Regional Case Study

Application of Chemical Mass Balance (CMB) Receptor Method for Identification of the PM10 Pollution Contributions at Pekanbaru City, Riau

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Abstract

Air pollutant that known no administrative boundaries of the territory and have extremely detrimental effects on humans and the ecosystem including flora and fauna. The high of particulate matter contaminant explains the main problem of air quality in Pekanbaru City, Riau. PM10 is one of the air pollutant parameters that is very harmful for humans and the environment. This pollutant can come from many sources such as transportation activity, industry activity, and natural disaster. Many receptor model applications were developed to solve this air pollution problem. One of the that is very popular is the receptor model US-EPA Chemical Mass Balance (CMB). This receptor model application is used to estimate potential PM10 sources and to quantify the contribution of emission sources such as transportation, industry and natural disasters that occurred in Pekanbaru City, Riau. This PM10 data was collected at the Sukajadi monitoring station for the Pekanbaru City BLH air quality monitoring center. The results of the research used the CMB receptor method using the PM10 concentration produces PM10 contribution values including 76.45% of land fires, 15.44% secondary particles, 4.8% of soil dust, electricity generation of 1.56%, as well as industrial and transportation sources were 1.31% and 0.44% respectively.

Keywords: PM10, Air Pollution, Chemical Mass Balance (CMB)

1. Introduction

Global environmental studies have shown that air pollution poses significant health risks in many developed and developing cities around the world (Sicard et al., 2023; WHO, 2021). Air pollution occurs when the air contains a certain number of substances that can harm the environment, affecting not only human comfort and health, but also the ecosystem of plants and animals (Humairoh, Syafei, & Santoso, 2019). Particulate matter is one of air pollutant parameters that has the most harmful impact on human health because of its ability to enter the deepest respiratory system (Kim, Kabir, & Kabir, 2015). The term PM is used to describe airborne and dispersed solid or liquid particles (Jayaraj, Sanjana, & Darshini, 2016). Particulates matter is divided into two, namely PM2,5 and PM10. PM2,5 is a particulate material with an aerodynamic diameter less than or equal to 2,5 mm. PM2,5 is considered a better health indicator than coarse particulate matter, PM10. While PM10 is a particulate matter with an aerodynamic diameter less than or equal to 10 mm (WHO, 2013)

World Health Organization (WHO) reported that 6% of deaths were due to lung cancer and most of them diseases are generally directly or indirectly related to respirable particulate matter (PM10). It was reported that global level of PM10 has increased by 6% from 2009 to 2012 (WHO, 2014). The high concentration of particulate matter explains the major problem of air quality in Pekanbaru City, Riau. This research focuses on PM10. This research aims to find about sources and their relative contribution to ambient air PM levels.

Coarse particulate matter (PM10) is the type of pollutant generated by mechanical processes, spray evaporation and suspension dust. PM10 is composed of oxides of aluminium silicates and other earth elements. Primary sources include fugitive dust from roads, industry, agriculture, construction and demolition, and fly ash from fossil fuel combustion. PM10 has a lifetime of a few minutes to a few hours, and it is traveling distance varies between < 1 km to 10 km (Humairoh et al., 2019). PM10 is a pollutant originating from human activities which produces high particulate and hydrocarbon emissions (Fernando, Huboyo, & Zaman, 2017)

Air pollution in an area does not only come from local pollutants but can also come from transportation across provinces and countries (Rixson, Riani, & Santoso, 2015). Studies revealed that higher concentration of PM in deeper subway station (Figueroa-Lara et al., 2019). Transportation activities in big cities such as Pekanbaru City and industrial activities around Pekanbaru City, Riau Province can contribute to PM10 sources in Pekanbaru City (Fernando et al., 2017). Increased industrial development activities lead to an increase in waste emissions from industries, including air pollutants that can alter the surrounding air quality (Zheng, Jiang, Qiao, Zhu, & Kennedy, 2016). Industrial activities are complex activities and involve a variety of processes. The use of fuels, the incineration process or the burning of raw materials at high temperatures is commonly seen in industrial activities. Emissions from industries are considered a main contributor of pollutant sources to airborne particulates. Therefore, this study is necessary to estimate the location of PM pollution sources (Humairoh et al., 2019)

