

Azni Idris · Bulent Inanc · Mohd Nassir Hassan

## Overview of waste disposal and landfills/dumps in Asian countries

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**Abstract** Many cities in developing Asian countries face serious problems in managing solid wastes. The annual waste generation increases in proportion to the rises in population and urbanization. Asian countries with greater rural populations produce more organic waste, such as kitchen wastes, and fewer recyclable items, such as paper, metals, and plastics. Reliable data on solid waste compositions are difficult to obtain, and even if available, they are often not updated. We report the most recent waste composition data in some developing Asian countries. We suggest that a better classification system for landfills is needed to address inconsistencies in data for sanitary landfill sites versus waste dumps. We also discuss the information on waste disposal trends and problems associated with general solid waste management in developing Asian countries.

**Key words** Asian cities · Dump sites · Landfill sites · Waste composition

### Introduction

Many cities in developing Asian countries face serious problems in managing solid wastes. The annual waste generation increases in proportion to the rises in population and urbanization, and issues related to disposal have become challenging as more land is needed for the ultimate disposal

of these solid wastes. Several major cities in developing Asian countries have reported problems with existing landfill sites.<sup>1,2</sup>

Rapid development and changing lifestyles in growing cities have also changed waste composition from mainly organic (putrescible) to mainly plastics, paper, and packaging materials that are complex in nature. Storage and collection systems are becoming more sophisticated and costly as the types and sources of waste produced become more diversified, and as the availability of disposal sites within the collection areas becomes limited. Information on the characteristics of solid waste is essential for planning disposal methods for solid wastes. Reliable data on solid waste compositions are difficult to obtain, and even if available, they are often not updated. Furthermore, a better classification system for landfills is needed to address inconsistencies in data for sanitary landfill sites versus waste dumps.

In this article, we provide an overview of waste disposal issues in several Asian cities, placing emphasis on the waste characteristics and disposal trends. Information on landfills versus dumping sites in selected cities is also highlighted, and waste management in Malaysia is introduced as an example.

### Generation and composition of wastes

The amount and composition of the wastes that are generated are critical data for the formulation of new waste management plans and technologies. Accurate estimations of these variables are essential to the design of resource recovery and materials cycles. Waste minimization will not be carried out effectively without having reliable waste composition data. An evaluation of the impacts of certain types of waste and an estimation of the life of landfills require sufficient waste composition data.<sup>3</sup> Both the quantity and composition of waste vary widely from day to day and season to season, and considerable differences may be observed not only between countries, but also between neighboring localities and between types of property within the same city.

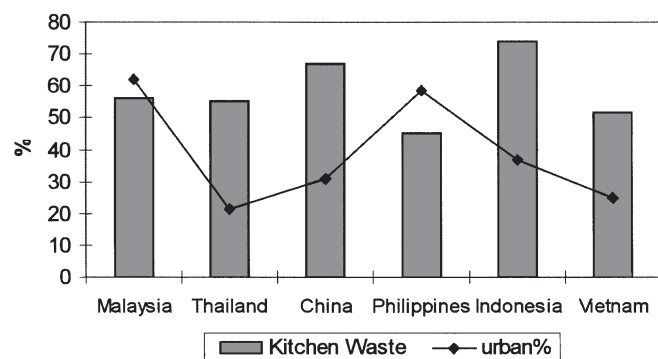
A. Idris (✉)  
Department of Chemical and Environmental Engineering, University  
Putra Malaysia, 43400 UPM-Serdang, Selangor, Malaysia  
Tel. +60-3-89466302; Fax +60-3-86567099  
e-mail: azni@eng.upm.edu.my

B. Inanc  
National Institute for Environmental Studies, Tsukuba, Ibaraki, Japan

M.N. Hassan  
Department of Environmental Sciences, Universiti Putra Malaysia,  
Selangor, Malaysia

**Table 1.** Waste composition from various Asian countries<sup>4</sup>

Component (% by weight)	China (Shanghai) 1998	India 1995	Indonesia 1993	South Korea 2001	The Philippines 1999	Turkey (Istanbul) 2000	Japan 2000
Organic matter	67.3	41.8	70.2	32.8	49	43	34
Paper and cardboard	8.8	5.7	10.9	23.8	19	7.8	33
Plastics	13.5	3.9	8.7	—	17	14.2	13
Glass	5.2	2.1	1.7	2.8 <sup>a</sup>	—	6.2	5
Metals	0.7	1.9	1.8	—	6	5.8	3
Textile and others	4.5	44.6 (textile 4.3)	6.2	40.6 <sup>b</sup>	9	23.1	12

