not well known and expensive in Indonesia.

The result of simulation can be shown in Figure 12 below.

Figure 12. Simulation Results



	Diarrhea Area-1	Diarrhea Area-2	ARI Area-1	ARI Area-2
Data	491	267	3396	285
Simulation	516	313	4088	323
Intervention	387	238	4088	323

DECISION SUPPORT SYSTEM

The aim of this paper is to propose a decision support system (DSS) for decision makers (DMs) on creating policy regarding the health aspect that affected by flood in South Bandung.

Based on model construction there are three aspects that DMs can considered in creating the policy :

1. The budget allocation.
2. The prevention intervention
3. The mitigation intervention

Those three aspects are interconnected. The budget allocation will affect on the efficacy of both prevention program and mitigation program. The target area or rate on both prevention and mitigation programs correlated with the total cost needed, which also related to the capability of current budget availability. The most effective cost and also intervention will depend on this three aspects. How much budget can be allocated, to which program, and for how many targeted area or rate.

LIMITATION AND FUTURE RESEARCH

The limitation of this research is that the populations that being modeled are assumed to be homogenous, no age cohort which might have different probability on being infected (i.e children under 5 years old is more vulnerable to get infected by diarrhea and pneumonia).

The intervention programs are input simultaneously. It means that the trade-off between each intervention programs are not calculated to see which program has the most cost-effective effect to prevent or mitigate both diseases.

Therefore, it is a hug opportunity for future research on developing the simulation model to be more sophisticated and complex.

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