On the other hand, the fog disaster at Pekanbaru City in 2015 causes air pollution which is very bad for public health and disrupts various activities daily residents from August to November 2015. 174,000 hectares of land in Riau Province burned. Based on this, the air pollution that occurs in Riau Province is an impact from land fires (Fernando et al., 2017).

Based on the problems above, it can be said that the air pollution in Pekanbaru City is caused by burned land. That air pollutant which is caused by burned land containing lots of contaminants such as carbon monoxide (CO), carbon dioxide (CO_2), particulate, hydrocarbon, and other organic chemicals (Fernando et al., 2017).

The study of the distribution of PM10 are still hampered due to the complex nature of the sources and analytical techniques used for its identification (Roy, Singh, & Yadav, 2016). Over 20 years, the scientist made the significant model to solve the air pollution problems. But there are still many examples where models are insufficient to provide comprehensive development for effective and efficient air quality management strategies. Receptor models are often applied to air quality problems in order to investigate the contribution of single specifics sources including industrial sources (Contini, Cesari, Conte, & Donateo, 2016) and disaster sources.

Newdays, there has been a resurgence of interest in the source PM10 distribution study, One alternative model developed to help identify sources and distribution of pollutant concentrations in the air is Chemical Mass Balance (CMB) (Hopke, 2016). Chemical Mass Balance was commonly used to identify the possible sources of pollutants (Roy et al., 2016). This type of Chemical Mass Balance (CMB) receptor model can be used to estimate the emission contribution from various existing source categories to the concentration measured in the receptor area. Use of receptor models, such as CMB, in combination with disperse models highly recommended in air pollution control management (Mircea, Calori, Pirovano, & Belis, 2020). However, application of the dispersion model and the receptor model together often produce different results and these results must be concluded and re-evaluated.

