Study on Integrated Solid Waste Management: Padang City, Indonesia

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Study on Integrated Solid Waste Management: Padang City, Indonesia

PADANG CITY, 2022

Acknowledgment

The Study on Integrated Solid Waste Management: Padang City, Indonesia was conducted based on the agreement between the Padang city and IGES Centre Collaborating with UNEP on Environmental Technologies (CCET) that the city action plan on integrated solid waste management would be elaborated based on the study of the current situation of waste management. The Study is the outcome of committed team effort led by the Mayor with Environmental Agency (DLH) of Padang city. The Study also received inputs from various stakeholders including academic institutions, private sectors, non-governmental organisations (NGOs), community groups, and civil society organisations (CSOs).

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Introduction

One emerging issue in Padang City is waste management. In addition to a rise in population, modern lifestyles and tourism development have resulted in burgeoning waste generation, as well as more littering and burning of waste. This problem has exceeded the waste management capacity of the city. Consequently, the Batang Arau river, one of the most important rivers in Padang, has become polluted with litter. Furthermore, the life of the final disposal site (TPA) is getting shorter, due to uncontrolled amounts of collected mixed waste being transported there. The city needed a feasible and sustainable plan of action to improve its waste management capacity.

At the request of the city through IMT-GT, IGES-CCET with the support of UNEP-IETC and the MoEJ established an agreement with Padang city to provide support in developing a city action plan for integrated solid waste management. As a first step, situation analysis was conducted to capture the current waste management status and capacity from various aspects. This report “Study on Integrated Solid Waste Management: Padang City, Indonesia” provides scientific and up-to-date data and local knowledge to understand the waste flow, waste generation and composition, waste management operation of key stakeholders in terms of available resources and partnerships, and awareness and waste handling habits of local populations. It also helps Padang city develop an integrated city action plan and take transformative actions to solve environmental pollution through improved waste management.

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1. Overview of Padang City

Padang City, the capital and largest city of West Sumatra province, is located on the west coast of Sumatra Island (see fig. 1). The city of Padang has an area of 646.96 km^2, and consists of 11 sub-districts (kecamatan) and 104 urban villages (kelurahan) with a population of 950,871 as of 2019 – a 14% increase compared to 2010. Table 1 gives the distribution of the area and population of Padang City. Geographically, the city also includes 19 small islands, and overall exhibits a very varied topology and relief from sea level to 1,853 m at the highest, in Lubuk Kilangan District.

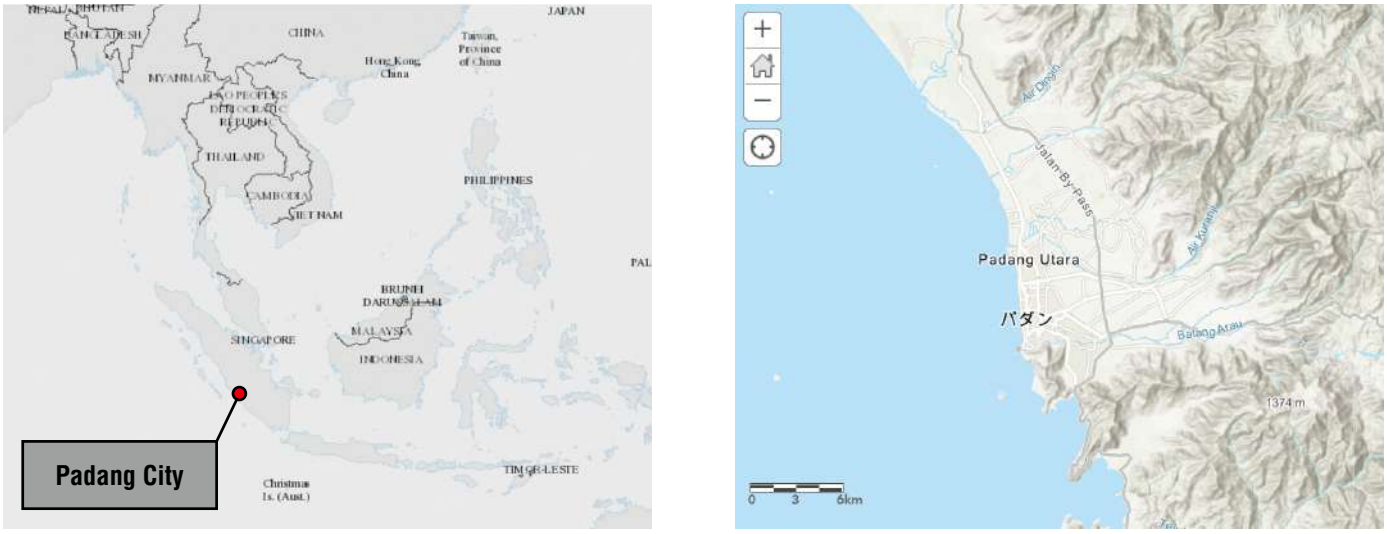


Figure 1. Map of Padang City (source: UN base map)[1]

Table 1. Distribution of population by Kecamatan (sub-district) in Padang City, 2019

Kecamatan	Total population	Population distribution (%)	Total population per Kecamatan	Area (km^2)	Density (people/km^2)
Bungus Teluk Kabung	950,781	2.67	25,415	100.78	252
Lubuk Kilangan		6	57,032	85.99	663
Lubuk Begalung		13.15	125,032	30.91	4,045
Padang Selatan		6.33	60,172	10.03	6,000
Padang Timur		8.39	79,754	8.15	9,788
Padang Barat		4.85	46,101	7	6,588
Padang Utara		7.48	71,112	8.08	8,802
Naggalo		6.52	62,001	8.07	7,682
Kuranji		15.97	151,860	57.41	2,645
Pauh		7.93	75,387	146.29	515
Koto Tangah		20.72	197,005	232.25	848

Sumber: BPS, 2020

Padang is one of Indonesia's wettest cities, with an average rainfall roughly 4,300 mm/year. The rainiest days occur between October and December, while the driest month is February. Air temperatures range from 26.1–28.1°C, with humidity levels reaching 76–85%. Almost half of the area is covered by dense forest (51%), followed by agriculture fields including plantations (33%), residential settlements (10%) and other land types (BPS, 2020).

1 The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

2. Solid waste management policies and regulations

2.1. National level

In Indonesia, waste management is mainly regulated by two acts: the **Environmental Protection and Management Act No. 32/2009**, which defines the planning, utilisation, control and enforcement of environmental protection and also includes water and waste quality standards and a guiding framework for environmental conservation, and **the Solid Waste Management Act No. 18/2008,** Indonesia's first comprehensive waste law, which covers the principles for solid waste management service provision, allocation of responsibilities, incentive and disincentive mechanisms and penalties for legal infractions. Other acts related to waste management in each sector include the Tourism Act (10/2009), Management of Coastal Areas and Small Islands Act (1/2014), Ocean Act (32/2014), and Regional Governance Act (23/2014).

Environmental pollution control sits among the top priorities of the Government of Indonesia[2], and the government has established national policies, target indicators, and ministerial regulations related to waste management (see table 2). Indonesia's **National Long-Term Development Plan (RPJPN) 2005-2025** is aimed at establishing a developed and self-reliant, just and democratic, peaceful and united country, and is divided into four separate **Medium Term Development Plans (RPJMNs).** The current and fourth RPJMN (2020-2025) comprises targets including increasing urban waste management coverage to 80% (baseline in 2016: 59.45%) and reduction of municipal solid waste by 20% (baseline in 2016: 1.19%). Moreover, the country's roadmap for solid waste management, or **National Policy and Strategy for Developing Solid Waste Management Systems 2017-2025 (JAKSTRANAS),** calls for reductions in waste at the national level and improved recycling rates. Key national targets, which are more ambitious than the RPJMNs, call for a 30% waste reduction and 70% handling rate by 2025.

Management of plastic waste, which causes pollution of the marine environment as well as successive risks to human health and economic activity, has become an emerging global issue. In Indonesia, annual plastic waste leakage into the environment is estimated at 0.7 million tonnes[2]. In view of this situation, Indonesia enacted Presidential Regulation No. 83/2018, or **The National Action Plan (NAP) for Combating Marine Plastic Debris**. This action plan, aimed at combating marine plastic debris, comprises five main pillars: (1) behavioural change, (2) reduction of land-based leakage, (3) reduction of sea-based leakage, (4) reduction of plastics production and use, and (5) enhancement of funding mechanisms, policy reform and law enforcement. The reduction target for marine plastic debris is 70% by 2025. To support implementation of NAP, Indonesia has committed a budget of 1 billion USD, as stated in **the Our Ocean Conference 2018** commitments.

2 Closing the Loop on Plastic Pollution in Surabaya, Indonesia; baseline report (2021, UNESCAP) https://www.unescap.org/projects/closing-the-loop/cities/surabaya

Table 2. Key national policies and ministerial regulations associated with waste management

Regulation	Reduce/Reuse	Recycle	Litter prevention
1. National Midterm Development Plan 2020-2024 (RPJMN)	20% waste reduction compared to 2016	Concept of circular economy is adopted	Urban waste management coverage by 80% compared to 2016
2. National Policy and Strategy for Developing Solid Waste Management Systems 2017-2025 (JAKSTRANAS)	30% waste reduction by 2025		70% handled by 2025
3. National Action Plan (NAP) for Combatting Marine Plastic Debris 2017-2025	70% reduction of marine plastic debris by 2025		
4. Government Regulation concerning Management of Household Solid Waste and Household-like Solid Waste, 2012	Defines household solid waste and household-like solid waste		
5. Our Ocean Conference, 2018	Target of 30% reduction by waste producers by 2029 compared to 2019	Asphalt for road construction to contain plastic bag wastes at rate of 5-7%. Plastic producers to make 100% of their packaging recyclable and increase the use of recycled plastic as material in bottles to 50% by 2025.	
Ministerial regulations	Ministry of Home Affairs, Regulation concerning **Waste Management Guideline**, 2010 Ministry of Environment, Regulation concerning **Implementation of 3R through Waste Banks**, 2012 (revised in 2021) Ministry of Public Works, Regulation concerning **Implementation of Infrastructure and Facilities in Handling Household Solid Waste and Household-like Solid Waste**, 2013 Ministry of Environment, Regulation concerning **Waste Reduction Roadmap for Producers,** 2019 Ministry of Research, Technology, and Higher Education, **Instruction concerning Bans on Single-Use Drinking Water Plastic Bottles and Single-Use Plastic within the Institution**, 2019		

In 2012, Government Regulation No. 81 set in place definitions for household waste, which is that derived from daily activities in households - excluding feces and specific waste, and household-like waste, which is that derived from commercial and other areas such as social and public facilities. A year later, a new regulation (No. 03/PRT/M/2013) concerning the **implementation of Infrastructure and Facilities** in the handling of household and household-like wastes was issued by the Ministry of Public Works. Specifically, this regulation concerns the planning, construction, operation, monitoring and evaluation of waste handling. The Ministry of Public Works is responsible for providing waste processing and disposal facilities and the closure/rehabilitation of landfills. Further, a feasibility study is required for infrastructure and processing facilities of greater than 100 tonnes/day capacity.

At the same as time waste reduction became recognised as an essential element to good waste management, the Ministry of Environment issued a regulation (No. 13 of 2012) to promote the concept of reduce, reuse, and recycle (3R) through waste banks. As of 2021, 11,556 waste bank units were in place across 363 regencies/cities throughout Indonesia with 419,204 waste bank customers, producing a monthly turnover of 2.8 billion IDR in July 2021. However, in total this resulted in a waste reduction of only 2.7% at the national level. Accordingly, the regulation was revised in 2021 (No. 14 of 2021) as the level of waste reduction anticipated had not been achieved, despite the rapid creation and expansion of waste banks. The newly revised regulation states that waste banks should also serve as a medium for education, behaviour change and the circular economy, which in effect shifted the burden of responsibility from municipality-driven to community-driven waste management. To better organise and enhance operations of the waste bank network, it was determined that each sub-district (kecamatan) should contain a central waste bank to collect small amounts of recyclables sorted and received from other waste bank units in urban villages (kelurahans) from the same kecamatan. While the government facilitates the involvement of waste banks in the recycling industry, waste banks themselves are required to monitor their management from the perspectives of institutional structure, facilities, performance in terms of accounting and waste handled, and partnerships with buyers and sellers. They are required to submit monitoring reports to the government once every six months. Waste bank managers demonstrating good performance are offered incentives such as awards, recognition through publication of their performance, recommendations for financial assistance and training on waste management from the government.

In 2019, the Ministry of Environment and Forestry established a Ministerial Regulation regarding **Waste Reduction Roadmap** for producers to achieve 30% waste reduction by 2025, as stated in JAKSTRANA. This regulation was drawn up for producers, including retailers, manufacturers, and food and beverage companies that manufacture packaging, produce goods with the packaging and distribute domestic and imported goods using packaging. Such packaging is difficult or impossible to decompose under natural processes. The regulation calls for each company (1) to have in place a waste reduction roadmap that consists of a waste volume baseline, waste reduction trial plan, execution, monitoring, evaluation, and reporting mechanism that can be accounted for, and (2) to formulate a waste reduction report that is delivered to the Ministry, governor, and regent/mayor according to jurisdiction. In parallel with this, the Ministry, governors, as well as regents/mayors (1) may provide incentives for producers in the form of awards, publication of good performance appraisals, and other forms that align with existing laws, and further, (2) may impose penalties on producers that do not comply with the regulation in the form of publication of negative performance appraisals.

To tackle the increasing volumes of plastic waste, the Ministry of Research, Technology and Higher Education issued an Instruction concerning **Bans on Single-Use Drinking Water Plastic and Single-Use Plastic within the Institution** (No. 1/M/INS/2019). With the aim of promoting a plastic-free society, the instruction targets higher education institutions in Indonesia to avoid using plastic items such as banners, posters and signs at events and gatherings. Furthermore, a general ban on single-use plastic in modern markets is to go into force in 40 local governments by 2025. Bali was the first province to put the regulation into effect in 2019, followed by the capital city of Jakarta.

The related campaign, themed on 'single-use plastic-free', is popular among private institutions, particularly in large cities. Retailers such as supermarkets, shopping centres, restaurants, and hotels have started charging for single-use plastic bags or replacing single-use plastic cutlery with reusable wooden items. However, despite such movement, volumes of single-use plastic are estimated to still be on the rise due to the lack of detailed instructions and law enforcement. Further, the COVID-19 pandemic has caused both a drop in the recycling of plastic items as well as an increase in disposal, especially of medical and packaging plastics, due to hygiene concerns, according to an interview conducted in 2021.

2.2. City level

The provincial government and district/city governments, including Padang city, are obliged to prepare Regional Policies and Strategies (**JAKSTRADA**) in waste management based on the JAKSTRANAs. The target of JAKSTRADA 2017-2025 (see table 3) is similar to that of JAKSTRANA, which targets a 30% waste reduction and 70% waste handling rate by 2025. JAKSTRADA 2019-2020 in Padang City states the following strategies:

1. Forming standards for appropriate technology criteria for waste reduction, reviewing the standards of facilities and infrastructure for 3R facilities, preparing operational procedures for handling 3Rs, and establishing a monitoring and evaluation system for 3R activities
2. Strengthening communication between the executive and legislature in Padang City in the form of meetings to discuss waste reduction
3. Implementing waste reduction advocacy by DLH and legislative institutions (DPRD) of Padang City in sub-districts (kecamatan)
4. Conducting waste reduction training with target-setting in sub-districts/kecamatan and urban villages (kelurahan)
5. Establishing a central waste bank in each sub-district/kecamatan
6. Developing a data network for the operational area of the waste bank and TPS3R integrated with the "Environmental Information System (SILH)" in sub-districts/kecamatan and urban villages/kelurahans

Table 3. Targets for waste reduction and waste handling in Padang City (JAKSTRADA 2018)

	2018	--	2021	2022	2023	2024	2025
Potential Waste Generation (tonnes/year)	233,775		246,481	250,869	255,334	259,879	264,505
Waste Reduction Target (%)	18		24	26	27	28	30
Waste Reduction target (Tonnes/Year)	42,080		59,156	65,226	68,940	72,766	79,352
Waste Handling Target (%)	73		74	73	72	71	70
Waste Handling target (Tonnes/Year)	170,656		182,396	183,134	183,841	184,514	185,154

Moreover, Padang city has begun to aggressively manage waste through the **Circular Economy Program** promoted by the Ministry of Environment and Forestry. The main principle of the circular economy is '5R': reducing or optimising the use of raw materials from nature (**Reduce**), reusing materials and products (**Reuse**), transforming used materials and products into new products (**Recycle**), recovering used material and products in the form of material and energy (**Recovery**), or repairing the products for their extended use (**Repair**).

