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# Analysis of Waste Management and Greenhouse Gas Emission Reduction (Case Study: Adiwiyata School SMPN 18 Surabaya and Non-Adiwiyata School SMPN 31 Surabaya)

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**Abstract**
In Surabaya, a city program named "*Perilaku dan Berbudaya Lingkungan Hidup di Sekolah*" (PBLHS), or Environmental Behavior and Culture in Schools, specifically targets Adiwiyata schools to promote sustainable practices. However, not all schools participate in this initiative. Non-Adiwiyata schools typically send their waste to the Final Waste Processing Site (TPA), which exacerbates the load on these facilities and contributes to increased greenhouse gas (GHG) emissions. This study aims to compare waste management and GHG reduction efforts between Adiwiyata and non-Adiwiyata schools in Surabaya. We conducted sampling at one Adiwiyata school and one non-Adiwiyata school, analyzing waste generation and management strategies using the SNI 19-3964-1994 method. Our findings reveal that Adiwiyata schools generate less waste, with an average of 0.0103 kg/person/day, compared to 0.0155 kg/person/day at non-Adiwiyata schools. Furthermore, the organic waste composition was significantly lower in Adiwiyata schools at 2.08%, versus 33% in non-Adiwiyata schools. Methane (CH4) emissions from Adiwiyata schools were also lower, measuring 0.123 Gg/year, as opposed to 0.405 Gg/year from non-Adiwiyata schools. These disparities in waste output, organic waste composition, and GHG emissions are significantly influenced by the environmental knowledge, attitudes, and practices within the school communities.

## 1. Introduction

Surabaya, located in the East Java province of Indonesia, is one of the most populous cities in the region, boasting a population of approximately 3.16 million people. With the increasing population, the volume of waste generated in Surabaya is also on the rise. According to the data from SIPSN, the Ministry of Environment and Forestry reported that in 2022, the city produced an annual waste amount of 651,043 tons, averaging about 1,783 tons per day.

One significant source of this waste generation in Surabaya comes from educational facilities. The Directorate General of Early Childhood, Basic, and Secondary Education under the Ministry of Education, Culture, Research, and Technology reports that there are 3,915 schools in the city. Population growth necessitates effective waste management, which traditionally has been limited to mere disposal without due consideration for human health and environmental impact. The primary goal of waste management is to protect public health, improve environmental quality, and transform waste into a resource.

In response to the challenges posed by increasing waste volumes and to mitigate the impact of Greenhouse Gas (GHG) emissions from waste, the Surabaya city government has initiated programs aimed at reducing waste generation at educational facilities. Through the *Gerakan Peduli* dan *Berbudaya Lingkungan di Sekolah* (GPBLHS) within the broader framework of the *Perilaku Ramah Lingkungan Hidup* (PRLH), the city implements waste management practices outlined in the Ministerial Regulations No. P52/MENLHK/SETJEN/KUM.1/9/201 and P53/MENLHK/SETJEN/KUM.1/9/2019. The Adiwiyata program, a part of these regulations, is an award given by various levels of government to schools that successfully implement environmental care and culture.

Despite these efforts, participation in the Adiwiyata program is low, with only 271 of the 3,915 schools in Surabaya enrolled as of 2022. This study aims to analyze waste generation, composition, and GHG emissions in both Adiwiyata and non-Adiwiyata schools. By correlating this data with the knowledge and behaviors of the school community towards waste management, the findings are expected to serve as a valuable reference for policymakers to promote and implement the Adiwiyata program across all educational facilities in the city. This initiative not only aims to reduce the environmental footprint of schools but also to instill a culture of environmental awareness and action among the younger generations.

## 2. Literature reviews

Waste can be defined as discarded items (items no longer in use) that are deemed valueless to the environment and, if disposed of indiscriminately, can have detrimental effects on it. Generally, waste is categorized into two types: inorganic and organic. Inorganic waste includes materials such as plastics, rubber, food wrappers, and styrofoam, whereas organic waste consists of biologically degradable materials like plant residues and food scraps, often referred to as wet waste. Both residential and commercial areas contribute to waste generation, which can include inorganic, organic, and even hazardous wastes (known as B3). Typically, organic waste is considered biodegradable, while inorganic or non-biodegradable waste comprises materials that do not decompose easily.

Waste generation activities fall into domestic and non-domestic categories. Domestic waste primarily originates from households, while non-domestic waste comes from activities in public facilities such as health, education, religious sectors, industry, and commercial areas. In the process of waste characterization, one of the goals is to analyze the quantity and composition of waste. The Indonesian National Standard (SNI) 19-3964-1994 is a tool used to measure waste composition and volume.

