

Trash-polluted irrigation: characteristics and impact on agriculture

D Sulaeman¹, SS Arif² and Sudarmadji³

¹Post Graduate School, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

²Faculty of Agricultural Engineering, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

³Faculty of Geography, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

sigitsupadmoarif@ugm.ac.id

Abstract. Trash pollution has been a problem in sustainable water resources management. Trash pollutes not only rivers, lakes and seas, but also irrigation canals and rice fields. This study aimed to identify the characteristics of solid waste (type, time of occurrence and sources of trash) and its impact on agriculture. The study was conducted in four irrigation areas, namely Gamping, Merdiko, Nglaren and Karangploso in Bantul District, Yogyakarta Special Region. We applied the Irrigation Rapid Trash Assessment (IRTA) as our field survey instrument. The results showed that trash was found throughout irrigation canals and rice fields, and the occurrence was influenced by water flow, time and farmer activities. The irrigation was dominantly polluted by plastic trash (52.2%), biodegradable waste (17.91%) and miscellaneous trash (12.3%). The IRTA score showed that Gamping Irrigation Area was at marginal condition, bearing a high risk of disturbing the operation and maintenance of the irrigation canals as well as farmers' health. Trash in irrigation also generated technical impact of the irrigation operation and maintenance, environmental quality, and social life. This research also offered environmental policy integration approach and water-garbage governance approach as an alternative solution to manage water resources and agriculture in a sustainable manner, under the pressure of increasing amount of trash.

1. Introduction

Trash pollution in water bodies has been widespread and caused serious consequences for the ecosystem and livelihood of people. In terms of water quality control, trash generated from human activities might be identified as litter, debris, rubbish, or refuse [31]. Currently, trash is easily found in rivers, lakes, beaches and seas [16, 17, 33, 35, 37].

Researches on trash in rivers, lakes and seas in diverse areas across the world reveal that no water bodies are free of trash. Like in Manipur, India, where trash was disposed in rivers which were used as the standard water resources [30], trash had also polluted rivers in the urban areas of Ondo State, Nigeria [27], and was found in rivers and seafloor in Los Angeles, USA [31].

Researches on coastal areas and oceans found that trash had polluted coastal and remote areas of oceans [33], up to the Arctic and the Antarctic [35]. According [11] trash produced by 192 coastal countries in 2010 was as much as 275 million metric tons (MT) and 4.8 to 12.7 million MT entered the oceans.

The condition in Indonesia is not much different. The Ministry of Environment and the Ministry of Health recorded that rivers were still used for trash disposal [21, 18, 19]. Cikapundung River in Bandung was polluted by 1,500 m³ of trash per week [14], Saguling dam was polluted by 250,000 m³ per year [20], Citarum watershed was polluted by domestic trash of the settlement located around the river [5], rivers and ponds in Jakarta were used for disposing both domestic and industrial trash [9] and



Code River in Yogyakarta was polluted by domestic trash from human settlement [13]. Indonesian seas were estimated to be polluted by plastic trash as much as 0.48–1.29 MMT/year due to mismanaged plastic waste on the land [11].

Not only has trash contaminated natural water bodies, rivers, lakes and seas, but also artificial water bodies such as drainage. Several studies had reported that most urban drainage was polluted by domestic and non-domestic trash [26, 27, 29]. Like in Cikapundung, drainage was polluted by domestic trash up to 44.3 m³/month [14].

Trash disposed at a site will not only contaminate the site, but also spread to other locations through water flow, wind and sea waves [17]. Waste was disposed or flushed into the rivers [27], pollutant from the municipal landfills/dump sites was carried away by runoffs to rivers [24], trash was dumped near the rivers, and when the rain fell most of these materials were washed away into the rivers [25].

Widespread trash disposal to water bodies has been suspected to be caused by the lack and weak infrastructure, management systems, management institutions and human resources who manage trash [10, 24, 25], and low awareness and community participation [3, 8, 30]. In fact, the impacts of pollution on water bodies have been widely reported, such as causing illness, water dysfunction, endangering aquatic life [10, 24], flood, erosion and infrastructure damage [27].