To respond to the Circular Economy Program, the following innovative activities have been carried out in Padang City.

a. Accept plastic waste as bus fares, which is a way to collect used plastic bags through the plastic alms activities
b. Collect littered waste along Batang Arau river with three boats donated by Bank Negara Indonesia and Bank Nagari (fig. 2)
c. Conduct broadcasts on waste handling through mobile radio
d. Introduce a plastic packaging-free day
e. Undertake campaigns such as clean Wednesdays, clean local elections, plastic packaging-free meetings, restriction of plastic bags, plastic straws, and styrofoam, carrying of "my tumbler", and use of biodegradable plastic bags for waste reduction
f. Select Sakinah waste bank as the central waste bank at Batu Gadang, Lubuk Kilangan. The central waste bank collects small amounts of recyclables from several waste bank units, enabling the central waste bank to negotiate smoothly with private aggregators

A boat donated by Bank Nagari

A boat donated by Bank Negara Indonesia

Figure 2. Boats donated by banks

A strategy currently being undertaken by Padang City involves selling recycled products, as regulated under **Peraturan Walikota Padang No. 39 of 2021** on the management and marketing of recycled products. DLH facilitates waste segregation at source and provides training to improve the quality of products made of recyclables. The products are promoted at the business location, or Pemasaran Produk Daur Ulang Sampah (P3DUS) by the government, with financial support and based on market price controls. Marketing can be carried out by parties outside the network (direct selling) as well as online. Currently, recycled products such as bags, baskets, and flower vases from the waste banks in Padang city have been marketed at Transmart Padang every Saturday and Sunday (fig. 3), SJS Plaza and Sari Anggrek. DLH maintains ongoing cooperation with shopping centres and supermarkets to create more demand.

Figure 3. Recycled products in Transmart

Table 4. Regulations on waste management in Padang City

No	Regulation	Regulatory Content	Actual situation
1	Peraturan Walikota Padang No. 39 of 2021 on **Management and Marketing of Recycled Products**	Obligations for managers of recycled products (regional officials, waste management institutions, waste banks, and waste recycling artisans) to participate in the marketing programme using the information system provided by P3DUS through the Department of Communication and Information	This regulation went into effect in June 2021, and the related products are marketed in three supermarkets in Padang City.
2	Peraturan Walikota Padang No. 109 of 2019 on **Instructions for Implementing Regional Regulation** No. 21 of 2012 on Waste Management	Instructions for waste management include licensing, sorting methods, selection of incentives and disincentives, compensation, complaints, prohibitions, supervision and guidance and procedures for imposing administrative sanctions.	Law enforcement is carried out through raids conducted by Civil Service Police Unit. A fine of 6.97 USD is imposed on those who litter waste.
3	Peraturan Walikota Padang No. 44 of 2018 on **Policies and Strategies for the City of Padang in the Management of Household Waste and Types of Household Waste**	Policy direction, strategies, programmes, and targets for 3R and handling (sorting, collecting, transporting, processing, and final disposal) of household waste and household-like waste	Each government agency and the business sector are obliged to support DLH in reducing waste in line with JAKSTRADA.
4	Peraturan Walikota Padang No. 36 of 2018 on **Control of the Use of Plastic Shopping Bags**	Obligation to limit the use of plastic bags is placed on business actors/activity in shopping centres, modern shops and traditional markets	This regulation is implemented at several markets in Padang city. DLH provides reports of monitoring and evaluation every six months to the mayor.
5	Peraturan Daerah Kota Padang No. 1 of 2016 on 2nd Amendments to Padang City **Regional Regulation** Number 11 of 2011 **on Public Retribution**	Amount of retribution for waste/cleaning services for each type and class of building	Waste retribution is divided into three categories: commercial (hotels, stores, restaurants, etc.), non-commercial (offices, education, etc.), and extraordinary costs (residential, etc.).
6	Peraturan Daerah Kota Padang No. 21 of 2012 on **Waste Management**	Comprises rules and sanctions that every citizen in Padang city must obey. Controlled by the Civil Service Police Unit (Satpol PP)	A fine for violations during the period varied from 3.51 to 70.20 USD.

3. Current waste management

3.1. Activities by stage

Previously, waste management was only limited to collection, transport and disposal in Indonesia. To reduce the burden on the final disposal site (TPA: Aia Dingin Tempat Pemrosesan Akhir) due to the increase in mixed waste, the government has made efforts to reduce waste generation by establishing waste banks and TPS 3R under the Circular Economy Program with a focus on 5R. Now that sorting and processing have been added to policies directing the waste management system, waste management now consists of sorting, collection, transportation, processing (treatment) and disposal. However, the reality is that such policy is not fully implemented on the ground.

Good waste management has to be planned and implemented under the waste hierarchy – a simple ranking system used for the different waste management options with a view to preserving the environment and efficient use of resources. The most preferred option is to prevent (reduce) waste, and the least preferred choice is disposal in landfills or disposal sites. (Fig. 4)

Figure 4. Waste hierarchy[3]

Table 5 shows the ideal management processes in each stage, which contrasts with the current management situation in Padang city, which involves three types of collectors. First, DLH collects waste directly from the waste generators by dump trucks and transports it to the TPA. This service covers offices, commercial sectors, and certain residential areas. The service fee is collected together with the potable water bill.

However, in most kelurahans household waste is collected by community collectors at the waste management institutions or Lembaga Pengelolaan Sampah (LPS) established in each kelurahan, which is the second collection method. Informal waste collectors also visit individual houses, commercial buildings, schools and TPSs to collect recyclables.

Typically, these collectors, who are paid by the kelurahan, transport waste from individual houses to Tempat Penampungan Sementara (TPS) by becak motor with a compartment of 1.5 m^3 size. Some supplement their income by selling valuable recyclables extracted from the collected waste or TPSs to aggregators or waste banks. The third collection method involves transport by DLH of waste from the TPSs to the TPA, located in Baringin, Koto Tangah District.

3 https://ismwaste.co.uk/help/what-is-the-waste-hierarchy

DLH owns 27 dump trucks, 31 carroll trucks, 13 pickup trucks, 28 motorised tricycles and 3 garbage collection boats. A total of 154 containers of 6 m^3 volume are distributed over 127 areas across the city. The TPA has an area of 17 hectares, and estimates show it can accommodate waste until 2026 based on current rates of waste disposal. Expansion of this into the adjacent community owned land (11.3 hectares) is being considered, for which the land acquisition process is currently under way. While the TPA has a composting facility, its capacity is insufficient at only 30 tonnes/month, thus most of the organic waste is left dumped in the TPA, and the rest of the waste is dumped without compaction. Consequently, the pile of waste continues to rise, which poses an operational risk due to the possibility of collapse. In addition to improvements in landfill site management, a waste reduction programme aimed at the source are crucial options that would extend the operating life of the TPA and reduce the levels of environmental pollution and hazard risk.

Generators of household and household-like waste are obliged to place waste in front of their respective houses, buildings, or TPSs during the hours of 5 pm and 5 am. However, this rule is not always respected, which leads to deteriorated environment and hygiene conditions in the proximity.

Table 5. Comparison between ideal and current situations of waste management

Stage		Ideal Management	Current Management
Segregation at the source		- Waste generators separate waste according to the types, such as waste containing hazardous and toxic materials, biodegradable waste, recyclable waste, and residues. - Storage facilities comprising bins or other containers are located at sources, and metal containers (TPS) at community collection points. Sorting and storage facilities are designed based on volumes of waste, types of waste, location, collection schedule and kind of transportation equipment/vehicle (truck, motorbike, cart, bicycle).	- Waste separation is not widely practiced, with the exception of those selling recyclables to waste collectors. - Faces criticism that sorted waste is remixed at the TPS despite being disposed of separately.
Storage and sorting	TPS	- There are 154 TPSs with a capacity of 6 m^3. - Sorted waste is collected and transported separately. - People dispose of their waste between 5pm-5am.	- Mixed municipal waste is disposed of by community waste collectors and individual waste generators. - Disposal times are not universally respected. - TPS is too small or insufficient; overflows often occur and some waste remains uncollected, resulting in nuisance and unhygienic conditions.
	TPS 3R	- Comprises an area greater than 200 m^2; easily accessible, within a radius of no more than 1 km from the service area. - Facilities exist to sort waste into at least 5 types; equipped with a room for sorting, composting organic waste, and a bio-gas generating unit, warehouse, buffer zone, and which do not disturb environmental aesthetics or vehicular traffic. - Provision of a processing waste container but not a permanent container. - Should not pollute the environment.	None of the nine TPS3R facilities previously installed are operational due to lack of finances for continuous operation.
	Waste bank	There are 21 active waste banks in Padang city. In addition to typical banking operations using waste, waste banks are encouraged to educate citizens to promote 3R.	- A central waste bank has been identified. - Handling of recyclables at insufficient rate to generate profit; operational capacity is limited. - Lack of vehicles prevents collecting more recyclables.
Collection and transportation	From source to TPS/ waste bank	LPS formed by the RT/RW is responsible	The operational capacity of LPS as well as the institutional capacity of RT/RW is limited.
	From TPS to TPS3R	DLH is responsible	Functional TPS3R no longer exists.
	From TPS3R or TPS to TPA	DLH is responsible	Functional TPS3R no longer exists.
	Other	- Collection schedule is fixed and adhered to by all. - Transportation equipment or vehicles do not pollute the environment.	DLH lacks transportation equipment or vehicles with sufficient capacity to collect and transport all municipal waste generated.

Stage		Ideal Management	Current Management
Processing	Composting	Sorted organic waste is processed into organic compost at the composting facility in the TPA. Organic waste residue from composting is deposited in the landfill area.	A small quantity of organic waste is processed into organic compost (1 tonne/day) at the composting facility in the TPA. A few people make compost at the household level.
	Recycling	More waste is collected as recyclables by waste banks and informal waste collectors to achieve a 30% reduction by 2025.	The current reduction rate is too low at 2.8%. Many people still consider recycling as a charity activity, while those in the city centre sort waste to sell the recyclables.
	Energy or material recovery	Coals are substituted with waste as refuse derived fuel (RDF) in the cement industry.	As RDF includes wet waste such as food waste which lowers the calorific value and requires an additional facility and energy to remove the moisture, refuse paper and plastic fuel (RPF) that excludes wet waste has been considered an alternative option.
disposal		- Residues, i.e., the waste left after removing all recyclables, is disposed of at a controlled landfill (sanitary landfill) or TPA. - Area needs to be greater than 20,000 m^2 if waste generation is greater than 500 tonnes/day. - At least 1 km away from settlement. - Appropriate techniques such as stockpiling/ compacting activities, land cover, leachate processing and gas handling are practiced. - Equipped with ramps, compaction facilities, special transportation and leachate storage facilities. - DLH is responsible for TPA operation and management.	The current-city owned TPA has 17 hectares. Municipal waste is transported by trucks to the TPA. Since all mixed waste is transported without sorting, it is estimated to accommodate waste until 2026. Waste pickers pick out materials at the TPA, under environment of pollution and safety issues. Designed to be a sanitary landfill but operated as a non-controlled disposal site or dumping site. Waste is dumped without compaction, which poses a danger of collapse.

3.2. Responsibilities of key stakeholders

A) Environmental agency (DLH)

According to Padang Mayor Regulation No. 76 of 2016 concerning the Position, Organizational Structure, Duties, Functions, and Work Procedures of the Environmental Service, DLH is responsible for the monitoring of soil and air pollution and waste management consisting of planning, implementation, supervision, sweeping, collection and transportation. They also have a unit, the Service Technical Implementation Unit (UPTD), which is responsible for final disposal site management.

B) Other agencies in local government

- Mayor, Regional Secretariat (Sekda) and Regional Council (DPRD): issuing policies and regulations;
- Civil Service Police Unit (Satpol PP): supporting law enforcement;
- Regional Financial and Asset Management Agency (BPKAD), Local Development Planning Agency (Bappeda): planning and financing projects;
- Public Works and Public Housing Agency (PUPR): financing and procuring of infrastructure and technology;
- Cooperatives & SMEs Agency (Dinas Koperasi dan UMKM), Tourism Agency (Dinas Pariwisata), Agricultural Agency (Dinas Pertanian), Industry & Trading Agency (Dinas Industri dan Perdagangan): marketing support for recycled products

C) Waste banks

Waste banks adopt the normal formalities of a standard bank but instead handle recyclables brought in by members, which are weighed and recorded in members' saving books. The equivalent value of the recyclables is either paid in cash or saved. Besides the banking function, waste banks also sort, clean, and store the recyclables and sell them to aggregators or a central waste bank. Some waste banks also fabricate handcrafts from recyclables to sell.

As of 2021 there were 21 active waste banks in Padang city (DLH, 2021; see table 6). The average amount of waste handled by all waste banks in 2020 was 1.72 tonnes per day. This amount is still less than that collected by informal waste collectors, mainly owing to the lack of awareness about waste banks in the community. According to the interviews conducted, another significant reason is the distance from individual houses to the waste banks, which

may affect the motivation for those living at a distance to bring in their recyclables. To receive more recyclables, some waste banks utilise their vehicles for awareness raising within the community.

Although the government promotes waste banks, DLH has little budget available to support their operation. As a consequence, many waste banks in Padang city are run by individuals, mostly women, or community organisations on a voluntarily basis rather than for profit, which means many waste banks cannot make their operations sustainable and thus remain small in size. Panca Daya central waste bank cooperates with PT Pegadaian (Pegadaian, 2020), which invests in gold. The recyclables brought to Penca Daya waste bank are exchanged for the value of gold and saved at PT Pegadaian. For every sale of recyclables valued at 6,000 Rp, the customer receives 0.01 grams of gold in their gold saving account in the waste bank. This has motivated people to save, particularly when the value of gold rises, and this waste bank currently has 600 members with a total savings of over 23 kilograms of gold accumulated over three years. The recyclables are collected from 18 waste bank units around Kuranji District. PT Pegadaian provides CSR assistance in the waste bank building, operational tools to support the waste bank activities and coaching for the waste banks every month. Panca Daya waste bank itself also provides operational training for member waste bank units and actively processes waste into crafts for sale, thus managing to increase profits while promoting recycling.

Sakinah waste bank, located in Lubuk Kilangan, Batu Gadang has followed a different path of development. Established in 2012, it has made significant innovations since 2014, and has around 500 members, of which 475 are active. It integrates microfinance into waste bank operations in which members pay a monthly fee (20,000 Rp; negotiable) and may borrow money. Monthly fees as well as loans can also be paid with recyclables. Through these practices Sakinah waste bank has managed to increase its members and amount of recyclables, especially plastic waste. The accumulated plastic waste is compacted with a compressor and transported by truck over 700 km to Medan city, the capital of North Sumatra Province in order to obtain more favorable prices for recyclables than in Padang. According to the owner, selling in Medan provides her more profit than in Padang even after deducting transportation costs. Further, Sakinah waste bank sells handicrafts such as shopping bags and aprons made from recyclables, many of which are purchased by government agencies that promote products made of recyclables. For these reasons Sakinah waste bank, which has various income sources and a membership that respects the loan conditions, has become a central waste bank owing to its rapid development.

Table 6. Waste banks in Padang City (as of 2021)

No	Waste Bank	Address
1	Sakinah (central waste bank)	Jl. Bukit Ngalau No. 8 Kel. Batu Gadang Kec. Lubuk Kilangan
2	Enviro Andalas	Kampus Universitas Andalas, Limau Manis - Padang
3	Hidayah	Jl. SMP 21 No. 18 RT.03/RW.06 Gadut Kel. Banda Buat Kec. Lubuk Kilangan
4	Panca Daya (central waste bank)	Jl. Bypass KM. 9, 5 Korong Gadang Kel. Kalum Buk Kec. Kuraji (Belakang Kantor Camat Kuranji)
5	Handayani	Jl. Handayani I Komplek Perumdam III, Siteba, Nanggalo
6	Saiyo	Purus, Padang Barat
7	Bangau Putih	Kampung KB Kel. Parupuk Tabing Kec. Koto Tangah
8	Hijau Lestari	Jl. Yogyakarta RT.02/RW.10 Kel. Ulak Karang Selatan Kec. Padang Utara
9	Asy Syifa	Jl. Penjernihan I RT.03/RW.07 Kel. Guning Pangilun Kec. Padang Utara
10	Lidah Mertua	RT.02/RW.05 Kel. Bungo Pasang Kec. Koto Tangah
11	Bank Sampah Mandiri	Jl. Pasar Mudik No. 14 RT.02 RW.01 Kel. Pasar Gadang Kec. Padang Selatan
12	Panca Daya 2	Jl. Manggis 14 No 231, Kel. Kuranji Kec. Kuranji
13	Panca Daya 3	RT. 03 RW.06 Kel. Sungai Sapih Kec. Kuranji
14	Andalas Sepakat	Jl. Andalas No 90 Rt. 02 / Rw. 04, Kel. Andalas, Kec. Padang Timur
15	Insan Oke	Kampus Politeknik ATI Padang. Bungo Pasang Tabing, Kel. Bungo Pasang, Kec Koto Tangah
16	Bina Sadar Mulia	Perum. Kamela Permai II Blok A. No. 29 Rt. 03 / Rw.13 Kel. Pasia Nan Tigo, Kec. Koto Tangah
17	Al-Hijrah	Jl. Raya Jundul, Kel. Rawang, Kec. Padang Selatan
18	ATT Berseri	Jl. Polonia Rt. 03/ Rw. 01, Kel. Air Tawar Timur, Kec Padang Utara
19	Tiga Sepakat	Jl. Parak Buruak Rt. 05 Rw. 02 Kel. Batipuh Panjang, Kec. Koto Tangah
20	Palito	Perum. Nusa Indah Permai, Kel. Air Pacah, Kec. Koto Tangah
21	Barokah Al-Salam	Komp. Dangau Teduh Jl. Pinus, Kel. Cengkeh Nan XX, Kec. Lubuk Kilangan

Source: Padang City Environmental Department

D) TPS3R

Tempat Pengolahan Sampah-Reduce Reuse Recycle (TPS3R) is where collection, sorting, reuse and recycling activities are undertaken at the sub-district level. Under the TPS3R programme, sorted organic waste is processed biologically such as through composting, non-organic waste is further sorted, cleaned and stored for recycling, while materials that cannot be recycled are transported to the TPA. TPS3R facilities operate under the Regulation of the Minister of Public Works and Public Housing (Permen PUPR) No. 3 of 2013 on the Implementation of Waste Infrastructure and Facilities in Waste Handling

Table 7 shows nine such TPS3R facilities installed in Padang city by the Ministry of Public Works and Public Housing. However, none of them are operational today due to the lack of finances to cover the hiring of operators as well as poor equipment maintenance, according to Gewe's 2018 field survey. Originally intended to enable sustainable and independent operation by community members by selling recyclables and compost, the government subsidy ran out prior to the TPS3R facilities securing sufficient profit to sustain operations. A contributory factor was complaints raised by many residents, who, while not participating in 3R activities asserted demands to halt the operation of TPS3Rs in residential areas due to lapses in environmental standards. Without operators, the collected waste at the TPS3R was neither sorted nor processed but transported to the TPA (Rizki, 2016).