2. Methods

2.1 Measurements Sites and Sampling Strategy

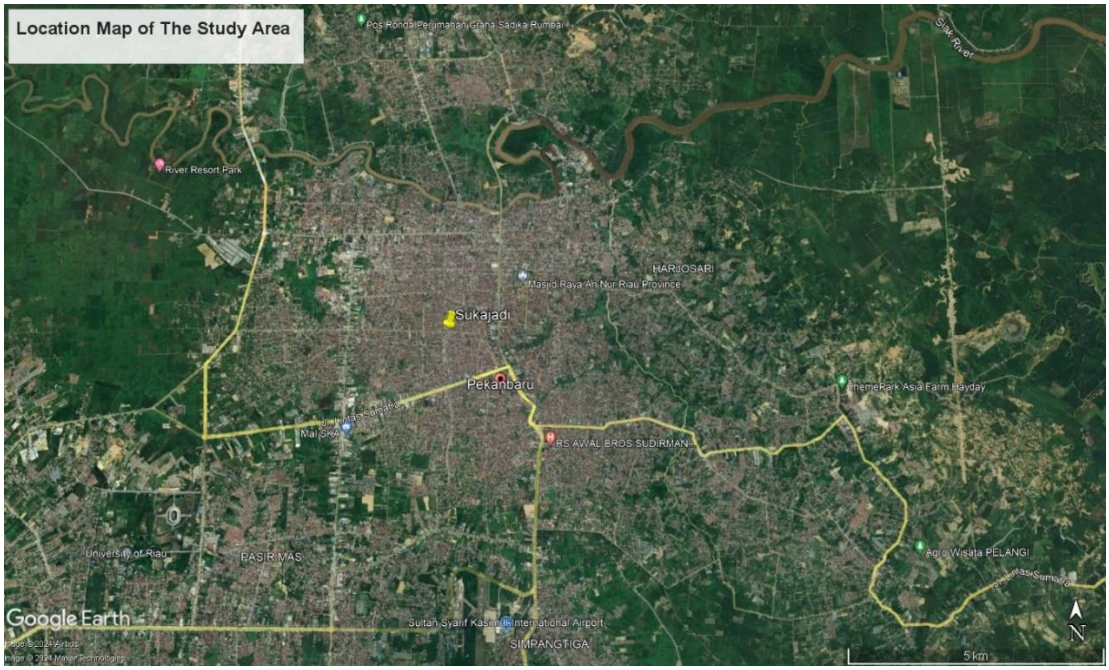

Figure 1. The location map of study area

Study site in Pekanbaru City is located on Sukajadi Air Pollution Monitoring Station and it belongs to Environmental Agency (BLH) as shown in Fig. 1. Pekanbaru City has a population of 1.122 million. The city has a diversified economic base anchored by wood industry or the pulp and paper industry that caused the PM10 level in the city are getting worse due to fast urbanization and industrialization (Zhang, 2022).

The research of PM10 contribute on Pekanbaru City, Riau is using the model of receptor chemical mass balance (CMB). This model is use to know the concentration of PM10 at Pekanbaru City area, elements, cation and anion that contain in PM10 and the main source of PM10 emission.

Ambient PM10 data is the most important data in this research. Direct data collection as well as sampling is carried out in the region study, namely Pekanbaru City, Riau. This research was carried out for 6 months, starting from October 2015-March 2016 where the sampling will be carried out in the area study at the Sukajadi air pollution monitoring station, Pekanbaru City, Riau belongs to the Environmental Agency (BLH), through 24-hour continuous monitoring. This sample was obtained with BAM-1020 equipment PM10 located at monitoring stations. This location is monitored every seven days on a sampling schedule. The monitoring tool operates continuously and shows ambient air PM10 concentration. Collection of actual concentration data from PM10 intended to see the quality of PM10 pollution in the study area. Besides that, PM10 samples obtained during this monitoring will also be used as data composition of chemical species contained in PM10. Composition of the sample analyzed in the Laboratory. There are four PM10 samples from monitoring results collected regularly every week. These are the figure of monitoring tools as general.

Fig. 2 BAM-1020 monitoring intrument

The BAM-1020 monitoring tool uses the radiometric principle with light beta by electronic sensors (Shukla & Aggarwal, 2022). Every particulate collected uses the single spot method. Previously placed particulates in the collection-measurement chamber until the filter load is full. In this case, if the circles on the filter have reached 2000 µg or a flow rate of 950 l/hour. After that, the new part of the filter will move towards the measurement position (automatic filter change). Each time this process occurs, the concentration value returns to zero and the concentration measurement is carried out again.

During sampling, the settled particles increase thereby weakening the intensity of beta rays in this section. The electrical signal is conveyed as actual mass information on the sample filter, so that concentration calculations are automatically carried out. Additionally, wind direction and speed data were collected to support the results monitoring PM10 concentrations and actual conditions occurring at the time monitoring is carried out. This wind direction and speed data is monitored continuously for the same time period as when the PM10 filter was taken.

From each check the mass value collected on a certain time, the mass slope value is calculated which is then displayed as a concentration value. The equation for calculating PM10 concentration monitoring tools following equation (1)

$$CLR = + \frac{\frac{dmLR}{dt} \text{x Treg}}{V} \quad (1)$$

2.2 Gravimetric Measurements and Chemical Analysis of PM10

PM10 samples obtained during the monitoring period were tested in the laboratory to obtain the concentration of a chemical species or its composition. The composition of PM10 is very varied so it is possible unidentified components are likely to occur (Dongarrà, Manno, Varrica, Lombardo, & Vultaggio, 2010). Measurement PM10 sample concentration is intended to explain the percentage value concentrations of unmeasured and measured chemical species, considering there were 6 samples analyzed over 6 months, each with a period taking filter samples 1 week in monitoring carried out for one month.