Irrigation system using river as its water source also has the potential of trash contamination. However, there are not many researches on trash contamination in irrigation that have been carried out. Previous researches only mentioned indications of pollution contamination in irrigation, but the information was limited to information on the trash in irrigation canals and its suspected impacts on irrigation system in the form of inhibition of water flow and farmers' working hours [1, 12, 15]. Therefore, research on the characteristics of trash in irrigation and its impacts on agriculture are needed to ensure that irrigation systems can proceed as planned and decision on food supply can be made.

2. The Methods

The study was conducted in four irrigation areas in Bantul Regency, namely Gamping Irrigation Area, Merdiko, Nglaren and Karangploso in Bantul Regency (figure 1).

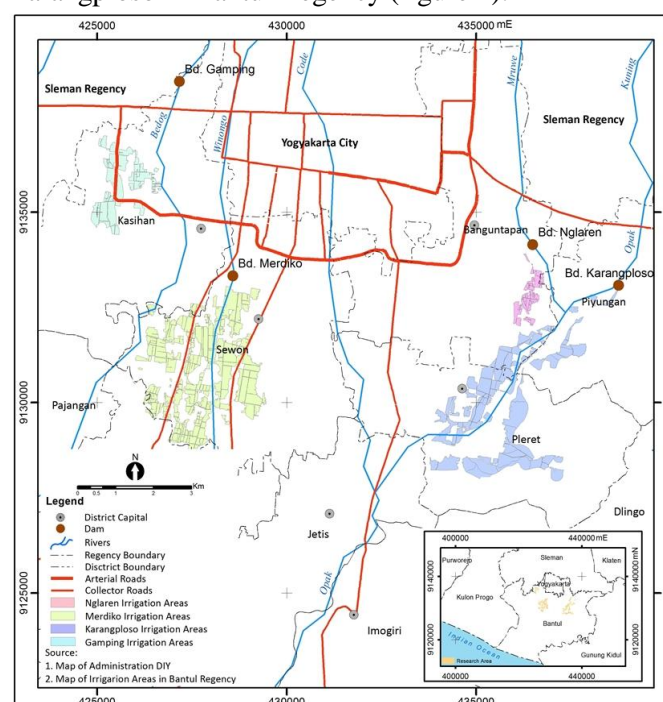


Figure 1. Irrigation trash assessment location map.

They were irrigation areas whose service was adjacent to Yogyakarta City, such as the district of Kasihan, Sewon and Banguntapan [22, 36]. Thus, this region experiences considerable environmental pressures [32] including land conversion, increasing population density, and domestic and commercial activities. The implication was that settlements and commercial activities were getting closer or closer to irrigation canals and agricultural land.

The data in this research was collected through questionnaires and interviews with farmers in 4 irrigation areas. In one of the irrigation areas, data collection was followed by direct waste measurement (figure 2). This research was conducted from December 2015 to April 2016.

In each irrigation area, 40 farmers were selected as respondents. They were members of the Group of Water-User Association (GWUAs). The number was based on input from GWUAs board. These farmers were those who were willing and had an opportunity to become the respondents. The questionnaires were used to collect information from farmers in the form of farmers' observation on the trash found, the time of trash emerging, and the impact of the trash on agricultural business. Interviews were also conducted with farmers to get a complete picture of the condition of irrigation, land and agricultural business.

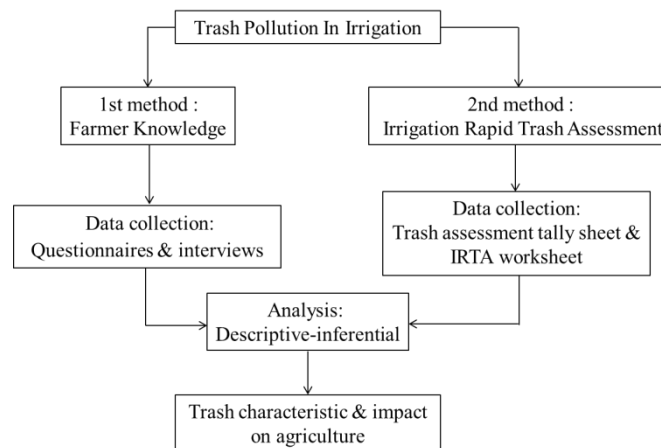


Figure 2. Research design flowchart.