<sup>a</sup>Metals and ceramics are included<sup>b</sup>Ash is included**Fig. 1.** Urban population ratio and organic waste generation in developing Asian cities

The compositions of wastes generated in several Asian countries are given in Table 1. The organic portion accounts for the major portion of the waste (except in Japan). The highest percentage of organic waste was recorded in Indonesia (70.2%), followed by China (67.3%). Countries with greater rural populations are expected to produce more organic waste, such as kitchen wastes, and fewer recyclable items, such as paper, metals, and plastics. The percentages for paper and plastics (19% and 18%, respectively) observed in the Philippines were comparatively higher than in other developing Asian countries.<sup>4</sup>

As a result of rapid urbanization, in particular, solid waste generation in Asian countries continues to increase. Figure 1 shows the urbanization pattern in selected developing Asian countries, including the level of kitchen waste production in the capital cities of each country. Countries with lower levels of urbanization, such as Thailand, China, Indonesia, and Vietnam, generate relatively large quantities of organic kitchen wastes. The level of urbanization of a country affects the composition of organic waste as a result of the growing incomes and new lifestyles of people living in urban areas. Greater consumerism tends to generate more packaging materials, which have a higher paper and plastic content.

An increase in urbanization also affects the overall rate of solid waste generation in many countries. Critical issues related to collection, disposal methods, and dumping sites for municipal solid waste (MSW) remain unsolved in many large cities. Owing to the relatively wet climate in many

parts of Asia, problems associated with the degradation of the organic portion in the waste pose the greatest challenge in terms of river and groundwater pollution.

At present, the per capita generation rate of MSW in Malaysia varies between 0.88 and 1.44 kg/day depending on the economic status of the area. It is generally assumed to be 1.0 kg/ca/day. By using this figure, it is estimated that Kuala Lumpur alone produces more than 3000 tons solid waste every day. The whole country produces around 6 million tons annually.<sup>1,2</sup>

The implementation of ecological waste management programs in the Philippines steadily increases recycling activities in major cities and municipalities.<sup>5</sup> The enactment of Republic Act 9003 (the Ecological Solid Waste Management Act) in January 2001 reinforced the local government units' responsibilities for the collection of residual/nonbiodegradable and special wastes, while the barangay (village/community) units are given the responsibility of segregating and collecting biodegradable, compostable, and reusable wastes. The latest figure for Manila's waste generation was 5900 tons/day, and the estimated nationwide MSW generation was 10 million tons/year. The sources of MSW are 48% residential, 26% informal settlers, and 26% commercial and industrial sources. Inadequate collection vehicles and a lack of disposal sites have contributed to a reduction in the collection efficiency of household wastes. Only 40% of the household waste is collected in rural areas, while 70% is collected in urban areas.<sup>6</sup>

Solid waste is one of the major environmental problems in Thailand. In 2003, solid waste was approximately 40 165 tons/day; 24% came from the Bangkok Metropolitan Administration, 31% from municipalities, and 45% from rural areas. In 1993, the waste generation from Bangkok was 9640 tons/day. It was estimated that the collection service covers 60%–80% of the residences in municipal Bangkok.<sup>7</sup>

In China, whose population was 1.29 billion in 2003, the average MSW generation was about 1.65 kg/ca/day. There are 660 waste treatment sites/plants, which treat 60.2% of the total MSW (118 million tons); the other 35% is dumped in the cities and suburbs.<sup>8</sup>

In Vietnam, 22 210 tons/day of waste was collected, which represents a collection rate of about 60%. There are about 55 waste disposal sites in Vietnam. In Hanoi, the capital city, the waste generation was estimated to be 1600 tons/day

(87% collection). The average amount of waste generated per person is 0.6 kg/day.<sup>9</sup>

For many developing Asian cities, materials recovery and recycling are not normally carried out by the local authorities or landfill operators. However, the activities of scavengers or unauthorized waste pickers at landfill sites reduce the amount of recyclable items such as paper, plastics, glass, and metals in the waste. The prospect for materials recovery and recycling in Asian cities appears to be good owing to the increasing quantity of waste as well as of recyclable material, in tandem with the move toward rapid development and industrialization.