Table 7. TPS3R in each kecamatan (sub-district) of Padang City as of 2021

No	Subdistrict	Established year	Name	Actual status
1	Lubuk Kilangan	2010	KSM Koto Lalang	Not operational
2	Pauh	2012	KSM Darul Ulum	Not operational
3	Kuranji	2009	KSM Korong Gadang	Not operational
4	Nanggalo	-	-	
5	Padang Barat	2009	KSM Fajar	Not operational
6	Koto Tangah	-	-	
7	Padang Utara	2007 2008	KSM Yayasan SAM KSM Babaliak Rancak	Not operational Not operational
8	Padang Selatan	2017	KSM Melati Rawang	Not operational
9	Padang Timur	2012	KSM Jati Bergema	Not operational
10	Bungus Teluk Kabung	-	-	
11	Lubuk Begalung	2013	KSM Kami Saiyo	Not operational

Source: Padang City Environmental Department

E) Informal sectors

Recycling activities can generate job opportunities for communities, and many waste collectors are involved in waste recycling in urban areas. Most are individuals, groups, or small businesses with no legal business status and operating under no standard regulations, who not only collect recyclables from various sources such as residential areas, schools, offices, industrial and commercial facilities, TPSs, and the TPA, but also sort and process them for reselling on to larger aggregators or recycling factories outside Padang city. Some use vehicles such as garbage motorbikes, tricycles, or bicycles, and others collect using handy carts (Andriyanti, 2009). The composition of recyclables handled by the informal sector in Padang City includes plastic waste such as bottles, buckets, gallon containers, etc. (37%), paper and cardboard waste (32%), and metal waste such as ferrous and non-ferrous metals (31%) (Stephanie H, 2020).

Waste recycling activities performed by the informal sector contribute greatly to reduced waste generation, however still only account for a less than 10% reduction in the total waste (Damanhuri, E. dan Padmi, T. 2016) owing to the relatively unorganised state of operations. Currently, neither national nor city governments can regulate waste management by the informal sector owing to its non-legal status.

F) Community-Based Organisations (CBOs)

The community's involvement in waste management is essential as it brings several benefits, namely maintenance of environmental cleanliness, and the ability to resolve common problems and peer learning, which provides a sense of solidarity. Various groups exist in communities in Indonesia, but their function and activities differ from place to place.

Women Association – One of the most active groups besides Family Welfare Development (PKK) and PKBS in waste management at the community level. They usually organise meetings to disseminate information about health, education, childcare, and the environment to educate and empower citizens,

especially women. Some members become environmental cadres and facilitators who raise awareness in the community and coordinate with government staff ranging from RT, RW, sub-districts, and districts to the city.

Community Institutions – Leaders of districts, subdistricts, RT, and RW are administratively responsible for waste management on the ground. These institutions can reach community groups such as women associations and youth unions to enhance community involvement. However, the authority level differs according to the area.

G) NGOs, academics/universities and experts

NGOs are involved in action plan development and implementation support. They also build community aspiration based on the bottom-up approach. NGOs actively support and conduct campaigns and events on waste separation and restriction of single-use plastic at the source.

Universities/academia and experts support module and curriculum development for schools, research on the various related technologies and study on GHG emissions. They usually work together with local government in line with established policies and strategies. The results, comprising findings and lessons learnt from the activities are disseminated through seminars and workshops.

H) Formal private sectors

Some private companies at local, national, and international levels can contribute funds to support waste management programmes under Corporate Social Responsibility (CSR), Extended Producer Responsibility (EPR), and other schemes that provide mutual benefits to both private companies and waste management. As of today, EPR has yet to establish firm roots in Indonesia.

PT. Semen Padang, a cement factory, is one of the potential private companies that can contribute to waste reduction and waste recovery directly. Located in Indarung Village, Lubuk Kilangan District, this factory, founded in 1910 under the name NV Nederlandsch-Indische Portland Cement Maatschappij (NV NIPCM), is one of the oldest cement producers in Indonesia. In 1958, the company was nationalised by the government of Indonesia from the Dutch government. In 2012, PT. Semen Padang, PT. Semen Gresik, PT. Semen Tonasa and Thang Long Cement merged under PT. Semen Indonesia (Persero), based on 51% ownership by the Indonesian Government.

Cement production is a thermally intensive process requiring high fuel input, and the fuel needs of PT. Semen Padang equate to 170 kt/month of coal with a calorific value of over 5,000 kcal/kg. However, consideration of global concerns over climate change prompted the need to reduce coal consumption, which they can achieve through installing a Refuse Derived Fuel (RDF) facility, which could reduce carbon emissions by substituting coal with solid waste as an alternative fuel. Waste that can be used as RDF is combustible waste containing plastic bags, paper, wood, etc., while non-combustible waste is iron, glass, metal, and other materials (Cheremisinoff, 2003). Various types of waste can be burned without the use of supplementary combustion aids.

After a feasibility study undertaken by University of Andalas, which delivered a positive result, PT. Semen Padang signed an MOU with Padang city regarding RDF. Use of RDF is based on standard specifications, which are in turn influenced by applicable local environmental regulations, impacts on kiln operation, cement quality, emissions and heavy metal content, which can be used as a national reference. The following table 8 describes the standards for each of the elements, which were developed through a series of discussions conducted by the Ministry of Industry and the Indonesian Cement Association and agreed upon by 10 cement companies in Indonesia.

Table 8. Standards required for RDF in Indonesia

Parameter	Unit	Limit value
Calorific value, min	kkal/kg	>=3,000
Cl	%	<=0.75
S	%	<=1
total water content	%	<=20
size	mm	<=50
form	-	Fluff
Na_2O	%	<=0.5
K_2O	%	<=1
MgO	%	<=2
P_2O_5	%	<=1
TiO_2	%	<=0.5
Trace Element (dry condition)		
Hg	ppm	<5
As	ppm	<200
Cd	ppm	<70
Cr	ppm	<1,500
Pb	ppm	<1,000
Sb	ppm	<200
Co	ppm	<200
Ni	ppm	<1,000
Cu	ppm	<1,000
V	ppm	<1,000
Zn	ppm	<5,000
Se	ppm	<50

Source: PT Semen Indonesia, 2017, Kemeterian Perdagangan, 2017

At present, however, Semen Padang and Padang city have been analysing the cost-benefit and operational sustainability of the RDF facility by comparing it with a Refuse Paper and Plastic Fuel (RPF) facility, which sorts out organic waste owing to its high moisture content. Using organic waste lowers the calorific value, which in turn lowers the value of material that the City can sell to PT. Semen Padang. Additional materials and drying steps are needed to reduce the moisture level and ash content and increase the calorific value if mixed waste is collected. The operational cost needs to be thoroughly factored in as this may represent a burden for the city budget. Therefore, to enable successful operation of the RPF it is recommended to separate the organic waste either at the TPA or at the source of generation, and handle it separately.

3.3. Financial situation

A) Government budget

The budget allocated to the waste management programme was 48% (or 2,521,277 USD) of the total city budget (APBD, USD 5,288,437.44) in 2021, the largest in Padang city among districts/cities in West Sumatra. Most of this is allocated to waste handling and facilities and infrastructure for TPA and TPS operations, with little allocated to supporting waste banks and community-based activities. With growing awareness of the fact that dumping increasing volumes of mixed waste shortens the life of the TPA, the need to reduce or divert waste entering the TPA is becoming more urgent. Reducing volumes of waste also has the benefit of reducing operational expenses for the TPA.

Table 9. City budget for waste management

Years	APBD DLH (USD)	Budget for waste management (USD)	%
2017	4,811,960.82	2,523,497.34	52
2018	4,520,958.11	1,585,212.65	35
2019	5,168,639.81	1,800,158.58	35
2020	4,205,530.70	1,809,915.02	43
2021	5,291,068.00	2,522,530.91	48

Source: DLH Padang City

B) Garbage and cleaning service fee

Based on Padang City Regional Regulation Number 11 of 2011 concerning Public Service Retribution, the Garbage/Cleaning Service Retribution is levied on garbage/cleaning services organised by the Regional Government. Waste management service is regulated in Perda No. 1 of 2016, which splits it into three categories: commercial, non-commercial and special costs. Table 10 shows waste management service fees by sector and type of business.

Table 10. Waste management fees

No	Retribution Object Type	Group	Fee (IDR)	Fee (USD)
A	**Commercial Retribution**			**USD/m^3**
1	Hotel/cottage/inn/guesthouse/	-	35,000	2.46
2	Lodging	-	35,000	2.46
3	Shophouse/Shop/Kiosk/Store	-	35,000	2.46
4	Motor/Car Show Room	-	35,000	2.46
5	Gas station	-	35,000	2.46
6	Public Facilities/Health Facilities	-	35,000	2.46
7	Shopping Centre	-	35,000	2.46
8	Restaurant/Catering	-	35,000	2.46
9	Bars/Discotheques/Pubs and the like	-	35,000	2.46
10	Workshop/Car Wash	-	35,000	2.46
11	Industry	-	35,000	2.46
12	Warehousing	-	35,000	2.46
13	Meeting/Exhibition Hall	-	35,000	2.46
14	Sports Facilities	-	35,000	2.46

No	Retribution Object Type	Group	Fee (IDR)	Fee (USD)
B	**Non-commercial Retribution**			
1	Apartment	-	29,000	2.03 USD/m^3
2	Education	-	29,000	2.03 USD/m^3
3	Dormitory	-	29,000	2.03 USD/m^3
4	Office	-	29,000	2.03 USD/m^3
C	**Special Retribution**			
1	Household building area	250 m^2 and above	15,000	1.40 USD/month
		From 200 to 249 m^2	10,000	1.05 USD/month
		From 150 to 199 m^2	7,500	0.53 USD/month
		From 71 to 149 m^2	5,000	0.35 USD/month
		70 m^2 and below	2,500	0.18 USD/month
2	Street Vendors (PKL)	Fruit	2,000	0.14 USD/day
		Cart	2,000	0.14 USD/day
		Food/beverage	5,000	0.35 USD/day
3	LPA users	Commercial	12,000	0.84 USD/m^3
		Non-commercial	7,500	0.53 USD/m^3
4	Crowd activity	-	51,000	3.58 USD/m^3

Source: DLH Padang City

Regional Income (PAD), which derives from taxes, public retribution and other sources, is one of the most important sources of finance for the region, and each region can freely regulate its use. DLH made efforts to collect retribution fees by cooperating with PDAM and charging a waste retribution in the water bill in areas where DLH collects waste directly from residents. In addition, DLH staff directly bill subjects of commercial and non-commercial retribution.

Part of the process involves the revenue treasurer transferring the PAD to the Padang city regional account. It has been noted that the ratio of total fees collected from waste generators against the target has dropped every year, though the total amount received has in fact increased owing to the expansion of PAD's targets in the waste sector from 2017-2020 (see table 11). However, community participation is still low in paying waste retribution fees. Further, since 2020 and the advent of the Covid-19 pandemic, the amounts received have dropped, which could be attributed to the suspension of waste management services.

Table 11. Regional income (PAD) of waste service

Years	Target (A: Rp)	Realisation (B: Rp)	(B)/(A) %
2017	580,947.05	599,577.58	103.2
2018	872,046.09	791,290.72	90.7
2019	1,049,921.59	880,689.87	83.9
2020	1,152,603.31	932,435.86	80.9

Source: Padang City Environmental Department

4. Waste flow analysis

4.1. Study area

Both a desk study and field survey were conducted to provide an overview of the waste flow and composition in Padang, both at the city and ward (kelurahan) level. Through discussions with DLH, five kelurahans (Kel.) from three sub-districts were selected as representative of the various regional conditions found in Padang City (see fig. 5 and table 12).

1. **Kel. Parupuk Tabing** and **Kel. Bungo Pasang** in Koto Tangah sub-district: sparsely populated

2. **Kel. Batu Gadang** and **Kel. Bandar Buat** in Lubuk Kilangan sub-district: predominantly forest and agricultural land

3. **Kel. Pasa Gadang** in Padang Selatan sub-district: City centre, more densely populated

Figure 5. Study area

Table 12. General information on the selected kelurahans

	Parupuk Tabing	Bungo Pasang	Pasa Gadang	Bandar Buat	Batu Gadang
Area	9.41 km^2	3.32 km^2	0.31 km^2	2.87 km^2	19.29 km^2
Population	20,368	12,885	5,753	16,303	8,174
Density (of population)	2.17/km^2	3.88/km^2	18.56/km^2	5.68/km^2	4.24/km^2
RW/RT	20 RW 82 RT	16 RW 53 RT	6 RW 24 RT	11 RW 45 RT	6 RW 31 RT
Commercial Activity*	Shops, restaurants, cafes.	Train stations, markets, shops, mini markets, restaurants.	Restaurants, mini food shops, grocery shops	PT. Semen Padang and other companies, shops, restaurants, and markets	
Office	Sub-district offices, schools, health facilities, hajj dormitories	Sub-district offices, schools, health facilities	Sub-district offices, schools, health facilities	Lurah Offices, health facilities, and schools	
Agriculture/Riceland	40 Ha Garden/Field; Protected Forest 61 Ha; Plantation 309 Ha (Koto Tangah District)		14 Ha (Padang Selatan)	Orchards/Farms 3,436 Ha; Forest 669 Ha; Sawah 578 Ha (for one Lubuk Kilangan District)	
Nearby waters	Batang Kuranji River dan Lubuk Minturun River	Batang Kuranji River dan Lubuk Minturun River	Batang Arau River	Air Putulalang River	Batang Idas River

Source: developed by the author

4.2. Field survey method

A waste generation and composition survey sampling were conducted at two types of sources (domestic and non-domestic) following SNI 19-3964-1994 for eight consecutive days. Weight and volume were measured and waste composition was identified in terms of organics (food waste and garden waste), wood, paper, plastic, glass, metal, diapers, and others (see fig. 6).

Figure 6. Waste composition

After classifying the waste, plastic debris was classified into three types based on economic value: plastic of high value, plastic of low value, and plastic packaging which has no economic value at present (see fig. 7).

Valuable Plastic

Not Valuable Plastic

Plastic Packaging (Sachet)

Figure 7. Plastic waste categories

A sampling of the generation and composition was carried out at domestic and non-domestic facilities. The domestic facilities comprised residential households, the sampling points of which were selected based on the income level according to the type of house. The non-domestic facilities included mosques, shops, offices, schools, food stalls, cafes, markets and clinics. Sampling was conducted at one facility per type in each kelurahan. Table 13 shows the number of domestic sampling points.

Table 13. Sampling points by income level

	Parupuk Tabing	Bungo Pasang	Pasa Gadang	Batu Gadang	Bandar Buat
Population	20,368	12,885	5,753	8,174	16,303
Sample population	143	114	76	90	128
Sample households	33	27	18	21	30
High Income (20%)	7	5	4	5	6
Middle Income (40%)	13	11	7	8	12
Low Income (40%)	13	11	7	8	12

4.3. Waste generation and waste handling

A) Padang City

Figure 8 shows the waste flow of Padang City in 2021. The average municipal waste generated in Padang City amounted to 660.5 tonnes/day in 2021, an increase of 7.9% from 612 tonnes/day in 2017, due to the rising population. This trend in rising volumes of waste with rising population is likely to continue if no measures are taken. All the sub-districts receive waste collection service, and waste directed to the TPA in 2021 amounted to 478 tonnes/day, representing 72% of the total waste generation. On the other hand, 133 tonnes/day of waste is unmanaged, being either burned or buried in open areas, or leaked into the surrounding environment.

The volume of unmanaged waste increased in 2020 due to the Covid-19 pandemic, when food waste and plastic waste from households increased. Research by Putri in 2021 shows that the share of food waste out of total waste increased from 64-70% before the pandemic to 65-72% during the pandemic (Putri, F.F., 2021). According to the Indonesian Environmental Scientist Association (IESA), the increase in waste generation in Indonesia occurred from March to May 2020, which indicates that food was consumed at home more frequently than eating out during the pandemic, due to lockdown or other restrictions related to the food business sector.