There have not been any established methods developed for the assessment of trash in irrigation. The method used in this study for the assessment of waste in irrigation is called Irrigation Rapid Trash Assessment (IRTA), an adoption and modification of the California Water Board (CWB) method [6] (Table 1).

The California Water Board (CWB) method is a river trash assessment method that has the closest characteristics for the assessment of trash in irrigation, that is, water flows in the canal almost all the time. However, there is a difference in the flow aspect between unsteady flow in the river and continuous and steady flow in irrigation.

Similar with the CWB method, trash assessment using the IRTA method was carried out in two sheets of paper work, namely trash assessment tally sheet and IRTA worksheet. Trash assessment tally sheet combined sheet of California Water Board (CWB) [6] and Southern California Coastal Water Research Project (SCCWRP) [31], which contained ten trash groups, namely plastic, biohazard, construction, miscellaneous, metal, large, toxic, biodegradable, glass, and fabric and cloth, with an addition of agriculture residues into biodegradable groups. Calculation of trash in this research was based on trash unit found. The IRTA worksheet contained a thorough assessment against the parameters and condition categories of the data of trash found in irrigation. A total of six parameters, combining the parameters of illegal dumping and illegal littering, were assessed in four categories of

condition: optimal, sub optimal, marginal and poor. Each subcategory was subdivided into five levels, except the poor with six levels and a continuous value of 0 to 20.

Table 1. Modified rapid trash assessment methods for rivers to irrigation.

Rapid Trash Assessment [6]		Irrigation Rapid Trash Assessment	
Trash Assessment Parameter	Condition Category	Trash Assessment Parameter	Condition Category
Level of trash	Visual observation of the presence and estimation of river filth. Value <10 up to >100 pieces.	Level of trash	Visual observation of the presence and estimation of river filth. Value <10 up to >100 pieces.
Actual number of trash items found	Amount of trash items per 100 ft stream	Actual number of trash items found	Trash items amount per 25 meters of irrigation canal
Threat to aquatic life	The trash types and nature that was hazardous for aquatic life	Disturbance in the operation and maintenance of irrigation, and crops	Trash type and nature that disrupts irrigation operation and maintenance, and rice crops
Threat to human health	Type, level of hazard and trash content that are hazardous to human health	Threat to human health and aesthetic	Type, level of hazard and trash contents that are hazardous to human health (especially farmers and irrigation operators), and aesthetic
Illegal dumping	Indication and evidence of illegal dumping	Illegal dumping	Indication and evidence of illegal dumping in borders or irrigation canals
Illegal littering	Indication and evidence of illegal littering	Illegal littering	Indication and evidence of illegal littering in borders or irrigation canals
Accumulation of trash	Indication and evidence of trash accumulation caused by river water flow	Accumulation of trash	Indication and evidence of trash accumulation due to irrigation water flow

Measurements with IRTA were carried out three times at weir, primary, terrain and tertiary canals with a gap of 3 days between measurements. The data was analysed descriptively to show the type, category, amount, and distribution of waste.

3. Result and discussion

3.1. Characteristic of trash pollution in irrigation

3.1.1. Trash characteristics in irrigation based on farmer observation. Observation of trash in irrigation had become part of the daily activities of farmers from the time of cultivation, planting, maintenance and harvesting. In the whole cycle of rice cultivation, they interacted with irrigation, land and crop for at least 3 months in each planting season. So, it was possible for them to know the condition of trash contamination in the irrigation canals and in rice fields.

Based on the research, all respondents stated that they had found trash in irrigation canals and their land. Meanwhile, observation on each irrigation network found different values with smaller trends for locations far from the farming lands (table 2).

Table 2. Outreach of farmers' observation on trash in irrigation area.