Daily human activities can produce greenhouse gases (GHGs) from various sources such as vehicles, industrial waste emitted through factory chimneys, and waste piles, which can generate significant GHG emissions. These gases are categorized by compounds: CFCs (chlorofluorocarbons), COx (Carbon Monoxide), NOx (Nitrogen Oxides), and $CH_4$ (Methane). Waste disposal and landfill activities contribute to GHG emissions; composting also releases $CO_2$ and $CH_4$. Waste is a notable source of GHG emissions, particularly methane ($CH_4$) and carbon dioxide ($CO_2$).

Most cities are transitioning from traditional open dumping waste disposal methods to more environmentally friendly Sanitary Landfill systems to mitigate adverse effects. However, poorly managed landfill sites can still pose significant environmental risks, including air pollution from methane emissions. Every landfill site should be equipped with a methane collection system designed and implemented according to the IPCC model, aiming to reduce methane accumulation, prevent landfill explosions, and prevent gas leakage into aquifers.

Educational facilities are significant contributors to landfill waste accumulation and GHG emissions from such waste. Not all educational institutions implement environmentally friendly programs; hence, the government recognizes schools that are committed to environmental care through an official award called Adiwiyata. Adiwiyata is an accolade given to educational institutions that successfully implement environmental care and cultural activities. This award is presented by the national government, provincial, and municipal authorities. The Gerakan Peduli dan Berbudaya Lingkungan Hidup di Sekolah (GPBLHS), or the Environmental Care and Culture in Schools Movement, is a collective initiative voluntarily undertaken by schools through awareness, collaboration, and continuous efforts. The movement aims to foster environmentally friendly behaviors.

The GPBLHS movement in schools promotes activities based on the 6 Environmentally Friendly Behaviors (PRLH), including maintaining sanitation and drainage cleanliness, waste management, energy conservation, water conservation, environmental-based innovation, and biodiversity preservation. These efforts create a clean and serene school environment, physically manifesting the school's commitment to environmental culture. Initiatives such as Green Gardens and greenhouses support greening efforts and help absorb air pollutants, enhancing the school's environmental impact.

## 3. Methodology

This study was conducted in the city of Surabaya, focusing on schools with and without Adiwiyata accreditation, a green school initiative in Indonesia. Specifically, SMPN 18 Surabaya was selected as the Adiwiyata school, and SMPN 31 Surabaya as the non-Adiwiyata school. The research was carried out by conducting field measurements at each school, involving school community members to assess waste generation and its composition. The waste sampling followed the SNI 19-3964-1994 methodology.

Waste generation at the schools was calculated using the following equation:
Waste Generation for Adiwiyata School = Daily waste (kg) / Number of school members …………...(1)

The total waste generation (kg/day) was determined by:
Total Waste Generation = Waste Generation Rate × Total School Population ………………………...(2)

Waste composition was assessed using the formula:
Waste Composition (%) = Weight of each waste type (kg) / Total waste weight …………………….(3)

After calculating the total waste generation and composition, the study proceeded to estimate the emissions of greenhouse gases (GHGs), specifically methane (CH4), using the Intergovernmental Panel on Climate Change (IPCC) methodology. The relevant equations included:

DOCi = Wi × DOC ……………………………………………………………………………….(4)
where DOC$i$DOC$i$ is the organic carbon degradation fraction for waste type $ii$, $WiWi$ represents the percentage composition of disposed waste, and DOC is the overall organic carbon degradation fraction.

The decomposed organic carbon mass (Gg) was calculated by:
DDOCm = W × DOCi × DOCf × MCF ………………………………………………………….(5)
where DDOC$m$DDOC$m$ is the mass of decomposed organic carbon, $WW$ is the mass of disposed waste (Gg), DOC$f$DOC$f$ is the fraction of DOC that decomposes under anaerobic conditions, and MCFMCF is the methane correction factor, indicating the portion of waste that will decompose under aerobic conditions before anaerobic decomposition occurs.

The potential methane production was estimated as:
Lo = DDOCm × F × (16/12) ………………………………………………………………………...(6)
where $Lo$$Lo$ is the potential methane production (GgCH4), $FF$ is the fraction of methane generation in landfills (with an IPCC default value of 50%), and 16/22 represents the molecular weight ratio (CH4/C).