Figure 2 shows the composition of recyclable items found in the waste stream for several countries. Items such as plastics, paper, glass, and metals are potential candidates for recovery, reuse, and recycling. Thailand and the Philippines produced more plastics than other developing countries (about 16%). Malaysia and China produced about 13% plastics, whereas Indonesia and Vietnam recorded the lowest values (8% and 3%, respectively). Paper items are also significant, and they are collected and recycled in many countries; the composition found in the waste was 8%–17%, except in Vietnam, which generates only about 2.7% paper wastes.

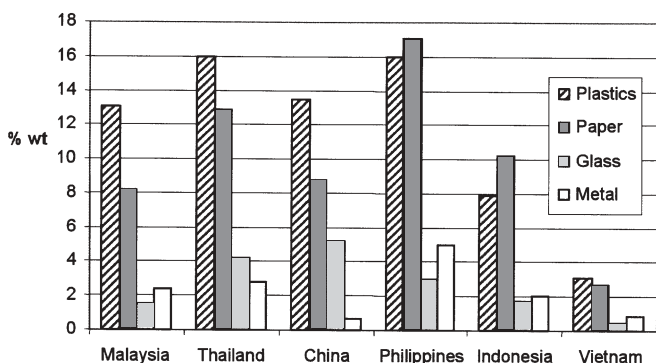
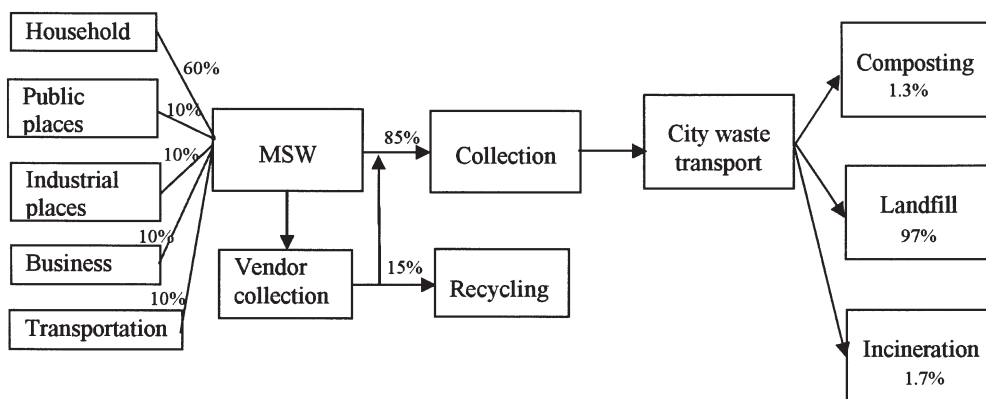


Fig. 2. Recyclable solid waste items in selected Asian cities

Fig. 3. Estimated waste stream route in Chinese cities<sup>12</sup>



## Waste disposal trends in Asian countries

Developing nations have various problems regarding MSW. When carrying out a systematic review of the MSW problems and formulating a well-considered management plan, it is extremely important to understand the present MSW flow in the region. However, despite these needs, developing nations do not generally conduct MSW stream analyses because of ignorance of the proper methods involved and a lack of funding. Usually, international support agencies such as the World Bank study the amount of waste generation and its composition in developing countries, but these studies do not determine the differences in urban MSW streams.<sup>10</sup> In the following sections, we have compiled waste disposal trends from the published data for three Asian countries, namely China, South Korea, and Taiwan, which exhibit dynamic trends in comparison to other developing Asian countries.

### China

Landfilling is the dominant method for MSW disposal in China. According to an investigation of 138 cities in 2000,<sup>11</sup> landfilling accounts for about 96.9%, composting 1.3%, and incineration 1.8% of MSW. This situation is not expected to change significantly in the near future, because the separate collection of recyclable items is not practiced in most of the cities. The installation and operation of incinerators are unaffordable for most Chinese cities. Currently, the simple landfill is considered a better option than doing nothing.<sup>12</sup> Figure 3 shows the municipal solid waste flow in Chinese cities.