Description	Farmer answer	
	Frequency	Percentage (%)
In general, did you find trash in land and irrigation canals?	160	100
Did you find trash in		
a. your land?	160	100
b. tertiary canals?	160	100
c. secondary canals?	135	84.4
d. primary canals?	62	38.8

There are at least two things that can be explained from this condition. First, the farmer's observation focused more on the location close to the land they were working on, and did not pay much attention to the condition of canals far from their location. Second, it also indicated the ability of farmers' individual contribution to solve the problem of trash in irrigation which focused on the land they had, then gradually they would expand their contribution in areas which were not within their responsibility.

The trash which the farmers said existing in the irrigation canals and the rice field reached up to 23 types (figure 3). Frequency of the type of trash mentioned by the farmers was related to the following four factors: often found, arousing emotion, hazardous to health and safety of the farmers, and disrupting water flow. Plastic bags, or any types of plastic items, were the ones the farmers mostly mentioned because this type of trash was found throughout the irrigation network reaching up to the fields. Being easily carried away by water flow, these plastic items were driven away from their disposal sites.

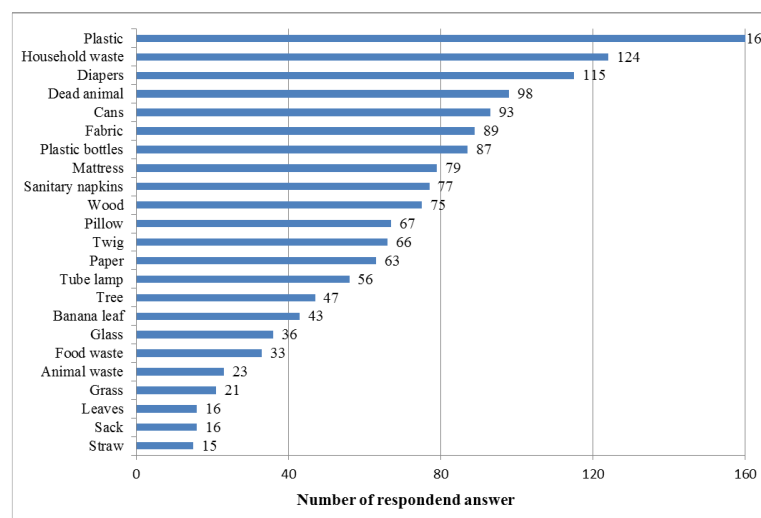


Figure 3. Type of trash based on farmers' observation, n=160.

Household trash, diapers and sanitary napkins were the types of trash that evoked emotion. Household waste, which the farmer declared as plastic bags filled with trash, evoked emotion due to the amount of trash in plastic bag units, and people who disposed the trash. When torn apart, the trash in the plastic bags would come out and spread. As a result, the number of the trash was large in unit although the number of bags was relatively small. According to the farmers, such domestic waste was disposed by workers who brought two bags— one briefcase and one plastic bag filled with trash – on their way to work. Diapers and sanitary napkins were supposed to essentially be disposed with certain treatment. Farmers considered this waste irritating because when they filled the canal and eventually were stranded in the field. They considered that such behaviour looked down at them because the trash made the farmers' environment dirty. Trash such as dead animals, lamp tubes and glass were considered hazardous to the health and safety of the farmers. Household trash, tree branches and plants were stated as trash that disrupted the water flow.

The time of trash emergence, which was divided into high and low-grade groups, in irrigation canals and rice fields referred to the terminology of water flow, time and farmer's activity (table 3). Based on the terminology of water flow, influenced by the season and water discharge, the terminology of time was expressed according to the time of disposal of trash into irrigation, while the terminology of the farmer's activity was related to activities inside and outside cultivation.

Table 3. Time of trash emergence in irrigation canals and rice fields.