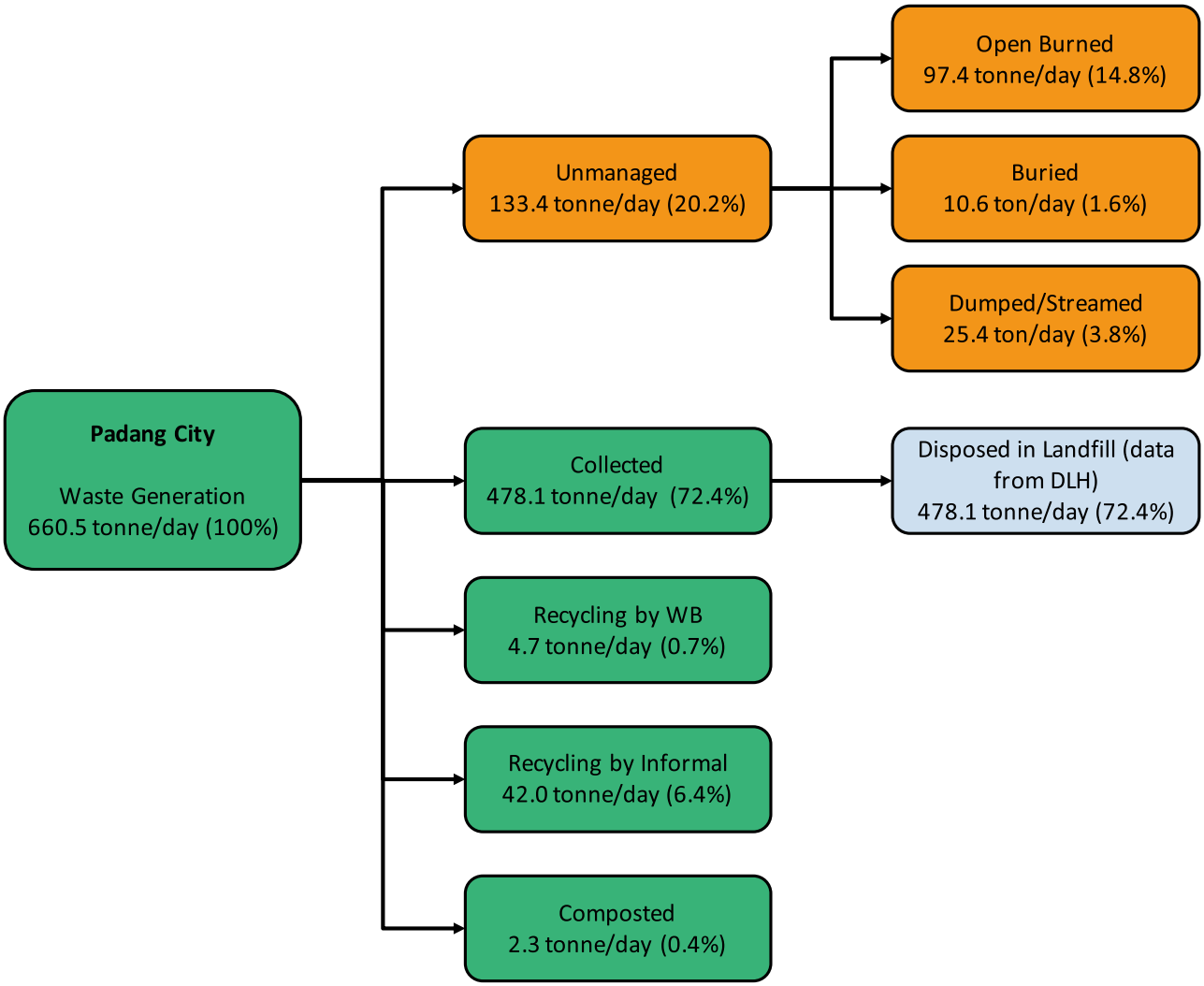


Figure 8. Waste flow of Padang City in 2021

Table 14. Waste flow in Padang City 2017-2021

Parameter	2017	2018	2019	2020	2021
Population (people)	927,168	939,112	950,871	973,152	982,884
Waste generation (tonnes/day)	612.00	640.48	657.88	665.00	660.50
Waste reduction (tonnes/day)	6.58	14.27	30.25	19.17	49.02
- by recycling by Informal Sector (tonnes/day)	4.00	7.00	28.50	16.45	42.03
- by recycling by Waste Bank (tonnes/day)	0.33	2.75	0.75	1.72	4.67
- by composting in TPS 3R (tonnes/day)	0.25	2.02	0.00	0.00	0.00
- by composting in TPA (tonnes/day)	2.00	2.50	1.00	1.00	2.33
Waste disposal in TPA (tonnes/day)	528.01	567.48	571.88	482.50	478.06
Unmanaged waste (tonnes/day)	77.41	58.73	55.75	163.33	133.42

Source: Padang City Environmental Department and field survey (2021)

B) Kelurahans

- Domestic sources
  The average generation from domestic sources (i.e., residents) in the five kelurahans was 0.27 kg/person/day, with the largest found in Kelurahan Parupuk Tabing at 0.37 kg/person/day and least in Kelurahan Batu Gadang at 0.21 kg/person/day (see fig. 9, left).

- Non-domestic sources
  As shown in fig. 9 (right), a large amount of waste from non-domestic sources is generated in Bungo Pasang and Parupuk Tabing, which is attributed to local markets. On the other hand, the highest amounts of non-domestic waste from the rest of kelurahans were generated in offices.

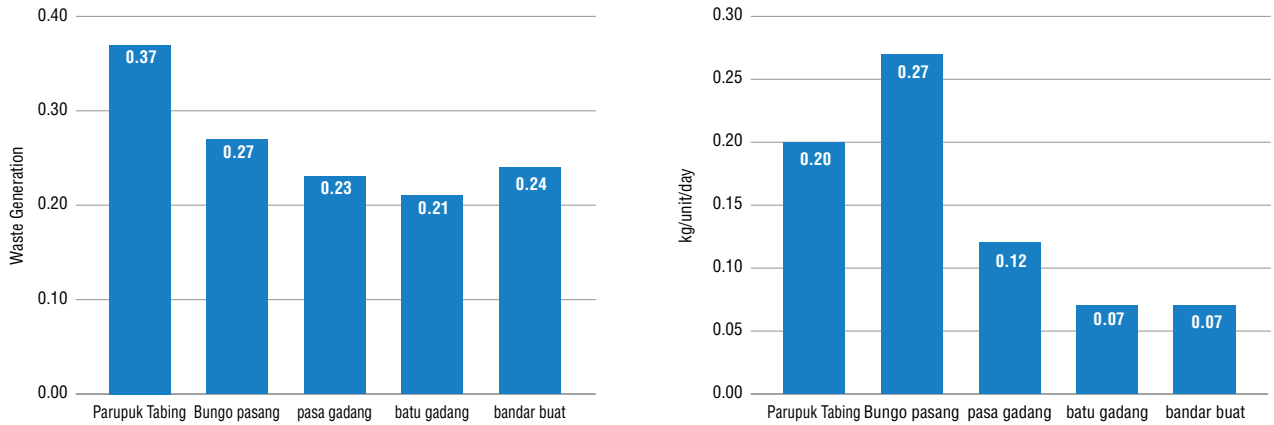


Figure 9. Average waste generation from domestic sources (left) and non-domestic sources (right) by kelurahan

4.4. Waste composition

A) Padang City

According to National Waste Management Information System (2021), of the total, 62% was accounted for by organic waste and 13% by plastic waste. Adding wood/twigs to the organic waste, a maximum of 70% of total waste can be diverted from the TPA if an organic treatment system were to be put in place. Likewise, a maximum of 34% of the total waste can be reduced from the total waste for recycling, based on the potential recyclability of plastics, paper, metal, glass, and rubber/leather.

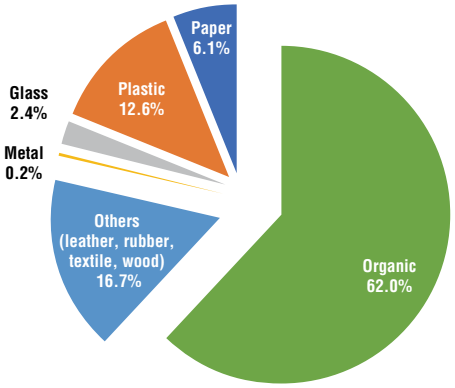


Figure 10. Waste composition in Padang City

B) Kelurahans

- Domestic sources

  Although food waste is the most significant portion of the total waste in all the selected kelurahans, the rate varies between 33.7-49.6%, which is lower than the city average (62%: fig. 10). Conversely, more plastic waste was found in the selected kelurahans than the city average. The significant finding was that nappies, which are usually made of polyethylene, accounted for more than 10% in Parupuk Tabing and Bungo Pasang (see fig. 11 below).

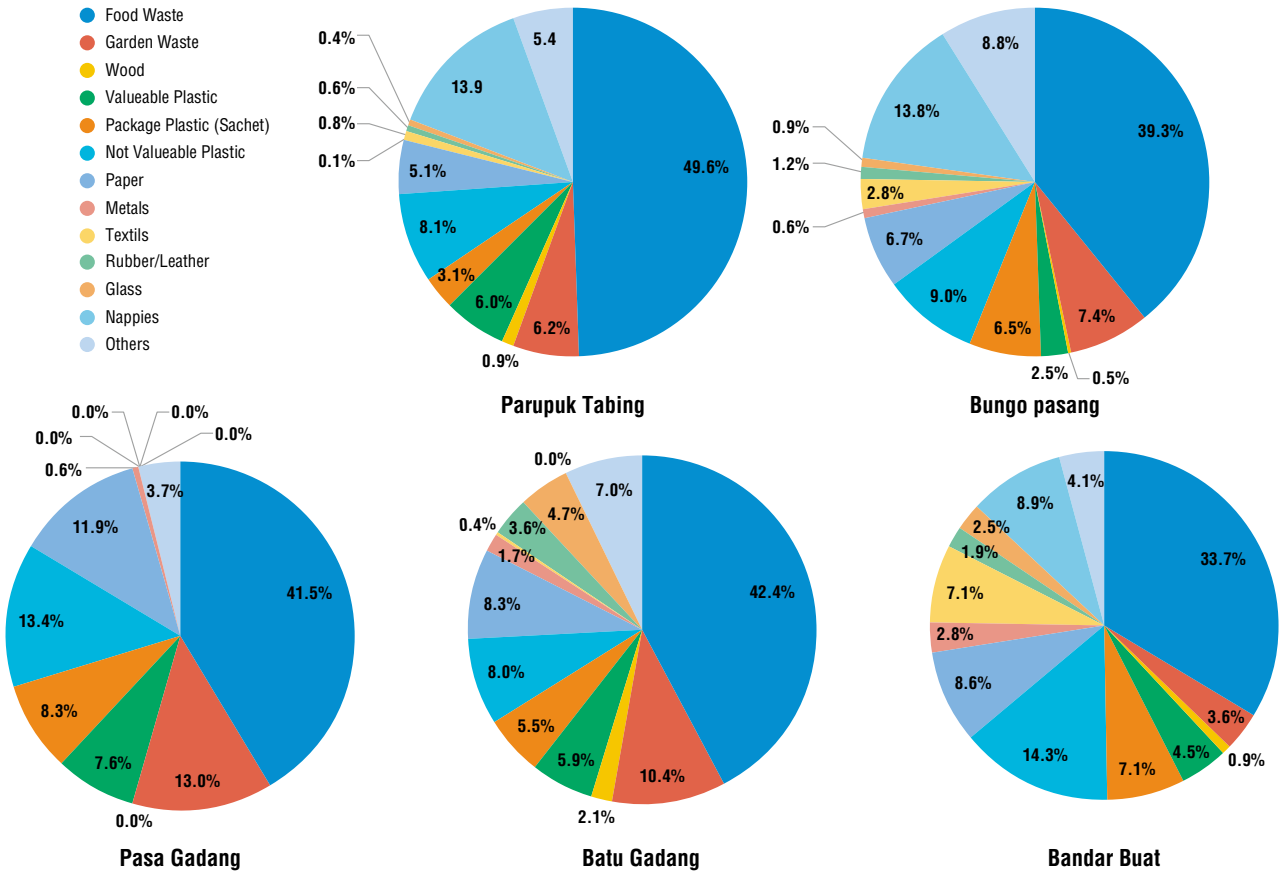


Figure 11. Composition of waste from domestic sources

- Non-domestic sources

  Similarly, with the waste composition from the domestic source, food waste from non-domestic sources comprises the primary waste in all kelurahans. Parupuk Tabing and Bungo Pasang generate very high rates of food waste due to the concentration of local markets – on average 1.29 kg/unit/day and 1.56 kg/unit/day in Parupuk Tabing and Bungo Pasang, respectively.

  For the other kelurahans, waste from offices comprises the largest portion among all facilities; Pasa Gadang, Bandar Buat and Batu Gadang generate 0.22-0.49 kg/unit/day. These kelurahans also generate large amounts of plastic waste.

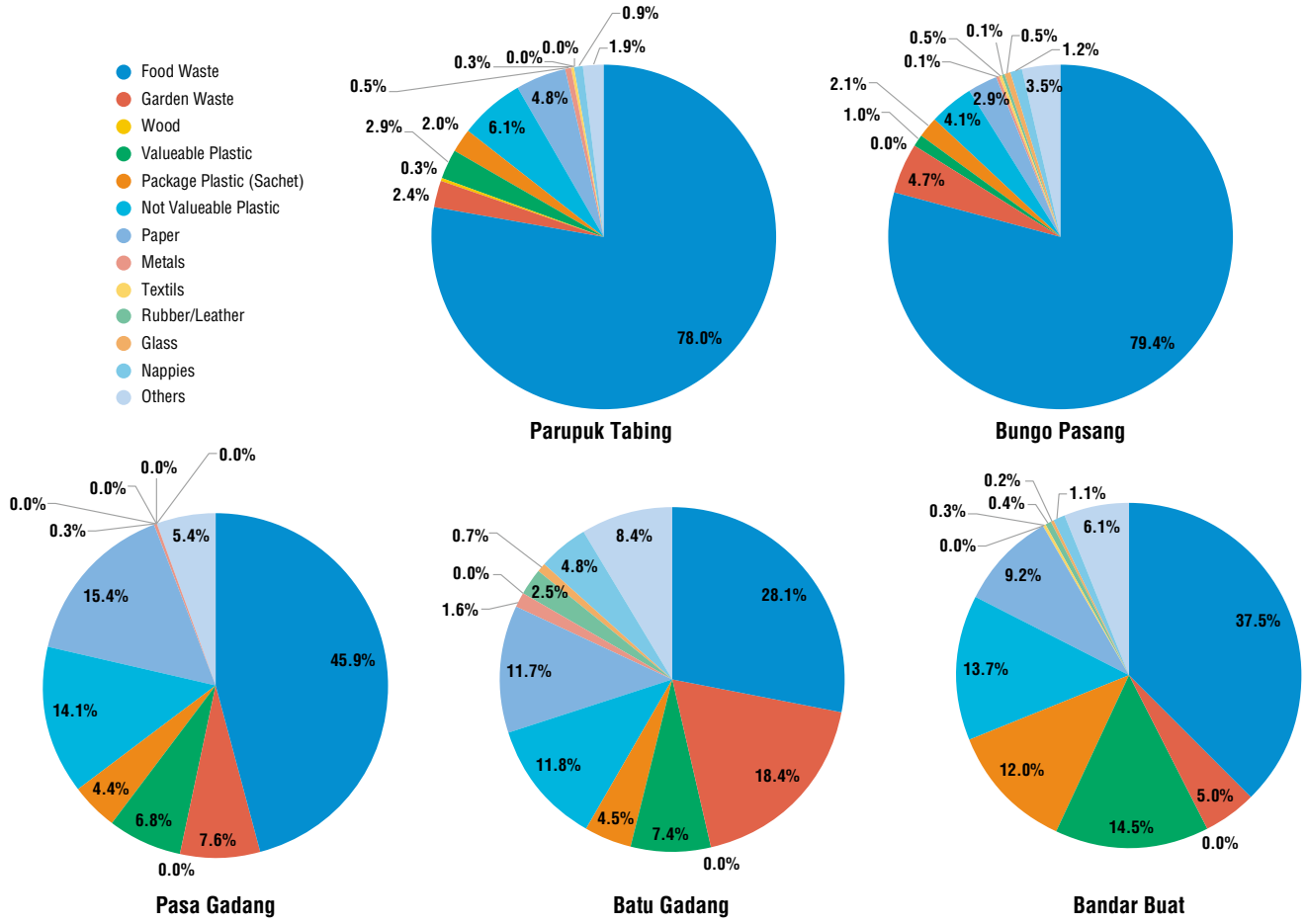


Figure 12. Composition of waste from non-domestic sources

4.5. GHGs and SLCPs emissions from the waste sector

Several types of GHG emissions, such as methane (CH_4), Carbon dioxide (CO_2) and Nitrous Oxide (N_2O) and SLCP emission such as BC, is emitted from municipal solid waste management (MSWM) in the city. Identification of hotspots of GHGs, SLCPs emissions across different stages from collection, transportation, processing, to final disposal and avoidance through resource recovery processes, is crucial for accurate assessment of overall climate impacts. On the other hand, under the UNFCCC framework, all countries must report the GHG emissions and reduction target from all the sectors including waste management sector to the UNFCCC secretariat through their NDCs. In addition, Climate and Clean Air Coalition (CCAC) member countries including Indonesia have to report the SLCP emissions and reduction target to CCAC. In this regard, IGES and CCAC developed Emission Quantification Tool (EQT) for cities to estimate the GHGs and SLCPs from MSWM sector.