### Taiwan

A study of MSW material flow was conducted for Taiwan.<sup>13</sup> On average, the ash amount is 20% of the amount of solid waste received at incinerators. Reduction by incineration is as high as 43.6%, and the final landfill disposal is about 40.20% of the original amount. The rate of improper disposal is 3.64%, and includes nonsanitary landfills (2.76%)

**Table 2.** Disposal methods for domestic wastes in South Korea between 1996 and 2002<sup>14</sup>

Category (%)	1996	1997	1998	1999	2000	2001	2002
Landfill	68.3	63.9	56.2	51.6	47	43.3	41.6
Incineration	5.5	7.1	8.9	10.3	11.7	13.6	14.5
Recycling	26.2	29	34.9	38.1	41.3	43.1	43.9
Ocean dumping	–	–	2.2	3.0	3.1	3.1	3.6

and the other methods such as storage and dumping (0.88%). The amount of waste that is recycled (i.e., diverted from incineration and landfill) is about 15.56%. However, the amount recycled or recovered that returns to the market is not clearly controlled, which means that the flow of waste and pollution transformation during the recycling processes is unknown.

According to Taiwan's incineration policy, 36 large-scale MSW incinerators were to be built. At present, 19 plants are in operation, and they incinerated 4.32 million tons (54.2%) of MSW and 1.28 million tons (2%) of general industrial waste in 2002. Six plants were cancelled, seven plants are under construction, and four plants are in the planning stage. The Taiwanese Environmental Protection Agency announced it would follow the international trend toward a "zero waste" policy. The goal for MSW minimization is 25% by 2007, 40% by 2011, and 70% by 2020.

### South Korea

In preparation for the 1988 Olympic Games in Seoul, South Korea instituted a solid waste management system focusing on waste reduction, recycling, and proper treatment. The Waste Management Law, the Resource Concentration and Recycling Promotion Law, the Law on the Waste Disposal Facilities Installation Promotion and Surrounding Area Support, and the Law on Waste Movement and Disposal were established, and were revised in the early 1990s.<sup>14</sup> Accordingly, disposal of domestic wastes does not solely depend on landfills (Table 2).

### Problems of solid waste management in developing countries

The general issues and problems concerning the entire solid waste management system in developing countries can be placed into three categories (summarized in Table 3), including the problems of landfill development and management.<sup>15–18</sup> The first category of problems are more or less external to the solid waste management sector, and to some extent are beyond the capability of the waste management authority to solve alone. The second category of problems are partly external and partly internal to the solid waste management authority and other related agencies. The third category of problems are mostly internal to the solid waste sector, and the solutions to these problems must be handled by the waste management authorities.

### Malaysian landfill and dump management

The word "landfill" is widely misused owing to the fact that there is no rigid definition, and hence the operational aspects of landfill are unclear. A site may be referred to as a "landfill" when in fact it is an "open dump." To reduce this confusion and to facilitate the proper management and improvement of poor landfill sites, examples from Malaysia are presented to introduce two classification systems for landfill sites.<sup>19</sup>

The first landfill classification system is based on the decomposition processes that occur in a landfill: (1) anaerobic landfill; (2) anaerobic sanitary landfill with daily cover; (3) improved anaerobic sanitary landfill with buried leachate collection pipes; (4) semiaerobic landfill with natural ventilation and leachate collection facilities; (5) aerobic landfill with forced aeration. For operational purposes, a second classification system is used: Level 1, controlled tipping; Level 2, sanitary landfill with a bund (embankment) and daily soil covering; Level 3, sanitary landfill with a leachate recirculation system; Level 4, sanitary landfill with a leachate treatment system.<sup>20</sup> The characteristics of landfill sites using the second classification system are summarized in Table 4.

Using the second classification system, all the landfill sites in Malaysia were assessed and classified into four types: (1) dumping into water bodies; (2) open dumps; (3) controlled tipping (levels 1, 2, and 3 landfills); (4) sanitary landfill (level 4 landfills). The results of this assessment showed that 25% of landfill sites in municipal councils and 59% in district councils are open dumps (Table 5). The major problems are insufficient application of cover material, odor from waste decomposition, flies and other vermin, and smoke and other dangers from open fires started either spontaneously or purposely by scavengers.