The six-month duration was chosen to ensure comprehensive data collection that captures seasonal variations and changes in PM10 composition due to environmental, climatic, and anthropogenic factors (Xu et al., 2015). Extended monitoring allows for a more accurate and representative analysis of the chemical composition of PM10, accounting for potential fluctuations in pollutant sources, weather conditions, and other variables that may influence air quality (Hamdan, Alawadhi, & Shameer, 2021).

2.3 Elemental Analysis of PM10 Samples using the Inductively Coupled Plasma Method

This method destroys the monitoring filter which is made from fiberglass. The filter results will be put into an Erlenmeyer and 3 ml of HNO3(P) + 3 ml of HCL (P) added. Then the solvent is heated on a hot plate for 30 minutes and cooled for 30 minutes. Then filtering filtrate and diluted with distilled water/aqua Demin up to 20 ml. The sample is inserted into the ICP-OES and inhaled through the nebulizer converting a sample in the form of a liquid into an aerosol which then flowed into plasma with a temperature between 600-1000K. The sample will undergo atomization and excitation. The excited atom will return to their initial state and emit light radiation (Mokrzyński, Krzysztyńska-Kuleta, Zawrotniak, Sarna, & Sarna, 2021). The light is scattered by the optics and focused onto the slits of a monochromator or polychromator, where it is successively scattered into the wavelengths of each element and converted into an electrical signal proportional to the amount of light emitted by the concentration of the element (Sagagi, 2013). The scattered light is measured by a line intensity detector after the emission lines are separated by a monochromator. The type of detector used in most ICP-OES is a photomultiplier tube (PMT). The anode current in the PMT can be converted to represent the emission intensity, which becomes a voltage signal converted into digital information that can represent the metal concentration in the sample (Wright, 2017).

2.4 Analysis of Inorganic Ion Concentration in PM 10 Ambien

Ion Shimadzu chromatography will be used to obtain the concentration of inorganic ions in PM10. Some of the Teflon is used for inorganic ion analysis. Each filter was extracted by ultrasonic agitation for 20 minutes using 4 mL of deionized water. The extract is filtered through Teflon syringe filter (pore size 0.45 m) and analyzed using the ion exchange method chromatography (HIC-10A, Shimadzu).

Fig. 3 Shimadzu Ion Chromatography
Source: http://www.shimadzu.com, 2016

2.5 Chemical Balance Model (CMB) Analysis

The CMB method is widely used for analysis of inferred source contributions without first requiring quantitative source composition data (Daniela Cesari, Donateo, Conte, & Contini, 2016). CMB analysis assumes that aerosol mass is conserved from the time at which a chemical species is emitted from its source to the time it is measured at the receptor (Roy et al., 2016). The mass conservation method in EPA's chemical mass balance receptor model software version 8.2 was used to analyze the contribution of PM10 pollutants. This analysis process is carried out as an iterative process, by adjusting the concentration of chemical species in PM10 analyzed in the laboratory with data regarding the pollutant source profile collected. The output of this model is the total PM10 concentration, along with its standard deviation.

The CMB method was chosen because it provides a robust and effective means of estimating source contributions to air pollution by directly utilizing chemical composition data of the samples and existing source profiles (Tian, Wang, Zhao, Shi, & Harrison, 2023). Unlike other methods, it does not require complex modeling of atmospheric transport and transformation processes, which can introduce uncertainties. The method's reliance on mass conservation principles ensures accurate identification and quantification of source contributions, making it particularly suitable for regulatory applications, air quality management, and pollution control strategies (Roy et al., 2016).

2.6 Input Data CMB

When working with the model in the CMB program, there are 6 main data used, where 1 data is data control for 5 other specific input data for ease of processing. However, if the controlling data is not created, the estimation of the CMB contribution can still be done by manually entering the required input data. The two main data that must be included in the input data are the source profile mass fraction data and the sample composition mass fraction data.