Methane emissions were calculated by:
CH4 Emissions = [Sum(CH4 Production_x - RT)] × (1 - OXT) ……………………………………….(7)
where $TT$ represents the waste production time period (years), $XX$ denotes the category/type of waste material, $RTRT$ is the recovered methane gas over period $TT$ (Gg), and $OXTOXT$ is the oxidation factor over period $TT$.

**Table 1**. Waste Generation at Adiwiyata School SMPN 18 Surabaya in 2023

| Waste Type | Waste Generation (kg/8 days) | Daily Waste (kg/day) | Reduction Potential (kg/8 days) | Recovery Factor (%) |
|---|---|---|---|---|
| Food Waste | 6.365 | 0.796 | 2.630 | 41.32 |
| Garden Waste | 22.43 | 2.804 | 9.543 | 42.55 |
| **Total Biodegradable Waste** | 28.795 | 3.599 | 12.173 | 42.27 |
| Plastic | 19.375 | 2.422 | 7.790 | 40.21 |
| Paper and Cardboard | 15.3 | 1.913 | 9.044 | 59.11 |
| Metal | 0.13 | 0.016 | 0.130 | 100 |
| Wood | 0 | 0.000 | 0.000 | 0.00 |
| Rubber | 0 | 0.000 | 0.000 | 0.00 |
| Textile | 0 | 0.000 | 0.000 | 0.00 |
| Masks | 0 | 0.000 | 0.000 | 0.00 |
| Diapers | 0 | 0.000 | 0.000 | 0.00 |
| Other (Inert) | 11.165 | 1.396 | 0.000 | 0.00 |
| **Total Waste** | 74.765 | 9.346 | 29.137 | 38.97 |
| **Total Waste per Capita** with 876 individuals | | | | 0.0103 kg/person |

Data gathered from this study were further analyzed to correlate knowledge with attitudes and actions of the school community using interviews and questionnaires. The correlation analysis of the questionnaire data was performed using SPSS version 25. This analysis aimed to draw conclusions on the differences observed between the two schools' waste management practices.

## 4. Results and discussion

Using the SNI 19-3964-1994 sampling method, waste generation data from Adiwiyata-accredited SMPN 18 Surabaya were collected and analyzed. The findings for the 2023 school year are presented in Table 1.

Conversely, waste generation data from non-Adiwiyata school SMPN 31 Surabaya are summarized in Table 2:

**Table 2.** Waste Generation at Non-Adiwiyata School SMPN 31 Surabaya in 2023

| Waste Type | Waste Generation (kg/8 days) | Daily Waste (kg/day) | Reduction Potential (kg/8 days) | Recovery Factor (%) |
|---|---|---|---|---|
| Food Waste | 8.005 | 1.001 | 0.000 | 0.00 |
| Garden Waste | 33.306 | 4.163 | 0.000 | 0.00 |
| **Total Biodegradable Waste** | 41.311 | 5.164 | 0.000 | 0.00 |
| Plastic | 33.573 | 4.197 | 0.000 | 0.00 |
| Paper and Cardboard | 18.915 | 2.364 | 0.000 | 0.00 |
| Metal | 3.39 | 0.424 | 0.000 | 0.00 |
| Wood | 1.3 | 0.163 | 0.000 | 0.00 |
| Rubber | 0 | 0.000 | 0.000 | 0.00 |
| Textile | 0 | 0.000 | 0.000 | 0.00 |
| Masks | 2.2 | 0.275 | 0.000 | 0.00 |
| Diapers | 0 | 0.000 | 0.000 | 0.00 |
| Other (Inert) | 24.43 | 3.054 | 0.000 | 0.00 |
| **Total Waste** | 125.119 | 15.640 | | |
| **Total Waste per Capita** with 1009 individuals | | | | 0.0155 kg/person |