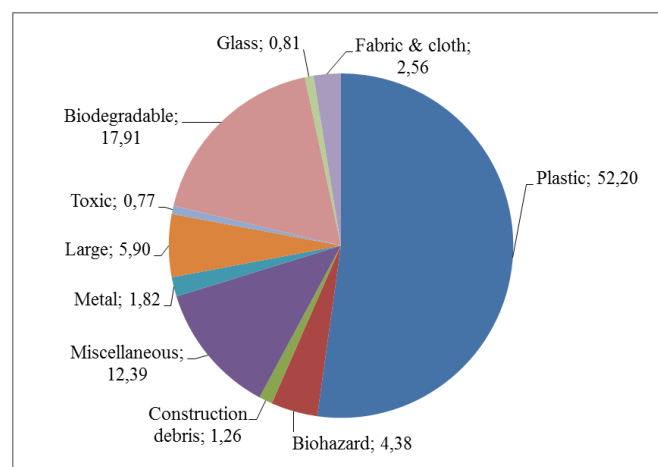
Description	A lot of trash	A little trash
Terminology of water flow	Rainy season	Dry season
	Every water flow	Water does not flow
	Canal flushing	Canal does not work
Terminology of time	Morning	Afternoon
Terminology of farmer's activity	No collective work	After collective work
	Post harvest	The beginning of planting season

In the water flow terminology, it appeared that the trash polluting the canals and rice fields was influenced by the flow of irrigation water. The water flow could come from the operation of irrigation gates, or river flow in certain seasons that swept away the trash and it entered the irrigation system. From this condition, the tertiary canals and rice fields became locations that received a greater trash load from secondary and primary canals.

The morning and afternoon were the times related to when the trash was dumped into irrigation canals and the farmers found the trash in irrigation. Morning was the time when most of the households were cleaning the house, including throwing trash, and it was also the time when the farmers began their activities in the fields. These two conditions met at one time: in the morning. The afternoon was not the time for the households to dispose their trash, and farmers were no longer had activities in the fields.

Farmers' activities influenced the cleanliness of irrigation canals. When the harvest finished, farmers usually spent some time without doing any activities in the fields, including cleaning the irrigation canals. As a result, more trash stayed longer in the irrigation canals. At the time when planting season began, the farmers prepared the land and cleaned the irrigation canals so that the water could flow smoothly into the rice fields.

3.1.2. Trash characteristics in irrigation based on IRTA. As many as 22 locations, which consisted of weir, primary, secondary and tertiary canals, were visited to confirm the height level of trash present in the irrigation system in Gamping Irrigation Area. On average, covering the entire locations and repetition, 52.2% of the total trash consisted of plastic items (Figure 4). Biodegradable (17.91%) and miscellaneous (12.39%) items were also commonly found. The biodegradable items which was most found were food waste, yard waste and agriculture residues.

**Figure 4.** Composition of trash (%), by category, per 25 meters reach for all sites.

Most sites contained less than 200 pieces of trash, while several sites contained many more pieces, up to a maximum of 419 pieces. In the observation locations of the secondary canals, it was recorded that the average number of trash was 196 pieces, 2.7 times of those in the primary canals, and almost twice of those in the tertiary canals (Table 4).

Table 4. Comparison of the number of pieces of trash in each observation location.

Observation location	Number of pieces of trash		
	The lowest	The highest	Average
Weir	11	61	31
Primary canals	45	121	72
Secondary canals	120	419	196
Tertiary canals	69	141	104

The distribution of the number of trash pieces from the weir to the tertiary canals reflected how much stream flow affected the accumulation of trash. In accordance with the irrigation stream management, the stream in the primary canals would be greater than that in the secondary and tertiary canals [4]. Therefore, although in the border line of the primary canals a number of illegal dumping points were found, where trash could be strongly possible to enter the canals, the trash in the primary canals would flow to the downstream. Another cause was when there was an accumulation of trash in the primary canals, people would relieve the blockage and flow the trash to the downstream. Accordingly, trash accumulation would, in fact, happen in the tertiary canals and the farming land.

The IRTA result showed, however, that the highest number of trash units was found in the secondary canals. Such a condition happened because of water management pattern in the secondary canals which was balanced and without any sluiceways, trash from the primary canals entered the secondary canals, a small number of secondary canals, settlement and commercial activities around the secondary canals were higher than those around the primary and tertiary canals. Water management to the tertiary canals was done through off take doors, so that trash from the secondary canals spread out to the tertiary canals.