The selection of sources, chemical species and samples is written in a special table prepared to make it easier to select the samples, chemical species and sources you want to calculate in the CMB model. With this data, elections do not need to be made every time the CMB program is started. This data can be useful for delimiting species and ambient sample data that you want to calculate in the program so

that these data do not have to be changed in writing even though not all chemical variables or source profiles are used in the capital. All this data can be created in a commonly used word processing stander.

Input data for ambient PM10 mass fraction can be compiled in CSV format with the help of the Microsoft Excel program. An example of the data writing model used to input the PM10 sample mass fraction can be seen in the table (1)

Table 1. Example of PM10 ambient mass fraction input data (ADsvjf.csv)

	Date	**DUR**	**STOUR**	**SIZE**	**TMAC**	**TMAU**	**N3IC**	**N3IU**	**S4IC**	**S4IU**
BAKERS	06/20/88	24	0	FINE	172.788	0.9920	0.2816	0.1715	28.204	0.1612
BAKERS	07/02/88	24	0	FINE	235.425	12.744	0.8306	0.1761	32.224	0.1791
BAKERS	07/26/88	24	0	FINE	267.742	14.250	0.2054	0.1715	34.881	0.1911
BAKERS	08/07/88	24	0	FINE	219.185	12.008	0.4096	0.1732	31.228	0.1748
BAKERS	08/19/88	24	0	FINE	226.664	12.339	0.5093	0.1729	37.134	0.2014
BAKERS	08/25/88	24	0	FINE	301.214	15.825	0.6130	0.1730	35.371	0.1932
BAKERS	08/31/88	24	0	FINE	253.387	13.569	0.4207	0.1716	34.671	0.1900
BAKERS	09/06/88	24	0	FINE	308.824	16.189	0.6670	0.1736	27.646	0.1586
BAKERS	09/12/88	24	0	FINE	276.091	14.641	0.6924	0.1745	32.503	0.1803
BAKERS	10/18/88	24	0	FINE	471.988	24.114	42.887	0.2760	54.811	0.2853
BAKERS	11/111/88	24	0	FINE	226.296	12.314	34.700	0.2431	16.402	0.1130
BAKERS	11/17/88	24	0	FINE	215.811	11.833	31.740	0.2328	11.997	0.0982
BAKERS	11/23/88	24	0	FINE	140.767	0.8563	26.161	0.2153	14.961	0.1081
BAKERS	11/29/88	24	0	FINE	444.116	22.761	133.413	0.6887	39.645	0.2131
BAKERS	12/05/88	24	0	FINE	1.364.439	68.398	488.061	25.320	80.547	0.4102
BAKERS	12/11/88	24	0	FINE	1.644.591	82.375	612.912	31.380	100.051	0.5063
BAKERS	12/17/88	24	0	FINE	437.105	22.394	104.595	0.5503	45.647	0.2412
BAKERS	12/23/88	24	0	FINE	327.483	17.082	57.176	0.3328	34.971	0.1914
BAKERS	12/29/88	24	0	FINE	780.441	39.326	157.947	0.8080	77.026	0.3930
BAKERS	01/04/89	24	0	FINE	585.364	29.669	138.542	0.7134	72.325	0.3699
BAKERS	01/10/89	24	0	FINE	499.733	25.453	145.694	0.7481	38.032	0.2054

3. Result and Discussion

3.1.1 Concentration PM10 in Ambient Air and Sources

The chemical species used for the source apportionment of PM10 are composed of the organic fraction (EC, OC), the major water-soluble ions (Cl , NO3, SO4 2 , Na+, NH4+, K+, Mg2+, Ca2+), and inorganic elements (Al, Si, Ti, V, Mn, Fe, Ni, Cu, and Zn) (D Cesari et al., 2021)