Based on the result of the waste flow analysis (see Figure 8), GHG and SLCP emissions was estimated (see Table 15). The potential climate impact from GHG and BC emissions per tonne of generated MSWM in Padang City is 860.3 $kgCO_2$ equivalent per tonnes and 155.3 $kgCO_2$ equivalents per tonnes, respectively. The GHG emissions is mostly due to the high percentage of organic components being disposed at the final disposal site where methane gas is generated through decomposition process of the organic waste under an anaerobic condition. The large BC emissions is attributed to the large amount of waste (97.4 t/d) or 14.8% of the total generated waste being openly burned in the environment. In terms of annual potential GHG and BC emissions, about 0.2 million tonnes of CO_2 equivalent and about 37 thousand tonnes of CO_2 equivalent are emitted, respectively.

Table 15. Summary of GHG and SLCP emissions from current waste management systems (BAU)

Emissions from MSWM	Padang (2020)	
	GHG	BC
Collection (kg of CO_2-eq/tonne)	13.0	9.2
Composting (kg of CO_2-eq/tonne)	183.7	0
Recycling (kg of CO_2-eq/tonne)	-688.5	-18.5
Final disposal (Open dumping) (kg of CO_2-eq/tonne)	1,133.6	1.5
Burning at final disposal site (kg of CO_2-eq/tonne)	0	0
Uncollected waste (scattered & openly burnt) (kg of CO_2- eq/tonne)	370.7	399.9
Net GHGs/SLCP emissions (kg of CO_2- eq/tonne)* from Padang city	860.3	155.3
Annual net GHGs/SLCP emissions (tonnes of CO_2- eq/yearly generated waste)	207,409 (85%)	37,526 (15%)

* Net GHGs/SLCP emissions from the integrated system (tonnes/per tonne of generated waste) = Net GHG/SLCP emissions from waste **transportation** (kg/per tonne of waste) + Net GHG/SLCP emissions from **composting** (kg /per tonne of organic waste) × Fraction of generated waste use for composting + Net GHG/SLCP emissions from **recycling** (kg /per tonne of recyclables) × Fraction of generated waste use for recycling + Net GHG/SLCP emissions from **incineration** (kg /tonne of mixed waste) × Fraction of generated waste use for incineration + Net GHG/SLCP emissions from **landfilling** (kg/tonne of mixed waste) × Fraction of generated waste use for landfilling + Net GHG/SLCP emissions from **uncollected waste** (kg /per tonne of uncollected waste) × Fraction of generated waste remained as uncollected

4.6. Recycling potential

The potential recycling rate of waste was analysed based on the waste composition survey on domestic and non-domestic sources. Here, organic waste and materials like plastic, paper, metal, and glass are considered recyclable waste with economic value.

On average, 50.3% of the total waste from the domestic sources is organic waste with the potential for composting or bio-digestion. Moreover, 16.3% of the total from the domestic sources can be recycled, provided appropriate sorting and cleaning take place.

As for waste from the non-domestic sources, 61.5% of the total waste has the potential to be composted or bio-digested, and 16.1% has the potential to be recycled. Parupuk Tabing and Bungo Pasang, where market waste dominates, have a high potential to reduce organic waste generation. On the other hand, Pasa Gadang, Batu Gadang, and Bandar Buat have a high potential for waste reduction through recycling.

If waste from domestic and non-domestic sources are combined, a higher rate of waste reduction could be realised in Parpuk Tabing and Bungo Pasang through better organic waste management. In contrast, a higher waste reduction rate can be expected through recycling in Pasa Gadang, Batu Gadang, and Bandar Buat than in the other areas.

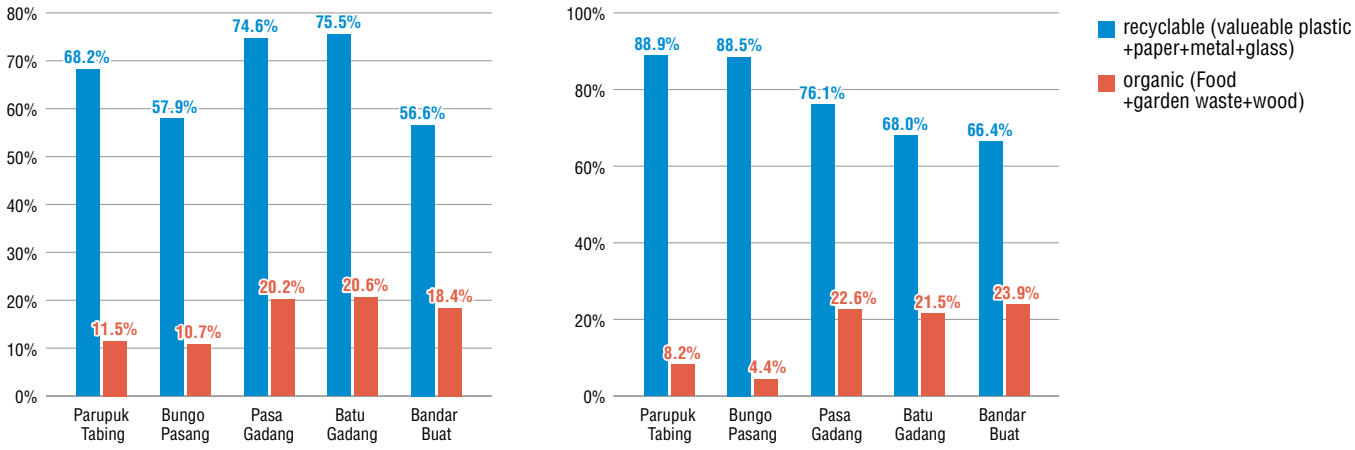


Figure 13. Waste with economic value (Right: domestic sources; Left: non-domestic sources)

4.7. Waste reduction

Based on a research conducted by Sustainable Waste Indonesia in 2019, only 3% of Indonesia's total waste was recycled and the rest ended up in final disposal sites (TPAs). Compared to the national average, recycling in Padang city is more advanced, mainly due to the collection performed by the informal sector. According to DLH and the field survey undertaken in 2021, the amount of waste reduced through recycling and composting was 49.0 tonnes/day in the city, or 7.4% of the total waste generated; 42.0 tonnes/day (6.4%) was recycled by the informal sector, 4.7 tonnes/day (0.7%) by waste banks, and 2.3 tonnes/day (0.4%) by composting. When summed up, the resulting overall waste reduction rate is far short of 24%, which is the city's target to be achieved by 2021 according to JAKSTRADA 2017-2025. Drastic improvement and substantial efforts are therefore required in waste management to achieve the JAKSTRADA target.

On the other hand, in terms of waste handled, 478.1 tonnes/day (72.4%) of the total waste ended up in the TPA, with the remaining 133.4 tonnes/day (20.2%) unmanaged. Compared to the target rate of 74% for waste handling by 2021 set in JAKSTRADA 2017-2025, the target has mainly been achieved. It is, however, important to point out that aiming to transport maximum amounts of collected waste to the TPA does not always contribute to environmental protection. This is because the current TPA is not operated as a sanitary landfill but as a non-controlled disposal site, and as such poses risks of air and water pollution, contributes to global warming due to emissions of greenhouse gases and methane gas, and poses health risks for those living or working in the TPA's surroundings.

Fig. 14 shows the historical trend of daily waste generation, reduction, and handling amounts. The handling amount in the graph represents the amount of waste disposed of in the TPA. The fact that unmanaged waste increased considerably over 2020-2021 could be attributed to the Covid-19 pandemic, resulting in reduced level of waste collection service or increase in waste burning at individual households due to lockdown or fear of contagion. However, burning waste generates emission of black carbon, particles, and CO_2, all of which contribute to air pollution or global warming. Certain measurement has to be taken based on clear and correct information to reduce unmanaged waste while protecting human health from air pollution.

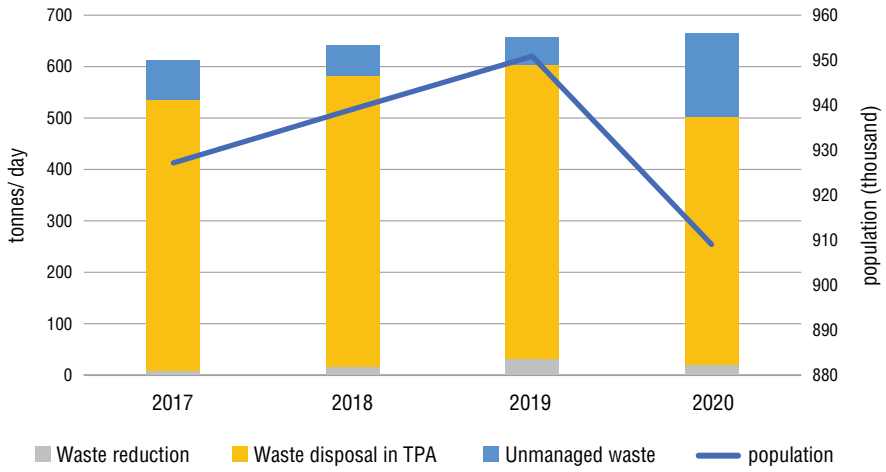


Figure 14. Waste reduction and waste handling in Padang City

5. Awareness and practices on the ground

5.1. Survey method

Interviews and the KAP surveys were conducted to understand the perception of the waste generators in Padang city on waste as well as actual practice of waste management. The term 'waste generator' refers to any person who generates solid waste at a domestic or non-domestic facility, and represents wastes from residential, commercial, academic, and public areas.

The KAP survey is an assessment tool used to quickly determine the level of knowledge, attitudes, and practice (KAP) trends of populations in a survey area. The results provide both quantitative and qualitative information and reveal any misconceptions or misunderstandings that may represent obstacles to behaviour change. It is important to note that a KAP survey reveals only what was stated, and that considerable gaps may exist between what is said and what actual actions take place.

The KAP components are as follows:

1. Knowledge: what is known
2. Attitude: what is thought or intended to do
3. Practice: what is done

Interviews and KAP surveys were carried out online and on-site in order to reveal the general level of knowledge, attitudes, and practices of the waste generators in the selected kelurahans regarding the current waste management by asking questions to the waste generators as samples of the population. The questions used in the KAP survey and the interview are shown in table 16.

Table 16. Questions for the KAP survey

Subject / Topic	Questions
Concern about and solutions to waste issues	- Are there any concerns about waste issues in the community? * Please say what the issues are. - What are the consequences if such problems continue? - What are your suggestions to deal with such problems? - In your opinion, what can you do to be part of the solution? - To overcome the waste problem in your community, how much more would you be willing to pay every month and to whom?
Awareness and practice on waste separation at source	- How do you dispose of your waste? (method of disposing of mixed waste, organic waste, recyclables, and waste without value) - Do you separate waste? Why or why not? (motive for recycling) - If you separate waste, how do you have the sorted waste collected? - Are there any regulations regarding the sorting of waste at the source in your community, and if so, what are the rules? - Have you ever heard about sorting waste at the source? - Circle all kinds of waste that you think is organic waste and inorganic waste. - Have you disseminated the need for waste separation to your family members, coworkers, friends and neighbours?
Awareness of open burning	- How often do you burn garbage? Mention all types of garbage that you burn. - How often do you see someone burning waste in your neighbourhood? - In your opinion, does burning waste provide benefits or cause concerns? - Have you ever heard about stopping waste burning? - Have you warned anyone to stop burning waste? Why or why not? - Are you aware if there are rules about burning waste?
Awareness of littering and open dumping	- How often do you litter waste on streets, open areas, or into rivers? Mention all types of waste that you litter. - In your opinion, does littering provide benefits or concerns? - Have you ever heard about stopping littering? - Have you warned anyone to stop littering? Why or why not? - Who should pick up waste scattered on land/in rivers? - Who should clean the streets, open areas, and riverbanks? - Are you aware if there are rules about waste littering?
Awareness and Practice on 3Rs	- What are the 3Rs? - Have you ever received training or information through awareness-raising activities on the 3Rs? - In your opinion, how important is it to practice the 3Rs? Why? - In your opinion, who should be responsible for management of the 3Rs? - Do you have any advice on promoting the 3Rs?

5.2. Results

A) Respondents

The number of respondents who generated waste from domestic and non-domestic facilities totaled 264. Fig. 15 shows the ratio of respondents by gender. Respondents were requested to select one person in charge of handling waste at home or at the sampled facility to respond to the interview and the KAP survey. The results show that women were more involved in handling waste than men.

- Kel. Parupuk Tabing: 71 (people)
- Kel. Bungo Pasang: 49
- Kel. Pasa Gadang: 42
- Kel. Batu Gadang: 39
- Kel. Bandar Buat: 63

Total: 264

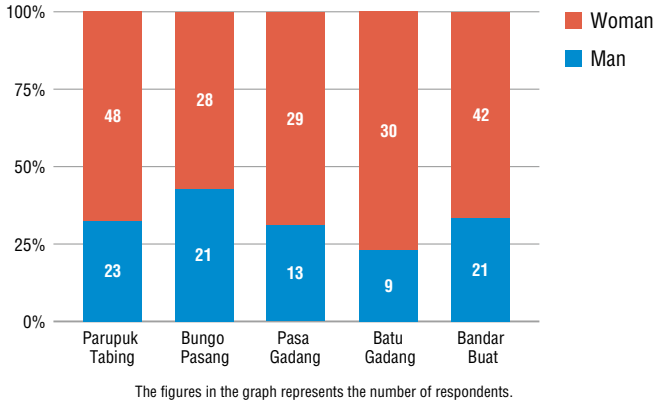


Figure 15. Respondents by gender

B) Concerns about waste issues

Figure 16 shows that nearly 80% of the total respondents have concerns about waste, except for those in Bandar Buat, who have a lower level of concern. Most respondents are concerned about littered waste. In response to the consequences of the concerns, the dominant answer was environmental pollution including water and air pollution (see fig. 17). Other responses included health problems caused by pollution, flooding caused by clogged waterways and drains due to littered waste, and deterioration of landscape and hygiene conditions. The answer "I do not know" from respondents in Bandar Buat fits with the low level of concern expressed on the issue of waste for nearly half of the respondents.

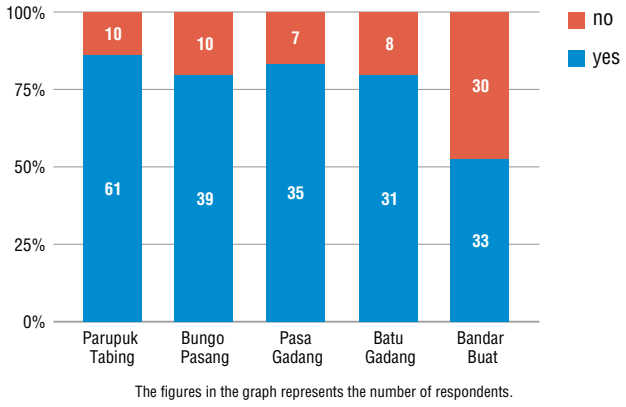


Figure 16. Concern about the waste issue

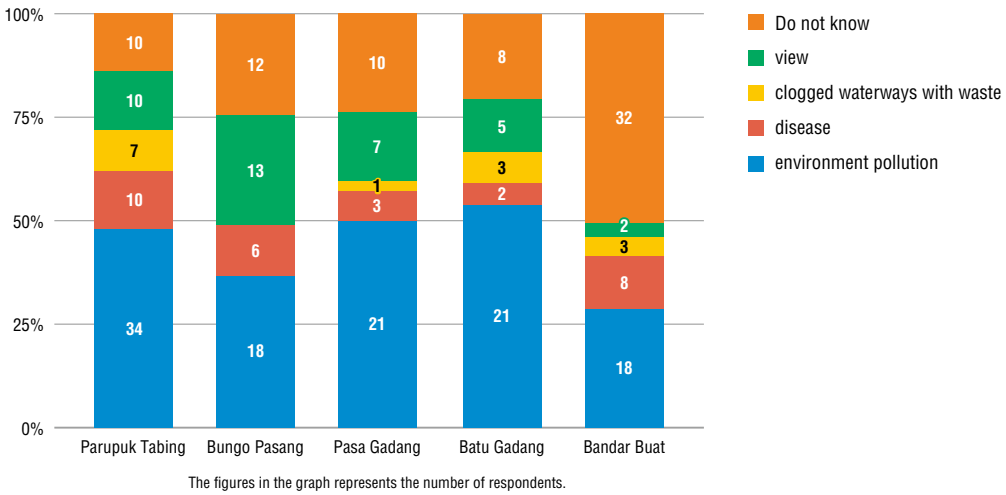


Figure 17. Possible consequences of waste issues

C) Suggested solutions to waste issues

Suggestions from respondents to overcome waste issues were grouped into four categories: technical training and improvement, awareness, laws and regulations, and other. The dominant answer was raising awareness, followed by technical training for improvement of waste handling (see fig. 18). It is noteworthy that nearly 8% of respondents in Batu Gadang believes that burning waste is one of the ways to overcome the waste issue as it can reduce waste volumes. Although few suggested "laws and regulations" as part of direct solutions – possibly because law enforcement is weak in Padang city – nearly half of respondents do not separate waste because of absence of laws and regulations (see fig. 22). In other words, changes in waste handling practices and habits cannot be expected without the introduction of laws and regulations.