The latest assessment of the landfill sites was carried out in 2002, and the results, summarized in Table 6, do not show much improvement. There were 77 open dumps, 49 controlled tipping landfills (level 1), and only 35 levels 2, 3, and 4 landfill sites. The results also show that the largest numbers of open dumps are in Sarawak, followed by Johor Sabah and Kelantan.

### Conclusions

We have highlighted the differences in the composition of solid waste and the disposal trends in developing Asian

**Table 3.** Problems in the management of solid waste services in developing countries<sup>19</sup>

Type of problem	Comments
External	<p>Population explosion, uncontrolled or unplanned urbanization, squatter area proliferation</p> <p>Socioeconomic crisis</p> <p>Huge external debt</p> <p>Economic austerities</p> <p>Prolonged recession</p> <p>High inflation</p> <p>High unemployment</p> <p>Social disorders, including wars</p> <p>Insufficient public education and limited communal participation</p>
External and internal	<p>Accelerated and uncontrolled generation of municipal wastes and industrial hazardous wastes</p> <p>Negligence of, and lack of interest in, solid waste management shown by national and local authorities</p> <p>Lack of intersectoral, interinstitutional, and intermunicipal coordination for sanitary education; lack of interinstitutional coordination between private and public collection services; lack of intermunicipal coordination for intermunicipal landfill</p> <p>Uncontrolled and uncoordinated scavenger activities</p> <p>Inadequately trained human resources</p> <p>High turnover rate of trained professionals</p> <p>Lack of personnel management program</p> <p>Productivity of human resources is low owing to:</p> <ul style="list-style-type: none"> <li>Untrained staff</li> <li>Poor pay scales</li> <li>Fixed working hours</li> <li>No incentive payment for good performance</li> <li>Inefficient working practices</li> </ul> <p>Labor conflicts, such as strikes by syndicated municipal garbage workers</p> <p>Incomplete and obsolete legislation and insufficient enforcement</p> <p>Lack of funds</p> <p>Low assessment rates, or rates that have not increased for many years</p> <p>Poor budgeting: no separate accounting kept for solid waste management, therefore budgeting for this area does not reflect the true expenditure involved</p> <p>The increase in population/generation of waste is not reflected in the assessment charges being levied</p> <p>No enforcement of debtors, resulting in poor collection of funds from the public</p> <p>No proper charging: tipping fees are low and do not reflect the actual cost of upkeep of landfills</p> <p>The rationale for privatisation is economic; public provision is more costly, as evidence seems to show; often public provision is unsatisfactory owing to the inefficiency and rigidity of public bodies; lack of standard financial reporting structure</p> <p>Lack of independent budget administration (in many cases, revenue raised through user fees or taxes become part of the general city treasury, and unexpected demands from other sectors are given higher priority to draw funds initially allocated for solid waste management)</p> <p>Poor monitoring of budget on solid waste management due to lack of basic data and untimely reports</p> <p>No benchmarking to assess efficiency of services</p> <p>No proper financial planning</p> <p>Budgets set are not based on levels of service to be provided</p> <p>Lack of exact cost determination (lack of independent accounting system for municipal solid waste management); it is not possible to monitor all of the costs of service provision; official figures may underestimate the true costs by as much as 50%</p> <p>No proper evaluation of capital expenditure</p>
Internal	<p>Structural and institutional weaknesses of municipal solid waste management system:</p> <ul style="list-style-type: none"> <li>Secondary priority in municipal administration</li> <li>Insufficient and deficiency of allocated resources</li> <li>Fragmented responsibilities borne by various departments</li> <li>Political pressures</li> </ul> <p>Lack of short-, medium-, and longterm solid waste management planning</p> <p>Lack of garbage collection route design</p> <p>Lack of supervision, with typical ratios of one supervisor per 10–30 vehicles</p> <p>Lack of equipment maintenance: maintenance is often reactive, that is, repairing vehicles after they have broken down rather than preventive maintenance with regular servicing and routine maintenance, owing to lack of training for maintenance staff, inadequate funds for vehicle repair, and lack of spare parts</p> <p>Technical problems</p> <p>Storage Problems. The present situation in respect of on-site storage varies from one area to another. However, in most cases on-site storage is not satisfactory; storage is not secure and does not allow for effective collection, resulting in health and environmental problems. Some of the common problems of storage are:</p> <ul style="list-style-type: none"> <li>Lost or damaged trash can lids are often not replaced, leaving waste exposed, emitting odor and attracting flies, rodents, and stray animals</li> <li>Residents with no proper waste storage facilities often hang waste packed in plastic bags outside the house, on fences, trees, or left at the roadsides. Apart from the aesthetic problems, this contributes to the inefficiency of collection</li> <li>Insufficient supply of communal trash cans results in the storage area becoming a dump site</li> <li>Scavenging by rodents and stray animals eventually leaves the waste scattered all around the site, and this is unhygienic</li> </ul> <p>Collection.</p> <ul style="list-style-type: none"> <li>Littering around communal trash cans contributes to inefficiency of collection</li> <li>Different sizes and weight of trash cans makes collection difficult</li> </ul> <p>Disposal.</p> <ul style="list-style-type: none"> <li>Crude dumping is widely practiced</li> <li>Poor control of the site results in haphazard tipping</li> <li>Shortage of suitable land for disposal</li> </ul>