Table 2. Average daily concentrations of PM10 in September 2015-March 2016

Date	September	October	November	December	January	February	March
1	309,3	255,12	39,37	13,37	7,62	14,93	27,35
2	452,41	136,08	41,42	20,35	10,38	28,45	32,12
3	335,24	251,29	48,29	33,09	16,32	24,33	27,86
4	358,38	479,81	25	17,06	22,55	18,79	26,23
5	245,37	390,02	21,53	17,32	20,28	16,41	26,1
6	268.64	458,42	11,014	18,47	21,06	11,45	22,35
7	392.18	179,11	8,59	26,75	14,3	7,39	16,11
8	374.39	129,43	14,3	22,2	23,56	17,39	18,52
9	116.63	110,13	19,22	21,7	27,1	26,15	31,8
10	163.15	137,03	32,73	23,1	20,95	29,62	32,31
11	417.27	162,61	28,05	18,47	34,7	20,98	27,19
12	393.66	148,45	15,25	18,47	28,8	16,59	25,31
13	471.74	192,2	21,59	18,47	22,29	22,45	25,31
14	497.69	112,63	24,7	15,68	17,58	19,42	6,8
15	301.81	112,22	14,51	13,12	6,74	20,77	16,99
16	376.26	141,52	10,02	15,15	9,13	17,84	6,49
17	237.21	247,09	11,07	20,41	13,7	20,66	43,6
18	431.39	458,45	25,01	21,81	13,48	20,66	34,79
19	191.28	418,59	19,32	27,17	14,74	10,56	41,15
20	191.26	417,5	18,71	11,35	17,6	14,78	20,72
21	149.4	500,36	20,39	18,51	24,73	24,87	15,46
22	167.23	475,2	20,39	17,22	26,27	25,98	5,81
23	110.08	569	20,39	12,73	36,84	28,22	14,99
24	114.6	343,88	14	18,47	18,53	27,56	21,74
25	201.47	177,05	10,21	18,47	13,21	22,22	26,39
26	510.12	255,1	16,54	18,47	21,43	29,32	16,86
27	400.62	174,17	12,08	18,47	14,57	27,96	23,15
28	300.09	99,93	19,39	13,73	11,34	17,85	28,35
29	430.88	55,99	11,09	7,88	15,91	15,61	32,02
30	399.46	47,19	17,63	16,21	18,82		35,05
31	309.3	24,47		19,03	18,82		45,56

Table 3. Avarage Monthly PM10 Concentrations in October 2015-March 2016

Monitoring time	PM10 Concentration (µg/m3)	Standard Deviation (µg/m3)
September	310,31	80.21
October	247,10	44.56
November	20,39	9.14

December	18,47	7.3
January	18,82	10.66
February	20,66	7.76
March	25,31	8.8

From the graph above it can be concluded that the highest monitoring during the research period (September 2015 March 2016) was the daily PM10 concentration value of 656.1 µg/m3 which was recorded on October 21 2015, this threshold is far beyond the national daily PM10 threshold of 150 µg/m3 is the same when compared with the PM10 quality standard from NAAQS US-EPA, namely 50 µg/m3. Therefore, daily concentrations measured above these two quality standards can be said to be extremely dangerous.

From tables above the PM10 concentration in the monitoring area experienced quite significant fluctuations or differences in concentration each month, especially the large differences occurred in October and November 2015 because November 2015 to March 2016 had entered the rainy season. So, the high rainfall and humidity in Pekanbaru City can reduce the number of hot spots around Pekanbaru City which also causes PM10 concentrations to decrease at the Sukajadi air monitoring station in Pekanbaru City.

The impact of PM10 can specifically cause a decrease in levels potential health, and for monitoring areas there are various sources emission sources that have the potential to make a significant contribution to ambient air (Manisalidis, Stavropoulou, Stavropoulos, & Bezirtzoglou, 2020). This source can be emissions from motor vehicles, soil erosion by wind, dust from unpaved asphalt roads, biomass burning, burning of vegetation, emissions from company activities and/or activities, agriculture and other commercial activities.