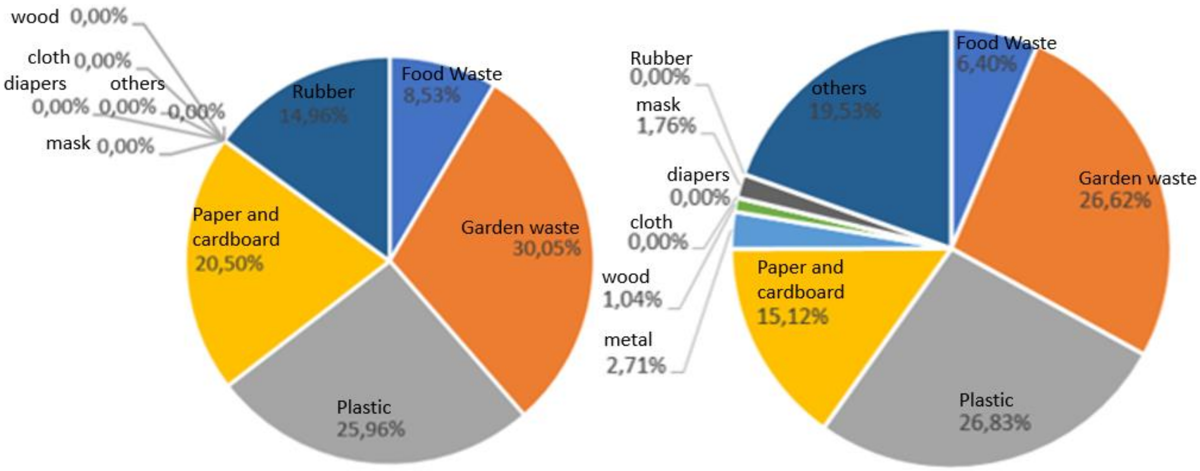


**Figure 1.** Waste composition at Adiwiyata School SMPN 18 Surabaya (left), Waste composition at Non-Adiwiyata School SMPN 31 Surabaya (right).

The data highlight a lower waste generation per capita at the Adiwiyata school (0.0103 kg/person) compared to the non-Adiwiyata school (0.0155 kg/person). This difference can be attributed to various environmentally friendly activities implemented at Adiwiyata schools, based on the "Six Environmental Friendly Behaviors" program. These activities range from sanitation and waste management to biodiversity, energy conservation, and innovative environmental care initiatives.

The differences in waste generation and composition between the two schools are illustrated in the following pie charts (figure 1).

These findings suggest that structured environmental programs in schools can significantly impact waste management practices, leading to reduced waste generation and potentially lower greenhouse gas emissions.

The differences in waste generation and composition between Adiwiyata-accredited SMPN 18 Surabaya and non-Adiwiyata SMPN 31 Surabaya can be attributed to the implementation of various environmentally focused activities at SMPN 18. These activities are part of the "Six Environmentally Friendly Behaviors" (PRLH) program, which includes maintaining sanitation and drainage cleanliness, waste management, biodiversity enhancements, energy conservation efforts, water conservation initiatives, and innovative environmental care projects. The implementation of these activities is organized and systematic, involving both students and teachers in dedicated working groups.

These programs significantly reduce organic waste, which in turn lowers greenhouse gas emissions from the schools. The following tables detail the methane ($CH_4$) emissions calculated for both schools:


**Figure 2.** (a) Students and teachers participating in waste measurement activities. (b) Waste sorting and utilization for composting and depositing at waste banks before transport to disposal sites. (c) Regular school-wide cleanup activities every Friday.

**Table 2.** Methane Emissions from Adiwiyata School SMPN 18 Surabaya.

| No | Waste Type | Wi (%) | W (Gg) | DOCi | DOC (Gg C/Cg Waste) | DOCf | MCF | DDOCm | F | 16/12 | Lo (Gg CH4/year) | CH4 (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Biodegradable: | | | | | | | | | | | | |
| 1 | Food waste | 6,0 | 0,0170 | 15% | 0,90 | 0,5 | 0,5 | 0,004 | 1,5 | 1,330 | 0,00256 | |
| 2 | Garden waste | 20,7 | 0,0588 | 20% | 4,14 | 0,5 | 0,5 | 0,061 | 1,5 | 1,330 | 0,04057 | |
| | Total | 26,7 | 0,0758 | 35% | 9,35 | 0,5 | 0,5 | 0,177 | 1,5 | 1,330 | 0,11813 | |
| Non Biodegradable: | | | | | 0,00 | 0,5 | 0,5 | 0,000 | 1,5 | 1,330 | 0,00000 | |
| 1 | Plastic | 18,6 | 0,0529 | 0% | 0,00 | 0,5 | 0,5 | 0,000 | 1,5 | 1,330 | 0,01912 | |
| 2 | Paper and Cardboard | 10,0 | 0,0285 | 40% | 4,00 | 0,5 | 0,5 | 0,029 | 1,5 | 1,330 | 0,00000 | 0,12338 |
| 3 | Metal | 0,0 | 0,0000 | 0% | 0,00 | 0,5 | 0,5 | 0,000 | 1,5 | 1,330 | 0,00000 | |
| 4 | Wood | 0,0 | 0,0000 | 43% | 0,00 | 0,5 | 0,5 | 0,000 | 1,5 | 1,330 | 0,00000 | |
| 5 | Rubber | 0,0 | 0,0000 | 39% | 0,00 | 0,5 | 0,5 | 0,000 | 1,5 | 1,330 | 0,00000 | |
| 6 | Textile | 0,0 | 0,0000 | 24% | 0,00 | 0,5 | 0,5 | 0,000 | 1,5 | 1,330 | 0,00000 | |
| 7 | Masks | 0,0 | 0,0000 | 0% | 0,00 | 0,5 | 0,5 | 0,000 | 1,5 | 1,330 | 0,00000 | |
| 8 | Diapers | 0,0 | 0,0000 | 24% | 0,00 | 0,5 | 0,5 | 0,000 | 1,5 | 1,330 | 0,00000 | |
| 10 | Other (Inert) | 17,9 | 0,0509 | 0% | 0,00 | 0,5 | 0,5 | 0,000 | 1,5 | 1,330 | 0,00000 | |
| | Total | 100,0 | 0,20801 | | 0 | | | | | | 0,13725 | |