Based on irrigation network system, it was visible that the percentage of the type of trash that could easily be carried away by the water flow had increased in the location near the downstream (figure 5). It became an indication that tertiary canals and farming land bore a high risk of accommodating plastic trash from the canals located in the upper area, which was worsened by trash directly disposed to the tertiary canals. In the tertiary canals, trashes in the form of pieces and the ones that were still wrapped in plastic bags, as well as old and new trash, were found.

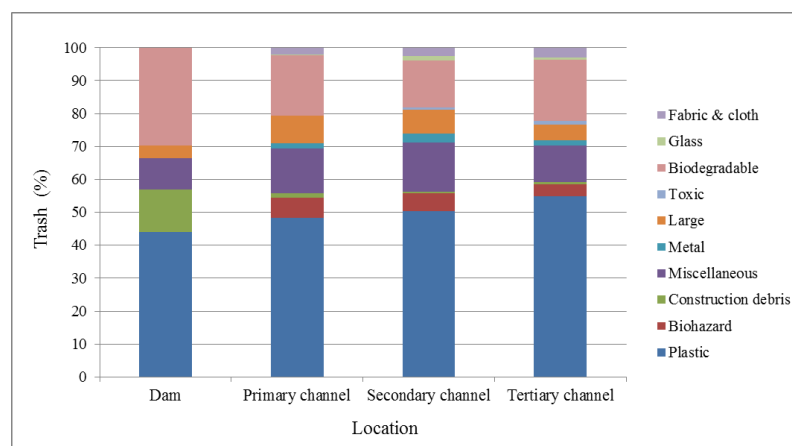


Figure 5. Percentage of trash based on category in each observation location.

In this research, plastic trash in various sizes filled with trash was categorised as “big” trash because the width of irrigation canals varied, starting from primary canals which was 2 meters wide to tertiary canals which was 0.4 meter wide. Therefore, a 0.25 m² plastic sheet was enough to clog half of the canal. It was different from what was defined as garbage bag of trash according to CWB [6], which was a plastic bag size 100x120 cm², because the object of the observation was river.

3.1.3. IRTA score. The average total Irrigation Rapid Trash Assessment (IRTA) score was 56, ranging from 38 to 110 and none had score of 120 (Figure 6). Lower IRTA score indicated the high level of trash. A high IRTA score, overall or in a specific category, represented that the location had a small amount of trash [6]. IRTA score was built from six parameters, each of which had a maximum score of 20. With an average IRTA score of 56, Gamping Irrigation Area fell under the category of marginal, which means that the level, amount, disturbance, and source of trash that entered the irrigation canals could result unsustainable irrigation system and need a serious handling.

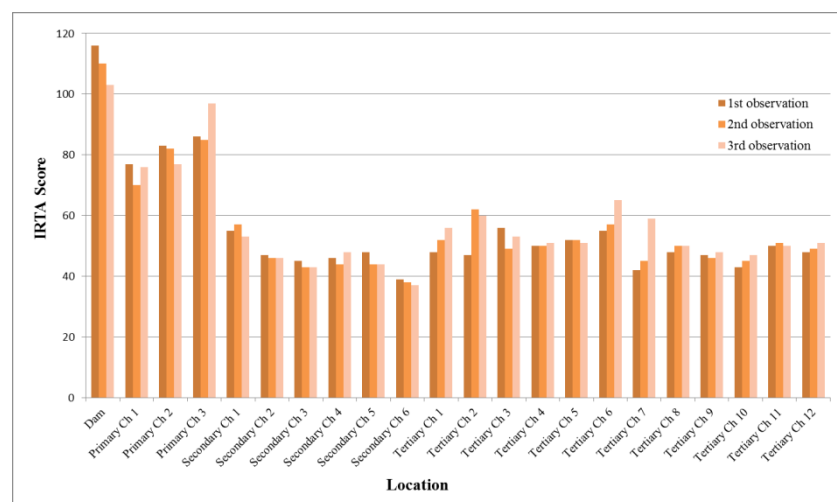


Figure 6. IRTA score in all observation locations and the repetition.