Potential emission sources in Pekanbaru City were obtained by reviewing PM10 emission sources, including (1) Data on wind direction and wind speed that affect the receptor area (2) PM10 monitoring location Jl. Sukajadi is linked to local land use. (3) Inventory data for medium and large businesses and/or activities and their types.

3.1.2 PM10 Chemical Composition

Of the four PM10 filters collected in the Sukajadi monitoring area, analysis was carried out for chemical analysis of the samples. Filters were collected every 1 day with PM10 concentrations during 3 months of monitoring. Elemental analysis was performed to each filter, namely 24 elements, varying from argentum (Ag) to mercury (Hg) use inductively coupled plasma optical emission spectrometry (ICP-OES). Additional chemical analysis was carried out for several ion species, namely sulfate (SO_4-), nitrate (NO_3-), ammonia (K+), magnesium (Mg^{2+}), calcium (Ca^{2+}) and chloride (Cl-) with Ion Chromatography (IC) (Ristić et al., 2013). Average results of chemical species composition data at monitoring sites Sukajadi can be seen graphically in the figure and table below

Table 4. Chemical species composition analysis table with sample standard deviation PM10 Sukajadi

Parameters	Concentration (µg/m3)	Deviation Standard
Mass	310.307	2862.320467
As	0.026357646	0.008785882
Bi	0.02144399	0.007147997
Cr	0.156854847	0.052284949
Cu	0.006312486	0.004402626
K	2.619575097	0.873191699
Mn	0.024199046	0.008066349
Ni	0.018774142	0.006258047
Pb	0.017327867	0.005775956
Rb	1.287434674	0.429144891

Se	0.002075974	0.000691991
TI	0.003506112	0.001168704
Zn	1.370739605	0.456913202
Fe	0.043857676	0.012817609
Mo	0.044762554	0.014920851
Hg	0.171961771	0.05732059
NO_3^-	0.922677	0.014881885
SO_4^{2-}	10.58279	0.22024536
K^+	0.611456	0.0156383
Na^+	5.372170847	0.233572646
Cl^-	1.436625059	0.040468312

In the table 4 above it can be seen that the average chemical composition is dominated by SO_4^{2-}, which is 3.4% of the average total sample mass that can appear as primary particles (directly emitted from the source) such as engine emissions diesel or as secondary particles (formed due to reactions in the atmosphere). The K composition is also quite large, namely 0.84% of the average total sample mass. This species is often described as a primary particulate that usually occurs as a result there is burning of vegetation or it can also originate from geological material in the area around. The element Hg can originate from fossil fuels. One of the fossil fuels is oil such as petrol and diesel despite the content in the resulting products This byproduct of petroleum is relatively small, and if these metal particles are deposited, it is possible that these elements can be suspended in the air again along with other materials (Chen, Maciejczyk, & Thurston, 2022).

3.1.3 Aplication of Chemical Mass Balance (CMB)

i. Preparation of Chemical Mass Balance (CMB) Source Profile

This source profile was collected from research studies that previously analyzed the composition of PM10 emission sources. Sources PM10 in the Sukajadi area, Pekanbaru which has been identified by analysis composition and correlation of chemical species in samples, combined into categories which is more general so that collinearity does not occur which could hinder it estimated contribution in the CMB. Collinearity occurs when there are variations in fractions of identical masses and chemical species in two or more source profiles. The degree of collinearity depends on the relative contribution (or mass fraction) of each type of source profile and variability of species mass fraction (Dai et al., 2019).

To avoid collinearity that occurs, for example, an industry source profile would better explain the estimated contribution rather than dividing these sources into individuals. Industries sources can be divided more specifically according to the chemical species emitted completely quantified, as in the specific components of organic carbon, which was not analyzed in this study.