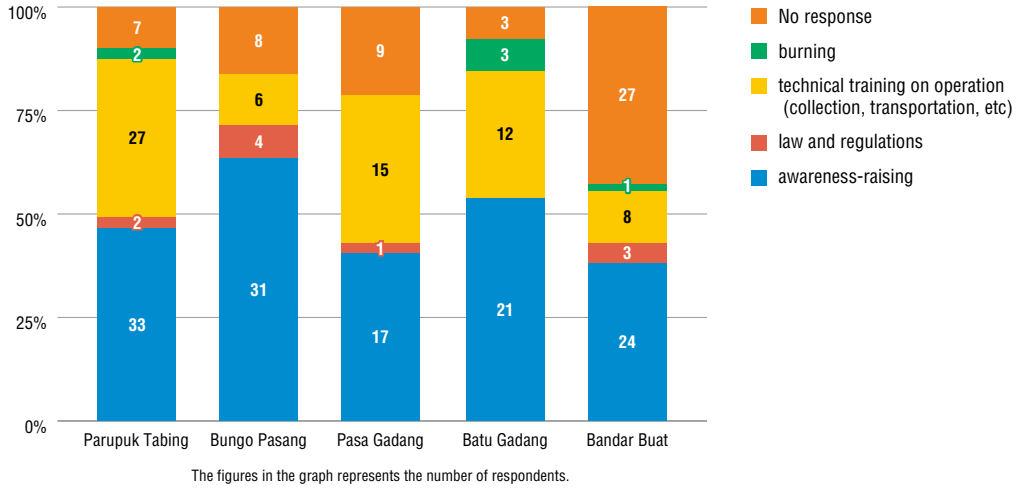


Figure 18. Suggestions to solve waste issues

In response to the question on willingness to pay to solve waste issues, the dominant answer was to pay an additional 25,000 IDR or lower per month, though many still do not want to pay more. In Pasa Gadang, the city centre, more than 20% of respondents answered that they could spend more than 26,000 IDR additionally per month (see fig. 19) to solve waste issues.

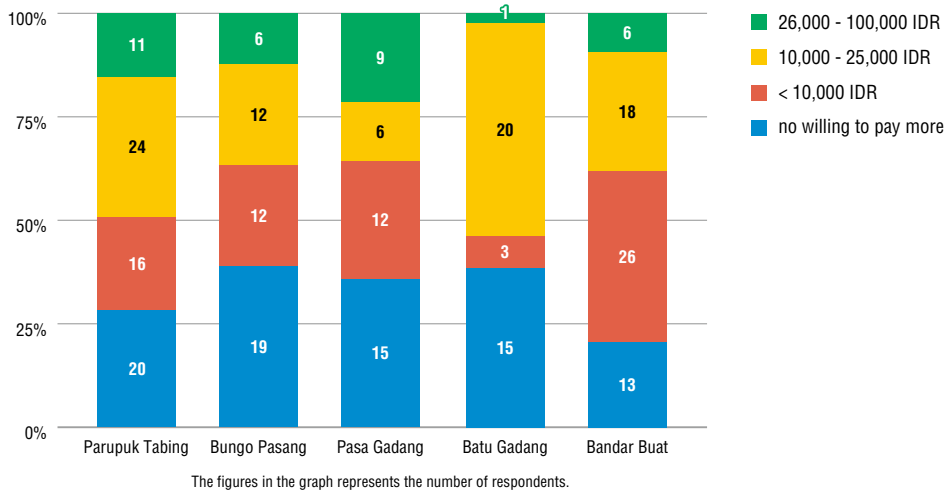
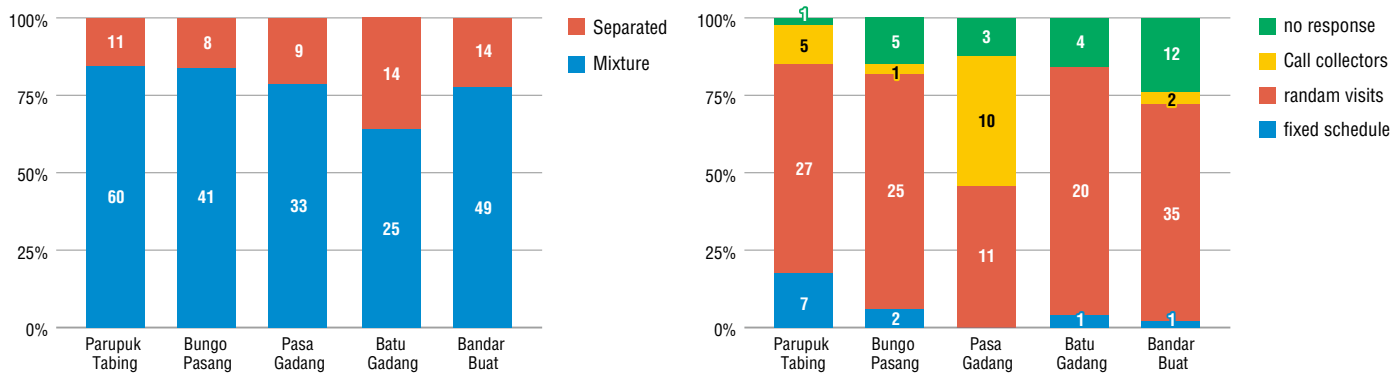


Figure 19. Willingness to pay as a solution to waste issues

D) Waste separation at source

The left graph of fig. 20 shows the current practice of waste separation at the source. Nearly 80% of the total respondents in all kelurahans except Batu Gadang dispose of mixed waste without segregation. In Batu Gadang, about 36% of the respondents separate waste at the source. This result contrasts with the graph on the right, which shows how the sorted waste is collected. In Pasa Gadang, 40% of respondents answered that they call waste collectors to have them pick up recyclables. In contrast, 65-80% of the respondents in other kelurahans do not call but hand over recyclables upon random visits from waste collectors. It can therefore be concluded that recycling is better organised in Pasa Gadang, located in the city centre, assuming that a recycling business can be systematically established between collectors and waste generators.



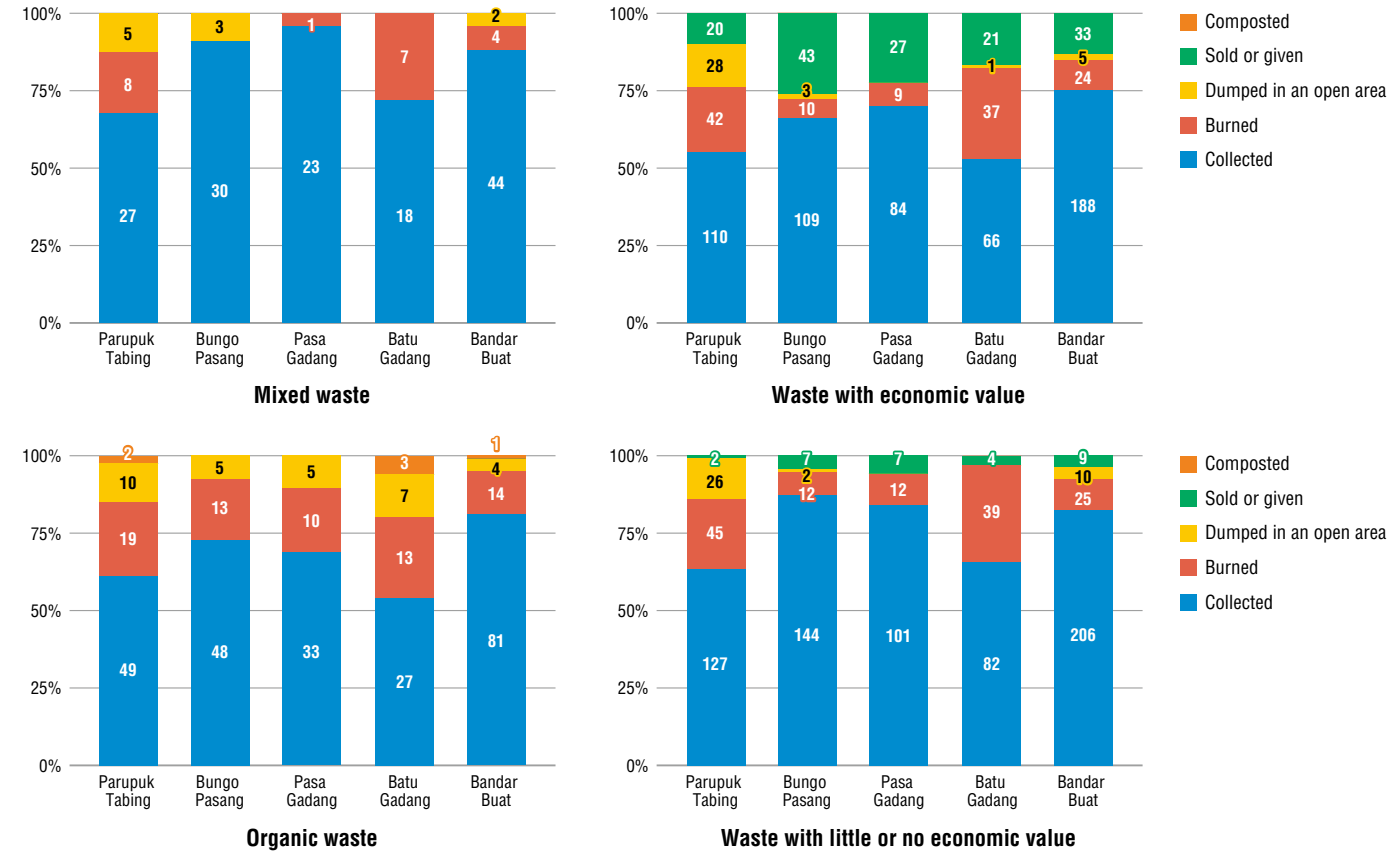
The figures in the graphs represent the number of respondents.

Figure 20. Practice of waste separation at the source (left); existence of fixed collection day (right)

A detailed interview was conducted for those who separate waste at the source. The waste is classified into four types as follows, to reveal how each type of waste is treated or disposed of:

- Mixed waste
- Organic waste; kitchen waste and garden waste
- Recyclable waste (waste with potential for recycling); paper, cardboard, PET bottles, metal cans, glass bottles
- Waste without economic value: plastic bags and films, cork waste, plastic, batteries, and electronic waste

Fig. 21 shows the four different results based on the type of sorted waste. A common finding is that most respondents depend on the available collection service for treatment or disposal regardless of the type of waste. Organic waste is more likely to be burned or dumped in all kelurahans, and composting is not commonly practice at the household level. Recyclables are more likely to be given away or sold than dumped except for Parupuk Tabing. It is important to highlight that the ratio of burning waste is relatively high regardless of the type of waste in Batu Gadang and Parupuk Tabing compared to other kelurahans. As for Parupuk Tabing, waste dumping occurs at a higher rate than in the other kelurahans.

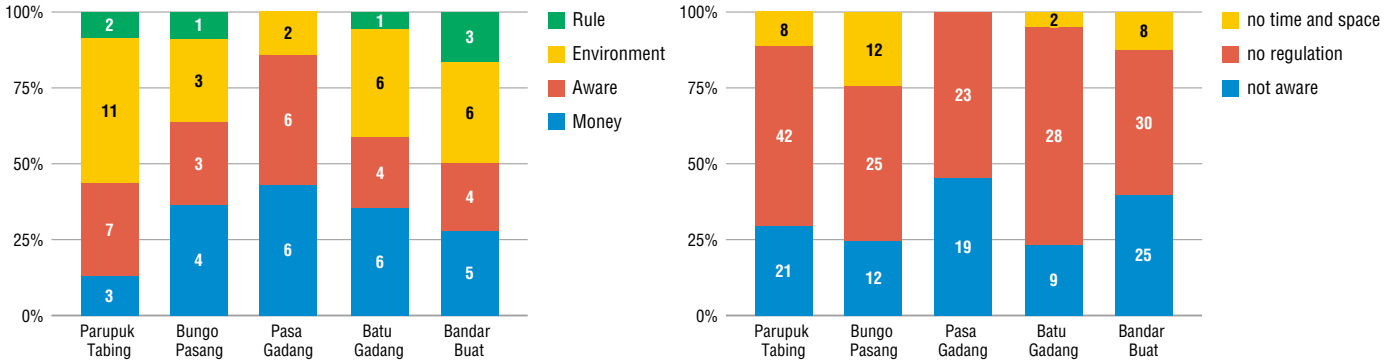


The figures in the graphs represent the number of respondents.

Figure 21. Treatment and disposal methods by type of waste

Fig. 22 shows the reasons why waste is separated or not. Reasons differ from place to place, but the main reasons or motives are awareness about the environment, and awareness of/incentive to raise income by selling recyclables. In Pasa Gadang and Batu Gadang, the perception of recyclables as valuable materials is high. On the contrary, those in Perpuk Tangang separate waste due to environmental concerns rather than to make money by trading waste. Answers from an interview support these results, from which it was found that approximately 17% of the respondents who separate waste for recycling in Pasa Gadang make 10,000-15,000 IDR per month by selling recyclables, whereas 80% of those in Parupuk Tabing separate and hand over recyclables to waste collectors for charity. Overall, giving away recyclables is considered a charity activity in the target kelurahans.

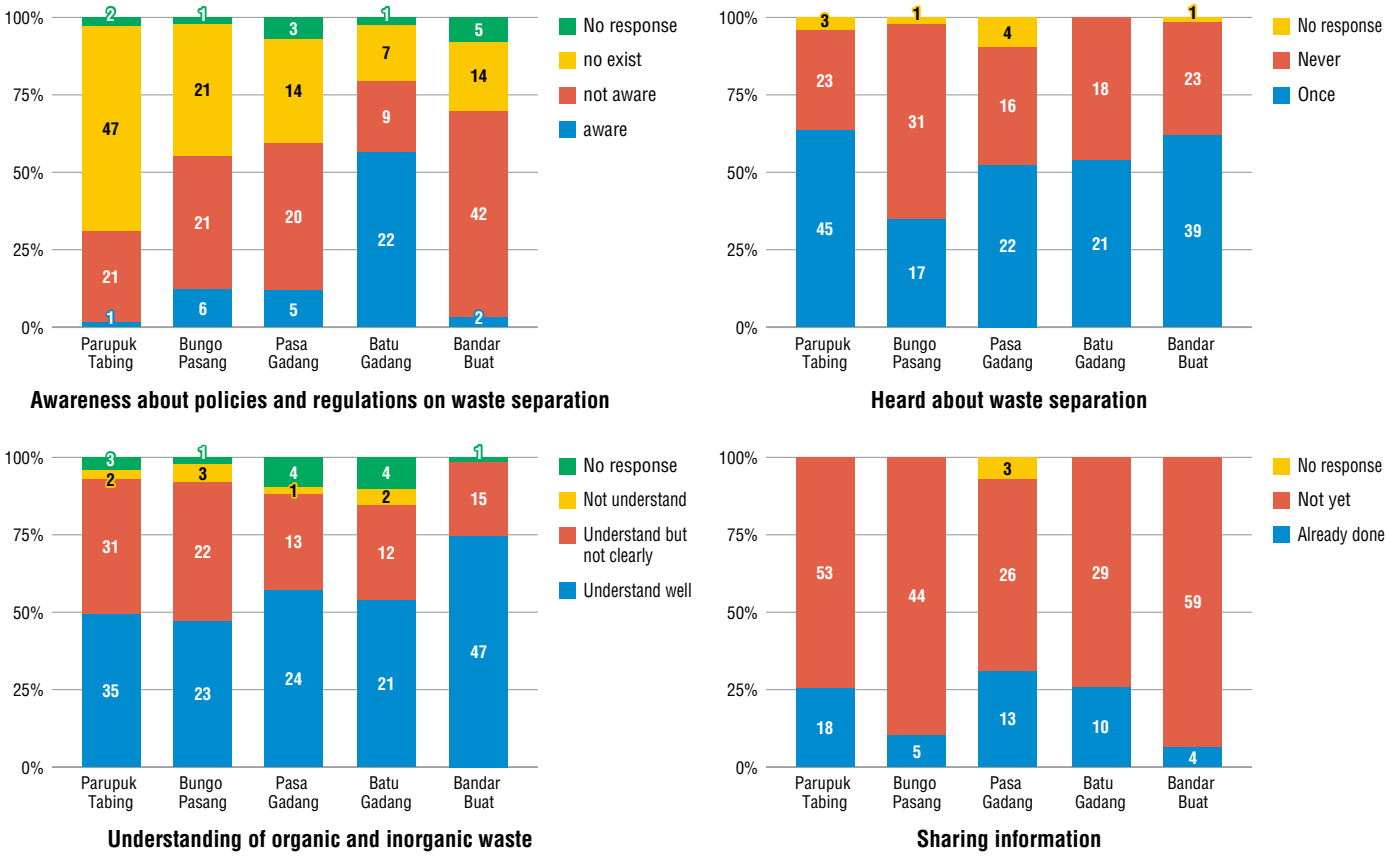
On the other hand, responses as to why waste is not separated was dominated by "weak enforcement of existing regulations", which explains the public sentiment that it is not necessary to separate waste.