**Table 4.** Classification of landfills in Malaysia<sup>20</sup>

Items	Level 1	Level 2	Level 3	Level 4
Enclosing bund (embankment)		o	o	o
Divider		*	o	o
Surrounding drain		o	o	o
On-site drain (surface water)		o	o	o
On-site drain (underground spring)		o	o	o
Drain for reclaimed area		o	o	o
Approach road	o	o	o	o
On-site road	o	o	o	o
Other access roads	o	o	o	o
Buffer zone		o	o	o
Litter control facility		*	o	o
Gas removal facility		*	o	o
Leachate collection facility			o	o
Leachate cycling facility			o	o
Seepage control facility			o	o
Leachate treatment facility				o
Site office	*	*	o	o
Weighbridge	o	o	o	o
Storage building			o	o
Safety facility		o	o	o
Fire prevention facility		*	o	o
Monitoring facility			o	o
Car wash facility				o
Landfill equipment	o	o	o	o
Personnel (management)	o	o	o	o
Cover material	*	o	o	o
Fuel	o	o	o	o
Water supply		o	o	o
Electricity			o	o
Insecticide	o	o	o	o
Monitoring chemicals			o	o
Main facilities		o	o	o
Environmental protection facilities		o	o	o
Building and accessories	o	o	o	o
Maintenance equipment	o	o	o	o

o, sufficient item; \*, insufficient item

**Table 5.** Condition of selected Malaysian landfill sites in 1990<sup>21</sup>

	Municipal council	District council
Sanitary landfill	4 (33%)	1 (2%)
Controlled tipping	4 (33%)	19 (38.8%)
Open dumping	3 (25%)	29 (59.2%)
Dumping into water body	1 (9%)	0 (0%)
Sample size	12 landfill sites	49 landfill sites

countries. The increase in the proportion of recyclable materials in the waste stream calls for better recovery, reuse, and recycling. Unlike other trends in economic growth and industrialization in developing Asian countries, the trends in solid waste management suggest that methods are outdated and show a lack of proper waste characterization, waste stream analysis, and landfill and dump site data. Many disposal sites are still open dumps, and are managed poorly either by the local authorities or by other landfill operators. These problems will have negative short- and longterm impacts on the environment and the safety of the general public. The dilemmas faced by operators of modern landfills are great and challenging, and the classification of existing landfill sites in many countries is not uniform. It is likely that

proper waste disposal will remain one of the most important environmental and health issues in the developing countries of Asia.

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**Table 6.** Number and classes of landfill sites in Malaysia (March 2002)<sup>22</sup>

State	Landfill types					Total
	Open dumps	Level 1	Level 2	Level 3	Level 4	
Perlis	0	0	0	0	1	1
Kedah	3	2	3	0	1	9
Pulau Pinang	0	0	1	1	0	2
Perak	9	5	2	2	0	18
Selangor	0	7	1	1	2	11
Negeri Sembilan	6	3	1	1	0	10
Melaka	2	0	1	0	0	3
Johor	13	8	4	1	0	26
Pahang	5	3	2	3	1	14
Terengganu	2	4	1	0	1	8
Kelantan	10	1	1	0	0	12
Kuala Lumpur	0	0	0	1	0	1
Labuan	0	1	0	0	0	1
Sarawak	15	11	2	0	0	28
Sabah	12	4	0	1	0	17
						161

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