**Table 3.** Methane Emissions from Non-Adiwiyata School SMPN 31 Surabaya.

| No | Waste Type | Wi (%) | W (Gg) | DOCi | DOC (Gg C/Cg Waste) | DOCf | MCF | DDOCm | F | 16/12 | Lo (Gg CH4/ year) | CH4 (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Biodegradable: | | | | | | | | | | | | |
| 1 | Food waste | 6,4 | 0,037 | 15% | 0,96 | 0,5 | 0,5 | 0,0088 | 1,5 | 1,33 | 0,00583 | |
| 2 | Garden waste | 26,6 | 0,152 | 20% | 5,32 | 0,5 | 0,5 | 0,2018 | 1,5 | 1,33 | 0,13463 | |
| | Total | 33 | 0,188 | 35% | 11,55 | 0,5 | 0,5 | 0,5434 | 1,5 | 1,33 | 0,36247 | |
| 1 | Non Biodegradable: | | | | | 0,5 | 0,5 | 0,0000 | 1,5 | 1,33 | 0,00000 | |
| 2 | Plastic | 26,8 | 0,153 | 0% | 0,00 | 0,5 | 0,5 | 0,0000 | 1,5 | 1,33 | 0,08685 | |
| 3 | Paper and Cardboard | 15,1 | 0,086 | 40% | 6,04 | 0,5 | 0,5 | 0,1302 | 1,5 | 1,33 | 0,00000 | 0,40465 |
| 4 | Metal | 2,7 | 0,015 | 0% | 0,00 | 0,5 | 0,5 | 0,0000 | 1,5 | 1,33 | 0,00044 | |
| 5 | Wood | 1 | 0,006 | 43% | 0,43 | 0,5 | 0,5 | 0,0006 | 1,5 | 1,33 | 0,00000 | |
| 6 | Rubber | 0 | 0,000 | 39% | 0,00 | 0,5 | 0,5 | 0,0000 | 1,5 | 1,33 | 0,00000 | |
| 7 | Textile | 0 | 0,000 | 24% | 0,00 | 0,5 | 0,5 | 0,0000 | 1,5 | 1,33 | 0,00000 | |
| 8 | Masks | 1,8 | 0,010 | 0% | 0,00 | 0,5 | 0,5 | 0,0000 | 1,5 | 1,33 | 0,00000 | |
| 9 | Diapers | 0 | 0,000 | 24% | 0,00 | 0,5 | 0,5 | 0,0000 | 1,5 | 1,33 | 0,00000 | |
| 10 | Other (Inert) | 19,5 | 0,111 | 0% | 0,00 | 0,5 | 0,5 | 0,0000 | 1,5 | 1,33 | 0,00000 | |
| | Total | 100 | 0,5699 | | | | | 0 | | | 0,4498 | |

**Table 4.** Simple Correlation Analysis Results

| Variable | Pearson Correlation | Significance (2-tailed) | N |
|---|---|---|---|
| Knowledge-Attitude | 0.292** | 0.000 | 210 |
| Knowledge-Action | 0.182** | 0.008 | 210 |

**Correlation is significant at the 0.01 level (2-tailed).

Methane emissions from Adiwiyata school are notably lower (0.123 Gg/year) compared to the non-Adiwiyata school (0.405 Gg/year). Mitigation and adaptation efforts to reduce methane emissions include promoting the 3R techniques (Reduce, Reuse, Recycle), optimizing composting from the source and at disposal sites, and improving landfill operations by periodically covering waste with soil and enhancing gas capture facilities.