The figures in the graphs represent the number of respondents.

Figure 22. Reasons for waste separation (left) and non-separation (right)

Below, we analyse how awareness has influenced the practice of waste separation. According to fig. 23, on average 78% of the respondents answered either that they are not aware of waste separation regulations or do not believe such regulations exist in Padang city.



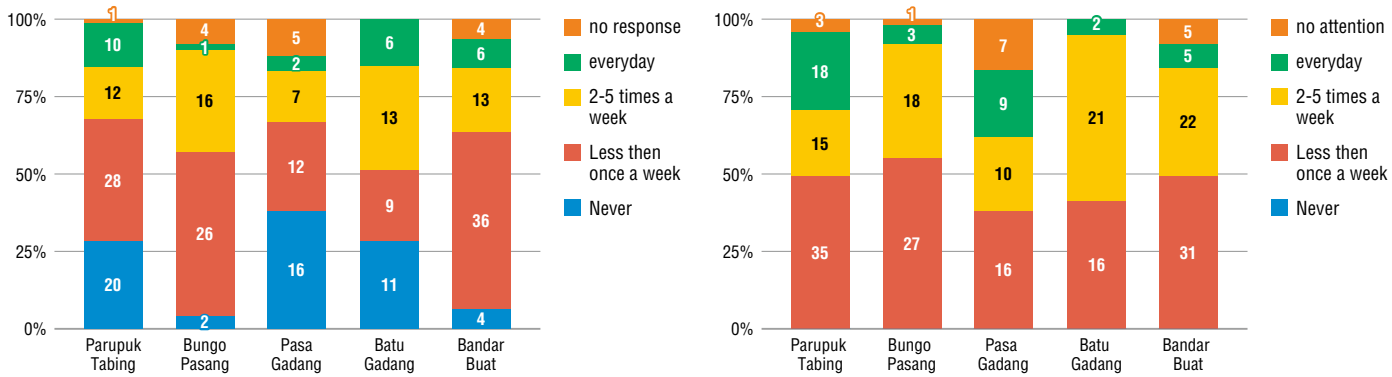
The figures in the graphs represent the number of respondents.

Figure 23. Awareness of waste separation at source

Although more than half of the respondents in Batu Gadang answered that they knew about regulations on waste separation, 46% of respondents had never known about the information in detail. It is presumed that nearly 80% of the respondents had not promoted waste separation among family, coworkers, friends and neighbours because they had not fully understood the necessity of doing this or had not been convinced to take part in waste separation. However, nearly half of the respondents had a good understanding of distinguishing organic waste from inorganic waste. To increase the awareness and practice of waste separation therefore, law enforcement, dissemination of correct information, and training are needed and should be practiced repeatedly.

E) Open burning

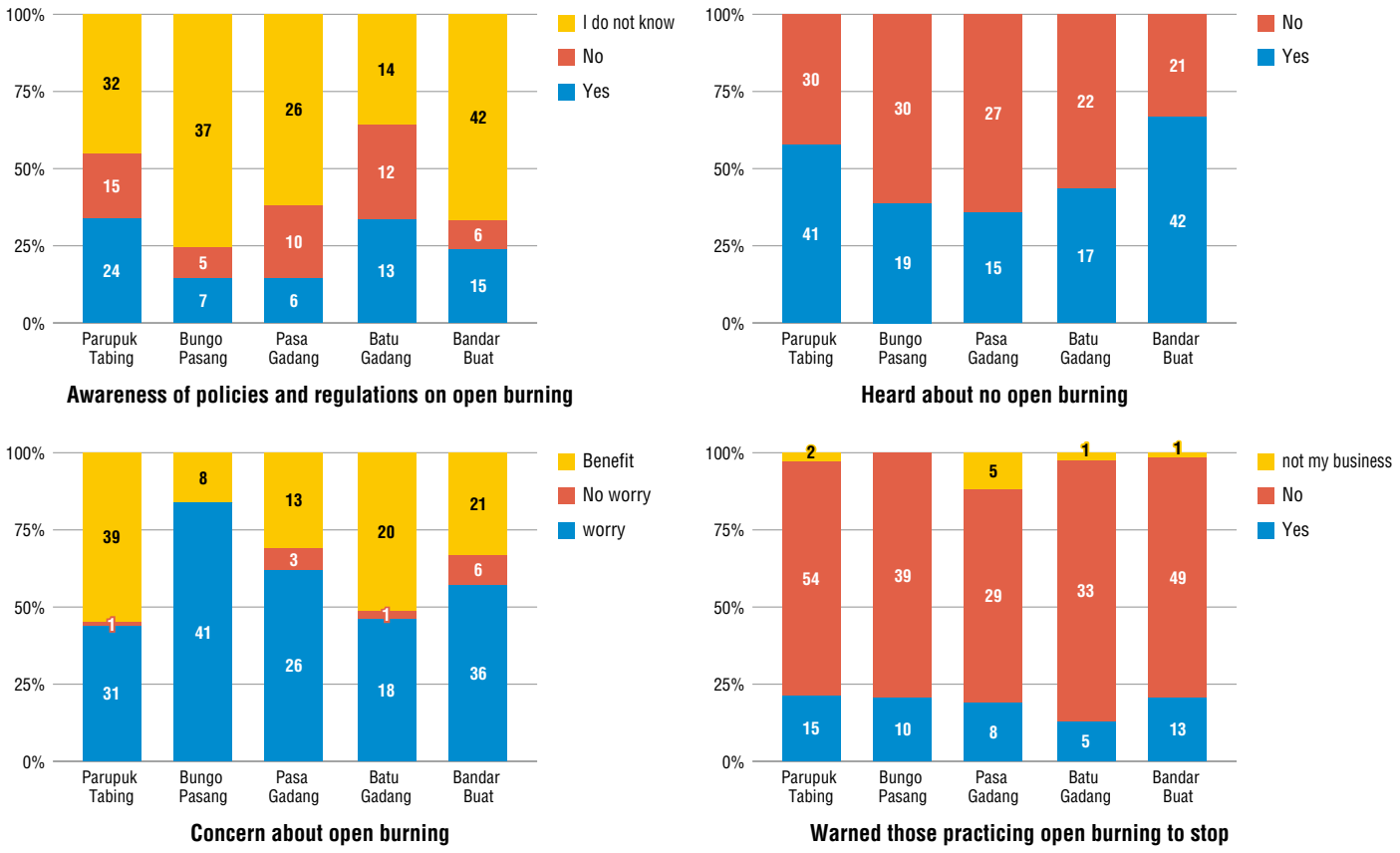
Fig. 24 shows the frequency of practice of open burning (left graph) and frequency of observation of open burning (right graph). Though some respondents answered they have never practised open burning, no one stated that they had never observed waste burning outside. Open burning is common in all the kelurahans, particularly in Batu Gadang and Parupuk Tabing. Nearly 15% of the respondents practice open burning every day though about 30-40% had never practiced open burning. However, when it comes to the observation of waste burning, nearly half respondents see people burning waste at least once a week.



The figures in the graphs represent the number of respondents.

Figure 24. Frequency of open burning practice (left) and frequency of observation of open burning (right)

To understand the level of awareness of open burning, questions related thereto were posed. Fig. 25 shows cognition and perception about open burning. Regarding the policies and regulations on open burning, more than 65% of the respondents answered either that they do not know about or are not aware of them. This rate exceeds 80% in Pasa Gadang and Bungo Pasang. Interestingly, respondents from these two kelurahans are more concerned about open burning than the other kelurahans. In contrast, more respondents from Batu Gadang and Parupuk Tabing instead answered that open burning is beneficial because it can reduce waste. It is presumed that people in Batu Gadang and Parupuk Tabing practice open burning without concern. On the contrary, fewer people in Pasa Gadang practice open burning possibly due to a lack of information, thus resulting in a cautious approach due to fears of its impact. In all kelurahans, 70% or more of the respondents had not warned those who practise open burning to stop doing so. The reason behind this is that they think it is not their responsibility to warn them, and that they expect a responsible agency to control open burning. It is assumed that the public is used to the practice of burning waste outside, i.e., that it is considered normal within society. From this analysis it could be concluded that stopping this practice in Padang city presents a challenge, especially in suburban or rural areas.

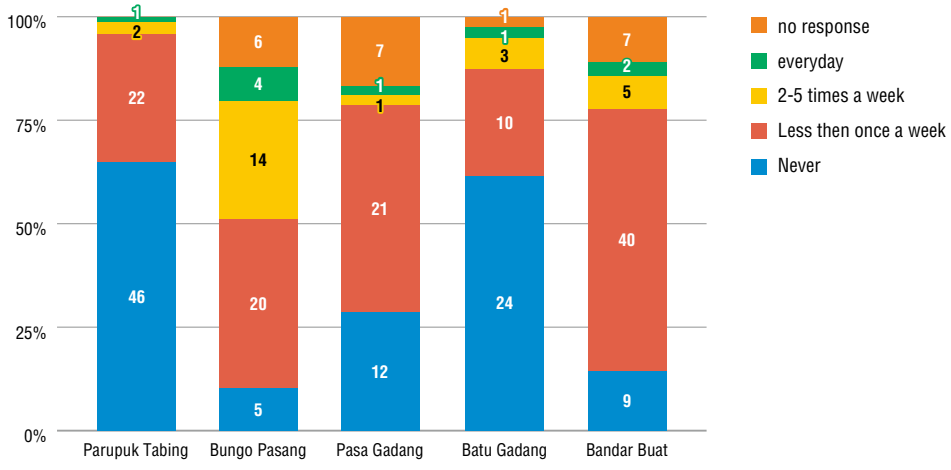


The figures in the graphs represent the number of respondents.

Figure 25. Awareness of open burning

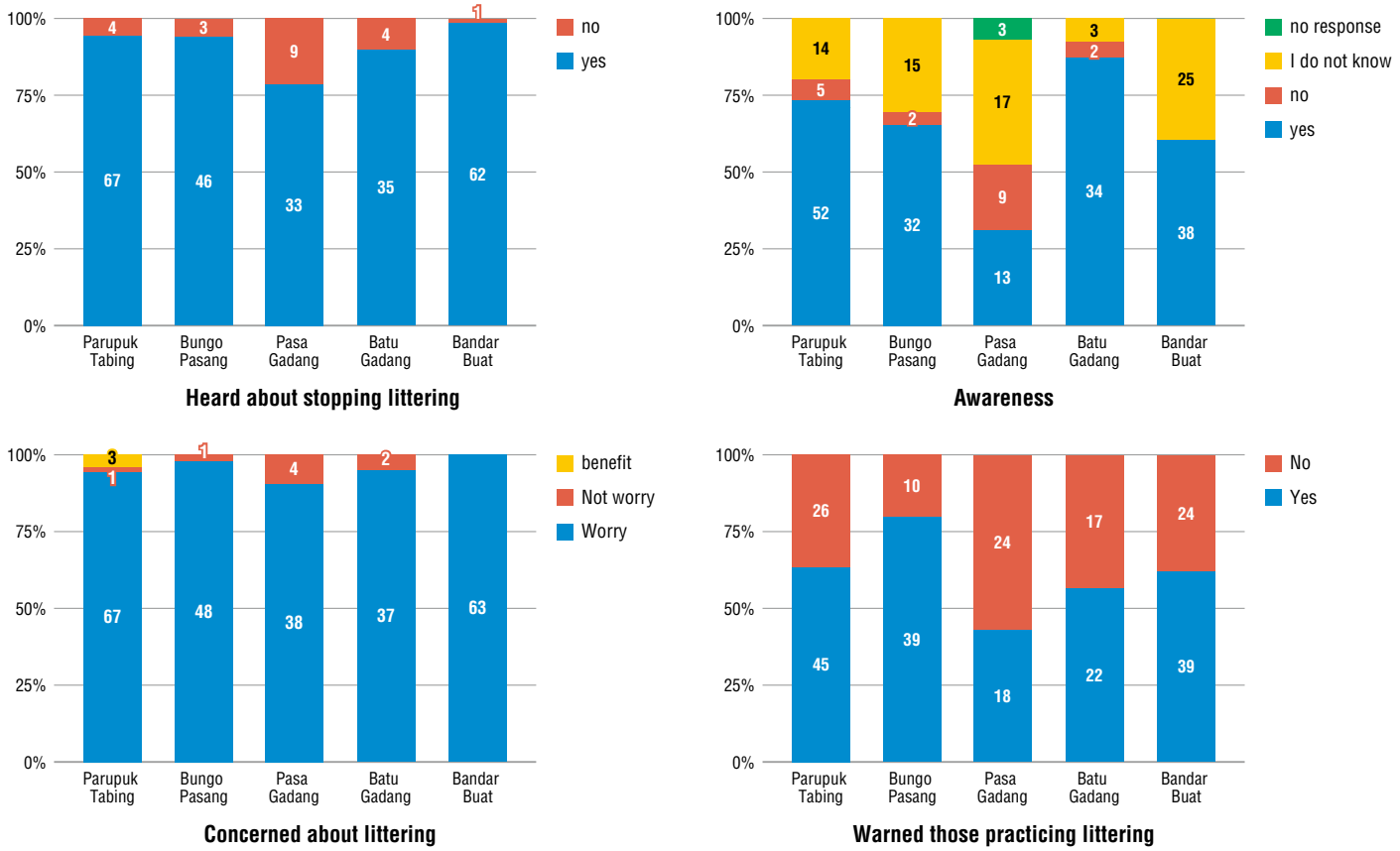
F) Littering and open dumping

In opposition to the result for open burning, more respondents in Parupuk Tabing and Batu Gadang answered that they never litter waste, while respondents in Bungo Pasang litter more than twice a week. (See fig. 26)



The figures in the graph represents the number of respondents.

Figure 26. Frequency of practice of littering

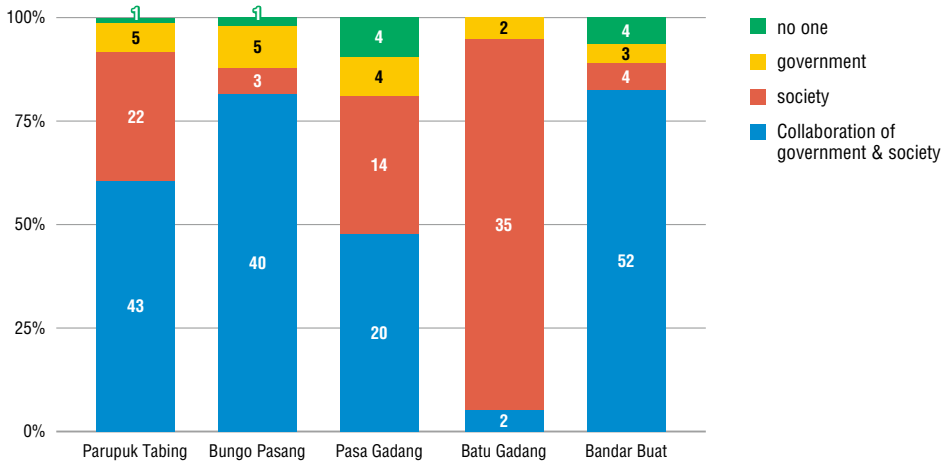


The figures in the graphs represent the number of respondents.

Figure 27. Awareness of littering

In Parupuk Tabing and Batu Gadang, where littering does not occur often, more respondents are aware of the policies and regulations on open dumping and littering. Though almost all respondents are worried about the consequence of waste littering, this concern does not stop them from littering, particularly in Bungo Pasang. At the same time, however, more people tend to warn litterers to stop, unlike the warning for open burning.

In response to the question about who is responsible for cleaning open areas, around 85% of the respondents in Bungo Pasang and Bandar Buat, where littering occurs at a higher rate, answered "collaboration of government and society", whereas the same answer was chosen by 50% of the respondents in Parupuk Tabing and Pasa Gadang where littering occurs less often. In Batu Gadang, nearly 80% of the respondents said it is society's responsibility.

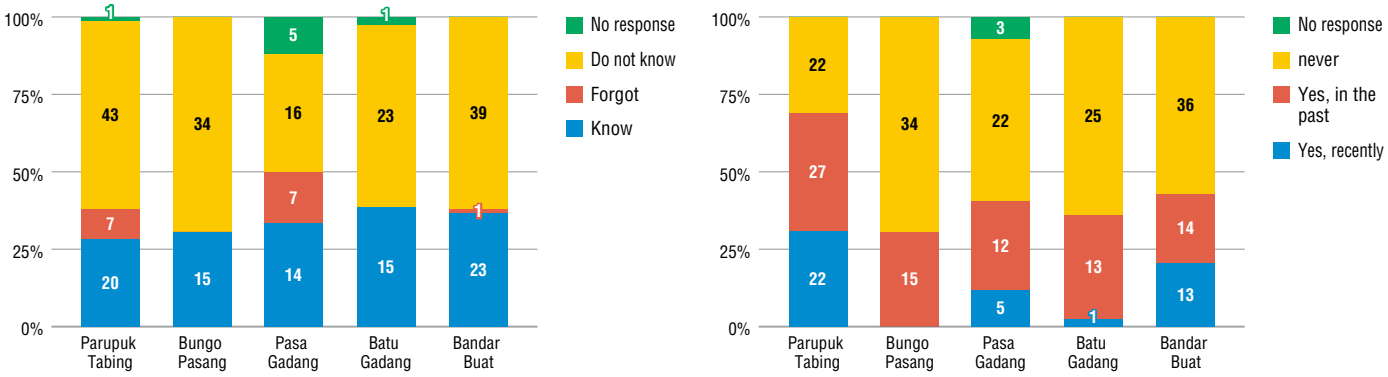


The figures in the graph represents the number of respondents.