Based on IRTA, other parameters that became the causes of score obtained and impacts on irrigation management could be seen. In irrigation system, there are five important pillars that are used as reference, namely water supply, infrastructure, institutions, irrigation management, and human resources [1]. The pillar of irrigation management in the form of operation and maintenance (O&M) at all levels becomes important to ensure the management and distribution of water. Pillar of human resources includes self and all capability possessed by each individual in her or his role in irrigation. Trash in irrigation seems to create disturbance for the pillars of operation and maintenance of irrigation as well as human resources in the form of health disorder (figure 7). The types of trash that disturbed the operation and maintenance of irrigation included mattress, pillow, wood, garbage bag of trash, furniture, concrete, and tree, whereas the types of trash that were hazardous to the farmers included diapers, animal waste, dead animals, sanitari napkins, tube lamps, metal, and glass.

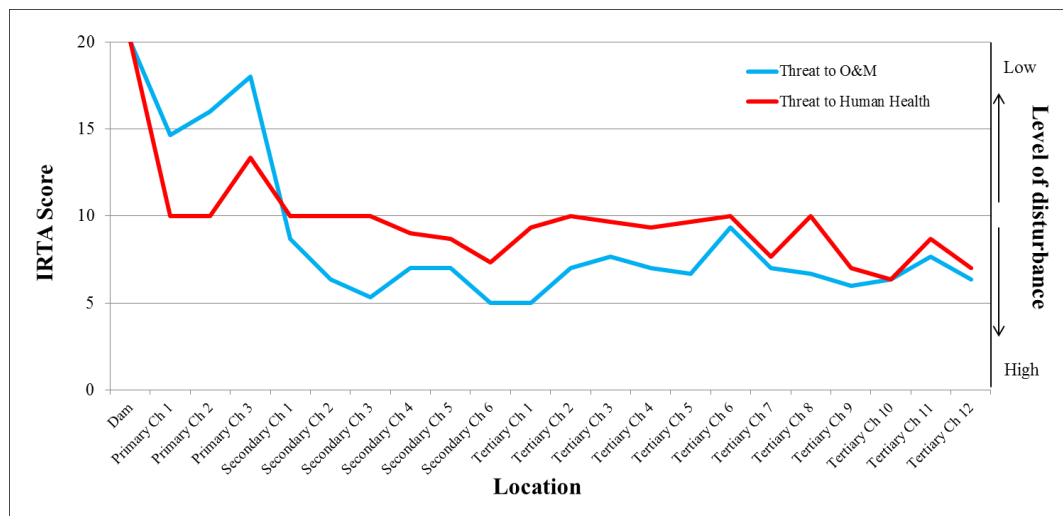


Figure 7. IRTA score in parameter threat to O&M and human health in all observation locations.

Increase of disturbance was higher in locations where the infrastructure dimension was getting smaller, which was in secondary and tertiary canals. Meanwhile, degradation in human health, particularly the farmers', increased in the irrigation canals where farmers did their activities. Both disturbances simultaneously would cause degrading performance of irrigation as well as degradation of the farmers' health.

3.2. Impacts of trash in irrigation on farmers

The impacts of trash in irrigation were identified to cause problems in operation and maintenance of irrigation, quality of irrigation water, and social relation. Operation and maintenance of irrigation were two activities that were interrelated. Operation of irrigation included water delivery schedule and maintenance included activities to keep the operation process running effectively through maintaining physical facility and cleanness of the canals.

The operation of irrigation disrupted by trash had something to do with the physical presence of big trash and high accumulation of trash which disrupted water flow, overflow of water over the canals, and increased delivery time. Considering the effectiveness of irrigation operation, the incrementing volume of trash in irrigation canals accordingly had increased irrigation maintenance in the form of irrigation canal cleaning. In reality, people in charge of irrigation, Water User Association (WUAs), and farmers had not yet been able to improve irrigation maintenance to overcome trash problems. Periodical irrigation maintenance had to be done more often as in three days, or even less, irrigation canals would be polluted by trash again.