Additional differences in waste outputs may be linked to the knowledge, attitudes, and actions of the school communities, as gathered through interviews and questionnaire surveys analyzed using SPSS 25. The correlation analysis results are as follows:

Based on Table 4, the significance value between the knowledge and attitudes of Adiwiyata school residents regarding waste generation at Adiwiyata school is <0.05. there is a correlation with the correlation coefficient value shown in the Pearson correlation. The p-value between knowledge and attitudes of school residents in reducing GHG emissions is 0.292, which is included in the low correlation because the p-value is between 0.20 to 0.399 [12]. The correlation relationship obtained between knowledge and attitude shows that there is a positive relationship, so that if 1 increase in the knowledge of the school community will increase 29.2% of the attitude of the Adiwiyata school community in producing waste generation at school.

The significance value between the knowledge and actions of Adiwiyata school residents on the value of waste generation at Adiwiyata schools is <0.05. The p-value between the knowledge and attitudes of school residents toward waste generation is 0.182, which is a very low correlation because the p-value is between 0.00 to 0.199 [12]. The correlation relationship obtained between knowledge and action shows that there is a positive relationship, so that if 1 increase in the knowledge of the school community will increase 18.2% of the actions of the Adiwiyata school community towards waste generation at school. Meanwhile, non-Adiwiyata schools produce the following calculations:

Based on Table 5, the significance value between the knowledge and attitudes of school residents towards the value of waste generation in non-Adiwiyata schools is <0.05. This significance value shows that there is a correlation between the two with the correlation coefficient value shown in the Pearson correlation. The p-value between the knowledge and attitudes of school residents towards the value of waste generation is 0.199, which is a very low correlation because the p-value is between 0.00 to 0.199 [12]. The correlation relationship obtained between knowledge and attitude shows that there is a positive relationship, so that if an increase of 1 in the knowledge of school residents will add 19.9% to the attitude of non-Adiwiyata school residents towards waste generation at school.

The significance value between the knowledge and attitudes of school residents regarding waste generation in non-Adiwiyata schools is <0.05. This significance value shows that there is a correlation between the two with the correlation coefficient value shown in the Pearson correlation. The p-value between the knowledge and attitudes of school residents towards the value of waste generation is 0.290, which is included in the low correlation because the p-value is between 0.20 to 0.399 [12]. The correlation relationship obtained between knowledge and attitude shows that there is a positive relationship, so that if an increase of 1 in the knowledge of school residents will increase 29% of the attitude of non-Adiwiyata school residents towards waste generation in schools.

**Table 5.** Simple Correlation Analysis Results for Non-Adiwiyata School

| Variable | Pearson Correlation | Significance (2-tailed) | N |
|---|---|---|---|
| Knowledge-Attitude | 0.199** | 0.004 | 210 |
| Knowledge-Action | 0.290** | 0.000 | 210 |

**Correlation is significant at the 0.01 level (2-tailed).

In non-Adiwiyata schools, there is also a positive correlation between knowledge and both attitude and action concerning waste management. This indicates that enhancing environmental knowledge can similarly foster positive changes in attitudes and behaviors regarding waste management in schools without environmental accreditations.

## 5. Conclusion

The waste generation at the Adiwiyata school, SMPN 18 Surabaya, produces 0.0103 kg/person of existing waste, which is lower than the non-Adiwiyata school, SMPN 31 Surabaya, which produces 0.0155 kg/person of existing waste generation. Likewise, the organic waste composition of Adiwiyata schools reached 38.58% while non-Adiwiyata schools reached 33%. With the Adiwiyata program, waste in Adiwiyata schools is reduced optimally to reduce GHG emissions so that there is a reduction in the percentage of waste, especially organic, from 38.58% to 2.08%, whereas for non-Adiwiyata schools, because there is no optimal reduction treatment for organic waste generation, then Waste wasted to landfill remains at 33%. The results of GHG emission calculations also show the same thing that Adiwiyata schools produce GHG emissions in the form of $CH_4$ gas generated by Adiwiyata schools of 0.123 Gg/yr, which is lower than GHG emissions in the form of $CH_4$ gas produced by non-Adiwiyata schools of 0.405 Gg/yr. This difference is triggered by the level of knowledge of school residents regarding attitudes and actions in the environment which have a correlation relationship. A caring attitude towards the environment refers to actions implemented in daily life to preserve, improve and prevent environmental damage and pollution.

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