Figure 28. Responsible entity for cleaning open areas

G) 3Rs

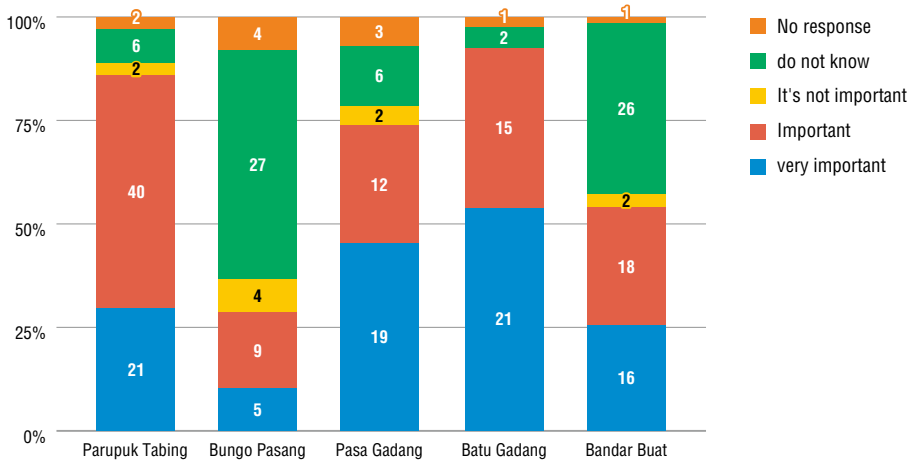
More than half of the respondents in all kelurahans do not understand the 3Rs. This result seems to be attributed to whether they had been previously informed about the 3Rs. Another finding from fig. 29 is that the sum of those who had received messages about 3R so far is greater than those who remember the correct meaning of the 3Rs, which means that some people forget the meaning of the 3Rs after having received the message. Therefore, in terms of future actions the same message needs to be disseminated repeatedly until it starts to be practiced to the extent it becomes a habit.



The figures in the graphs represent the number of respondents.

Figure 29. Understanding of 3Rs (left); becoming informed of 3Rs (right)

Fig. 30 shows that more than 80% of the respondents in Parupuk Tabing and Batu Gadang consider the 3Rs as important or very important. On the contrary, about 41-55% of the respondents in Bungo Pasang and Bandar Buat show no awareness of the importance of the 3Rs.

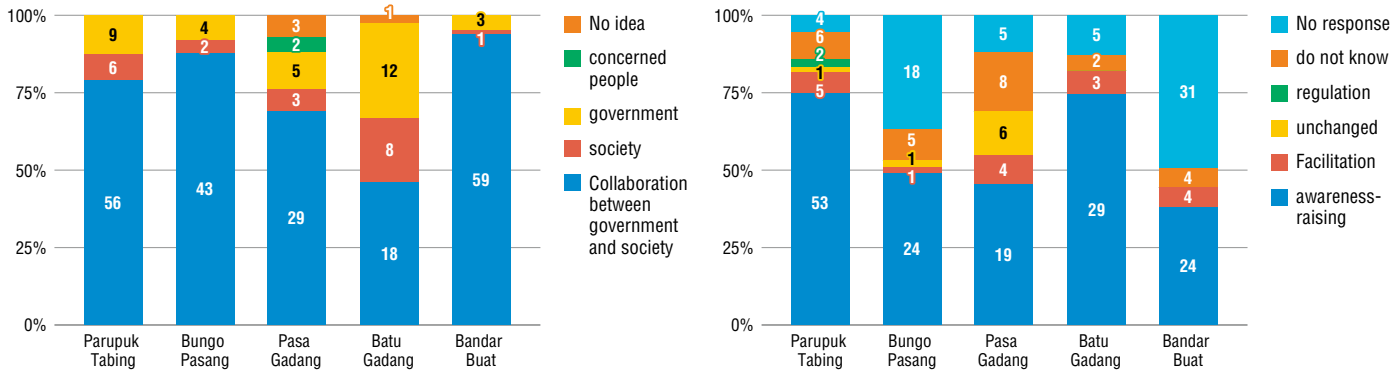


The figures in the graph represents the number of respondents.

Figure 30. Importance of 3Rs

In response to the question about who is responsible for promoting the 3Rs, the dominant answer was "collaboration between regional/city government" (see fig. 31, left graph). The rate is very high in Bungo Pasang and Bandar Buat (87% and up), relatively high in Parupuk Tabing and Pasa Gadang (69-79%), and low in Batu Gadang (less than 50%). Instead, the rate of those who answered "public society" is the highest in Batu Gadang. This is similar to the response to the question about littering (see fig. 28).

Regarding the type of activity of 3R promotion, "awareness-raising" is the dominant answer. However, a significant number of respondents in Bungo Pasang and Bandar Buat provided no response (see fig. 31, right graph), which could be attributed to the low level of concern about waste issues (see also fig. 16).



The figures in the graphs represent the number of respondents.

Figure 31. Responsible entity (left) and type of activities suggested for 3R promotion (right)

6. Recommendations for Action Plan

Cities play a vital role in responding to environmental pollution caused by improper waste management. Local governments are typically responsible for managing municipal solid waste (MSW) through proper control of waste handling including collection, transportation, recycling, disposal, storm drain and sewage system maintenance, public health, environmental protection, public funds, and so on. However, many cities find it difficult to address these issues due to a) the complexity of the waste value chain both from upstream and downstream, b) different uses and forms of materials, c) complex multi-stakeholder collaboration, and d) the need to integrate local knowledge and activities (Boucher, et al., 2020).

Developing a local action plan for solid waste management provides local governments and their partners with a strategic direction, innovative ideas, and tools to address adverse impacts on the environment, climate, human health, and economy while meeting other long-term goals such as environmental protection and circular economy. Finding actions that are appropriate to the local context to minimise the negative impacts on the environment, society, and economy requires an adequate understanding of the waste value chain, waste flow, waste composition, waste management capacity of key stakeholders in terms of available resources and partnerships, and awareness and waste handling habits of local populations.

The Action Plan on Integrated Waste Management in Padang city was developed through a participatory approach and analysis of the results of the literature review, field survey, interviews, focus group discussions, and KAP survey, which are summarised in this report. Waste issues were discussed among key stakeholders to develop a common vision, priority objectives, strategies, actions, and to identify responsible agencies for each action. In addition, a study trip to Bandung city where community-based waste management is well organised was carried out in January 2022. Fifteen representatives from DLH, University of Andalas, WALHI, and local RWs from Padang city visited and observed recycling facilities, composting facilities, and the community-based collection system. Discussions took place with local stakeholders in Bandung city in order to understand the background of and keys to successful and sustainable operations as well as on the importance of coordination among different stakeholders for effective operation and control. These lessons, combined with a concrete future vision have been reflected in the design of the Action Plan for Padang City.

Through these activities, the following three main waste issues have been identified in Padang city:

(a) The life of the TPA was shortened, resources with economic value were wasted, and the municipal budget was inefficiently used owing to the disposal of increasing amounts of mixed waste without due regard to the 3Rs.

Target in JAKSTRADA: 30% of total waste should be reduced through 5R activities

(b) Human health was impacted through risks from air and water pollution; frequent flooding occurred resulting from improper waste handling such as open burning, open dumping, and insufficient waste collection.

Target in JAKSTRADA: 70% of total waste should be properly handled

(c) Weaknesses in the waste management structure and lack of monitoring mechanism among different stakeholders and weak governance

The first issue (a) represents the biggest challenge faced by DLH and corresponds to one of the targets set in JAKSTRADAs. Integrated waste management is required **to urgently reduce the amounts of waste directed to the TPA**. To bring this about, **waste separation at source and diversion of both organic and inorganic waste fractions need to be enhanced** through collaboration between the waste generators, which include the citizens, schools and the business sector, and both informal and formal waste management operators such as waste collectors and transporters, waste banks, recycling operators as well as PT. Semen Padang.

Regarding the second issue, (b), it was revealed through the KAP survey that concerns over environmental pollution and possible flooding caused by waste littering and waste burning exist. Waste burning, which accounts for the largest portion of **unmanaged waste** according to the waste flow analysis, **should be reduced** through repeated awareness-raising campaigns and dissemination of science-based information. This needs to take place to counter the common misunderstanding in Padang city that waste burning is the best way to reduce waste, as well as to raise awareness of the related consequences of waste burning, which include air pollution, global warming, and respiratory ailments. Further, the waste collection service needs to be extended to more

comprehensively cover slum areas due to its current insufficiency. Uncollected waste is more likely to be dumped into waterways and open areas than collected waste, and adversely impacts the environment, human health, and the economy.

The third issue, (c), relates to the governance of waste management, which has been identified as a key to solving the two former issues. While waste management involves a wide range of stakeholders, realising a successful and feasible action plan relies on harnessing the capacities and mandates of all citizens and organisations towards a common goal. Most participants in the study trip to Bandung concluded that **coordination and collaboration among various stakeholders** and involvement of citizens in the waste management **are crucial to improving municipal waste management** as a whole. Strong leadership is also required. **Data collection for monitoring and evaluation is another important aspect of waste management**.

Although monitoring and supervision of waste management are responsibilities under DLH, establishing a horizontal network among different communities and vertical communication and reporting structure among DLH, kecamatans, kelurahans, RWs, RTs, waste banks, informal collectors, and environmental facilitators will help DLH in the aspects of monitoring and control as a part of waste management. The collected data requires careful analysis and the results should be used to evaluate past performance and to develop a new plan for future improvement, along with proper budgetary allocation. The fee collection mechanism and retribution amount for the waste collection service also need to be addressed. The budget for the data collection as well as monitoring and evaluation should be secured every year.

Table 17 gives a summary of the main three issues with the five objectives.

Table 17. Outline of Action Plan

Identified Issues	Primary Objective (JAKSTRADA)	Objectives and Targets
a) The life of the TPA was shortened, resources with economic value wasted, and the municipal budget inefficiently used due to disposal of rising amounts of mixed waste without application of 3Rs	Reduce total waste by 30%	O1. **Enhance waste separation** to achieve a 30% waste reduction at the source O2. **Increase organic waste reduction** to 10% (Baseline in 2021: 0.4%) O3. **Increase inorganic waste recycling and recovery** to 20% (Baseline in 2021: 7.1%)
b) Environmental pollution caused by improper waste handlings such as open burning, open dumping, and lack of waste collection	Proper handling of 70% of total waste	O4. **Reduce unmanaged waste** that leaks to the environment to 10% (Baseline in 2021: 20.20%)
c) Waste management structure among different stakeholders and governance is weak and monitoring mechanism is lacking	-	O5. **Enhance institutional capacity** for better SWM with focus on monitoring and evaluation (M&E) and collaboration with other partners

To achieve the objectives given above, the reasons for and consequences of each objective have been analysed. As a result, the four approaches below were identified. Based on these approaches, detailed actions will be developed under each objective (O1-O4). However, these four approaches will not be applied to Objective 5 (O5: Enhance institutional capacity for better SWM), as the types of issues to be tackled do not relate to waste itself but are more concerned with institutional capacity and arrangements, which together represent the root causes of the current poor state of waste management.

a) Establish and strengthen management structure for sustainable operation.

All nine TPS3Rs that had been installed in Padang city between 2007 and 2013 by the Indonesian government have been abandoned. A similar concern now surrounds waste bank operations. Despite their increased establishment in line with the regulation issued by the Ministry of Environment in 2012, most waste bank operations in Padang city are still not at the stage to secure a profit. It has been revealed through interviews that most of the waste banks in Padang city are run by female managers working in a voluntary capacity for the community. Although voluntary action should be praised, sustainability is called into question once managers are replaced. For more sustainable operations, therefore, the management structure of each facility needs to be better established and operational capacity strengthened to realise sufficient income to support operations. In this context, market research on the supply and demand of recyclables as well as collaboration with the government are also indispensable to determining which strategies can secure sustainable operations.

b) Develop and implement comprehensive environmental education through awareness-raising activities.

The collaboration and understanding of the waste generators and waste management operators are essential in advance of implementing new waste management policies and regulations. A clear, concise, and easy-to-

understand message has to be conveyed constantly and repeatedly to a wide range of actors, from residents, business and public sectors to religious groups and school children.

To achieve this, it is recommended to use the Training of Trainers (ToT) approach, in which selected members within communities or selected students and teachers in schools are trained up with the requisite knowledge to enable successive teaching in turn to others within their communities or schools, without involving additional human resources each time. In the community activity, women associations, youth unions, and other community-based organisations that are engaged in the waste management should be trained as trainers due to their abilities to reach out to, engage with and motivate and empower women and children in the communities. In addition to their daily activities as environmental facilitators, such bodies can organise events and campaigns to encourage people to practice waste separation and take 5R actions, and to promote recycled products.

c) Select and apply locally adaptable and affordable technology, techniques, and tools based on scientific research.

To carry out awareness campaigns in communities and education in schools, the correct information should be disseminated via the most appropriate communication channels and Information-Education-Communication (IEC) materials and tools so that the correct and intended actions can be initiated easily and smoothly. At the school level, the curriculum needs to be revised in a way to integrate environmental education, which should be in line with the existing national programme, Adiwiyata.

However, solely relying on supplying knowledge to change behaviours without also supplying the necessary tools and technologies as well can lead to delayed or stalled projects. Past experiences in Indonesia inform that promotion of waste separation at the source without the installation of treatment or sorted waste collection systems demotivated those who had started separating waste, who had low confidence in the sorted waste being treated separately for recycling or composting in accordance with plans informed via awareness-raising activities. Insufficient waste collection therefore led to such actors not separating waste at the source.

In a certain community in Bandung, sorted organic waste was left uncollected for several days owing to financial constraints of the operator, which generated a nuisance in the community and resulted in citizens resorting to their original practice of disposing of mixed waste. Waste collectors therefore need to ensure that their collection vehicles are always maintained in operational condition and that sufficient human resources and budgets are available for continued operations.

In this way, awareness-raising should go hand in hand with the installation of facilities such as composting facilities, bio-digesters, maggot (black soldier flies), recycling centres, and an RDF/RPF plant as well as new systems such as sorted waste collection with appropriate technology and tools, including distribution of buckets for organic waste collection. Such facilities and new system should be selected or designed based on comprehensive scientific research on waste management as well as social acceptance. Waste generators and facility operators also need to have a full understanding of the new facilities and system introduced.

d) Regulate and enforce the law and policies in waste management.

One of the main weaknesses of local governments exhibited in many low- and middle-income countries is the lack of controls and law enforcement, and in this respect Padang city is no exception. Though city regulations on the restriction of use of plastic shopping bags and the statement of sanctions for improper waste handling exist, these regulations are not fully executed. The control mechanisms therefore need to be strengthened along with the establishment of a monitoring system and identification of roles and responsibilities of each stakeholder involved.

The current waste collection system has to be reviewed and the sorted waste collection system should be designed for each type of sorted waste by identifying collection points, methods, frequencies, routes, dates, and types of collection vehicle, together with introduction and promotion of waste separation at the source. Although waste reduction is the main goal of the Action Plan, the reduction of Greenhouse Gas (GHG) emissions, mainly from the TPA and transportation, need to be addressed and monitored as per the Paris Agreement, an international treaty on climate change adopted by 196 parties including Indonesia. Under this treaty GHG levels need to be reported to the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) through national governments. Recently, Short-Lived Climate Pollutants (SLCPs), including black carbon emissions caused by waste burning have become considered as significant climate factors owing to their much higher potential to accelerate global warming than GHGs. The level of SLCPs has to be reported to Climate and Clean Air Coalition (CCAC).

Once the Action Plan is developed, the detailed pilot activities can be planned for implementation. Table 18 shows the recommended target areas and some factors to consider when planning the activities. As pilot activities should also act as a successful model for replication, the level of awareness and consciousness about waste issues as well as current waste composition were fully taken into consideration.

Table 18. Recommended target kelurahans and pilot activities

	Reduction of organic waste	Reduction of inorganic waste	Reduction of unmanaged waste	Awareness / consciousness
Parupuk Tabing	High possibility of reducing organic waste, especially from local markets	-	- Possibility of reducing open burning - High perception that burning is good as it reduces waste	High awareness and high consciousness
Pasa Gadang	Reduction of organic waste possible, especially in commercial sector	High possibility of reducing inorganic waste from non-domestic sources	- Possibility of reducing open dumping - Relatively low awareness	Relatively high consciousness
Batu Gadang	Reduction of organic waste possible from domestic sources and garden waste from non-domestic sources	- Relatively high awareness and practice of waste separation - Possibility of realising reduction of inorganic waste from domestic sources	- Possibility of reducing open burning - High perception that burning is good as it reduces waste	- High awareness and high consciousness - Self-responsible

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