Trash disposed in water bodies would degrade the quality of water physically, chemically [27, 30] and bacteriological [24, 25]. Although the study was conducted in rivers, since the type of trash disposed in the irrigation canals was generally the same, it could accordingly be predicted that the trash disposed in the irrigation canals would also degrade the quality of irrigation water. Poor quality of water used in agriculture affects the land and crop [2, 23, 38] which eventually will degrade the productivity of land and crop as well as the quality of the products generated. Therefore, the aspect of food security and safety will be disrupted.

Social turmoil also appeared in this condition. Complaints from the farmers to the irrigation officers about the late delivery of water, improper volume of water, and delivering water and trash, at the same time were conveyed. The farmers' trust to the irrigation officers would decline and the further impact was that the rules of cultivation pattern and water distribution that had been set were not thoroughly obeyed. There were also closed conflicts among the farmers in the form of bad expression and prejudice, especially by the farmers in the downstream against those in the upstream. When irrigation water flew in the tertiary canals in the downstream and carried along trash, farmers in

the downstream would suspect that the community members in the upstream disposed their trash in the irrigation canals and farmers in the upstream did not clean the irrigation canals. Such a closed conflict could potentially become an open conflict among the farmers and between the farmers and the community members if it was not solved.

3.3. Discussion

The handling of trash pollution in irrigation canals should become an important concern as it involves multi stakeholders [28, 34]. Water resources institutions, including those which managed irrigation, agriculture, waste, and the environment, as multi stakeholders, were supposed to respond the changes happening in the community, rivers, irrigation, and farming land. The persistent behaviour of the community members even got more unfriendly against the water resources [14, 19, 22], ineffective institutional performance, lack of funding, environmental policies that were not jointly [34] made, all of which aspects have to be improved.

With a minimal level of trash services in Bantul [7] and community behaviour that still made water bodies trash disposal site [18, 19], irrigation canals, including irrigation borders located close to residential and commercial areas, would continuously became location of waste disposal. Sources of trash in irrigation were also from rivers that brought the flow of trash to irrigation canals.

Trash entering irrigation canals was not only that which disturbed the operation and maintenance of irrigation, but also hazardous trash that affected the health of the farmers. The loss they had suffered due to polluted irrigation was their decreasing time for working on their farming land as their time was consumed for cleaning the irrigation canals beyond the schedule set for irrigation maintenance, increasing healthcare expenses for suffering from wounds, infection, and disease contracting, as well as estrangement of social cohesion. Trash in irrigation had also caused degradation of water quality which affected the quality and quantity of their agricultural products. These losses would eventually press the economic life of the farmers and push them away from welfare. In addition, non-economic loss, which was social loss, also happened and for farmers, it was a loss of such a precious thing.

4. Conclusion

Irrigation as the supporting factor of food production had received pressure with the increasing pollution in rivers and directly in irrigation. Trash was one of the pollutants that had not been properly identified in irrigation, although in reality it was indicated to be in a state that needed to be seriously handled by all stakeholders. Trash spread out in all irrigation canals and farming land and tended to spread more widely to the downstream. Time of occurrence of the trash in irrigation canals had reflected that irrigation was exposed to trash disposal almost at any given time.

Trash in irrigation was dominated by plastic items up to 52.2%. The percentage of plastic trash was increasing in the downstream, which was in the tertiary canals. With the use of IRTA, biohazard trash, particularly diapers, was found in all observation locations. IRTA score in Gamping Irrigation Area was 56, meaning that it was at marginal state. Based on IRTA method, it was identified that trash disrupted the operation and maintenance of irrigation as well as the health of the farmers. Another impact of trash pollution in irrigation was disrupted social relation among the farmers and between the farmers and the community members, although it was still in closed conflicts.

Some impacts of trash on agriculture had indeed been identified. However, to know how much the impact of trash on agriculture is will need further research on the disturbance on the technical aspects of the operation and maintenance of irrigation, health of farmers, social relation between farmers and the community, and how to develop garbage-water governance. The government and the community can also prepare several ways and short-term activities to overcome trash in irrigation and prepare a more comprehensive strategy to manage water resources and agriculture in a sustainable manner.

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