Preparation of soil dust source profiles, manufacturing industry, transportation, power generation, and land burning are carried out with the special version program 4.4 which was specifically created to assist in the quantification of source profiles for CMB PM10, PM2.5, TSP, and VOC. In this program, there are the following sources chemical composition and standard deviation required for the study source profile contribution of particulates and VOCs summarized from various studies ever done. Meanwhile, for the source profile of ammonium nitrate and sulfate taken from research by Chow et.al, (1992) regarding the contribution of particulates in San Joaquin Valley, California, which has also been frequently used as a profile source on research into the contribution of particulates to ambient air

ii. Contribution with Chemical Mass Balance (CMB) Modeling Applications

The CMB model output is the value of the statistical measurements used to assess the level of representation and accuracy of the CMB model process. The results of the CMB analysis carried out on filters collected at the Sukajadi monitoring location show the estimated contribution of PM10 pollution

sources for the seven categories of pollutant sources, namely land fires, manufacturing industry, power plants, soil dust/geological materials, transportation, ammonium nitrate and ammonium sulfate. which displays in average concentration units and mass percentage. The CMB model can predict mass concentrations that are greater or less than those measured on the filter, but in most samples the calculated mass of PM10 is less than 100%. This indicates that there are several mass concentrations whose chemical composition is unknown. Deviations in mass concentration and CMB sources are acceptable as long as they are less than 20% of the mass concentration value.

From the CMB calculation results, contributions from vegetation fires, land fires, and ammonium sulfate (a source of secondary particles) are the most significant sources of PM10 air pollution. Land fires contributed 76.45%, soil dust 4.8%, and ammonium sulfate 13.94% of the PM10 mass. Meanwhile, other sources, industry, power plants, soil dust, transportation, and ammonium nitrate contribute around 0-2% of the mass of PM10. Of the total mass calculated by the CMB model, there is approximately 71.57% of mass that is not quantified. This can be caused by other sources that are not identified in the monitoring area. However, this is still within tolerance limits because in CMB, PM10 can be estimated to contribute to the calculated mass value of at least 20%. The results of the validity of the data obtained from the application of the CMB receptor method are that it has an error of 21.11% and an average of 78.89% of the data is valid data and can properly estimate the contribution of the selected pollutant sources.

Table 5. Validity results of CMB Modeling Applications

Date	R Square	Chi Square	%Mass	Date	R Square	Chi Square	%Mass
01-Sep-15	0.81	1.43	18.70	16-Sep-15	3.31	2.17	24.80
02-Sep-15	0.71	4.95	17.40	17-Sep-15	5.68	0.94	21.90
03-Sep-15	0.82	2.93	20.40	18-Sep-15	1.66	4.88	25.20
04-Sep-15	1.01	3.96	23.90	19-Sep-15	7.91	5.96	22.30
05-Sep-15	1.03	0.59	21.50	20-Sep-15	5.31	1.98	36.00
06-Sep-15	0.71	6.95	23.50	21-Sep-15	5.31	1.98	36.00
07-Sep-15	0.71	6.95	23.50	22-Sep-15	5.31	1.98	36.00
08-Sep-15	0.69	1.25	21.60	23-Sep-15	5.31	1.98	36.00t
09-Sep-15	0.78	2.29	51.80	24-Sep-15	1.02	4.20	49.70
10-Sep-15	0.52	2.18	32.80	25-Sep-15	7.51	7.95	34.20
11-Sep-15	1.22	2.26	26.80	26-Sep-15	7.51	7.95	34.20
12-Sep-15	1.22	2.26	26.80	27-Sep-15	0.76	1.69	30.90
13-Sep-15	1.22	2.26	26.80	28-Sep-15	0.51	5.24	30.60
14-Sep-15	1.22	2.26	26.80	29-Sep-15	0.91	1.90	20.10
15-Sep-15	1.22	2.26	26.80	30-Sep-15	0.91	1.90	20.10

Table 6. Percent Data Validity

R Square	73.33%
Chi Square	70.00%
%Mass	93.33%
Average Validity Data	78.89%
Error Which Generated	21.11%

Note: * = Data that has a number less than the model's optimum number

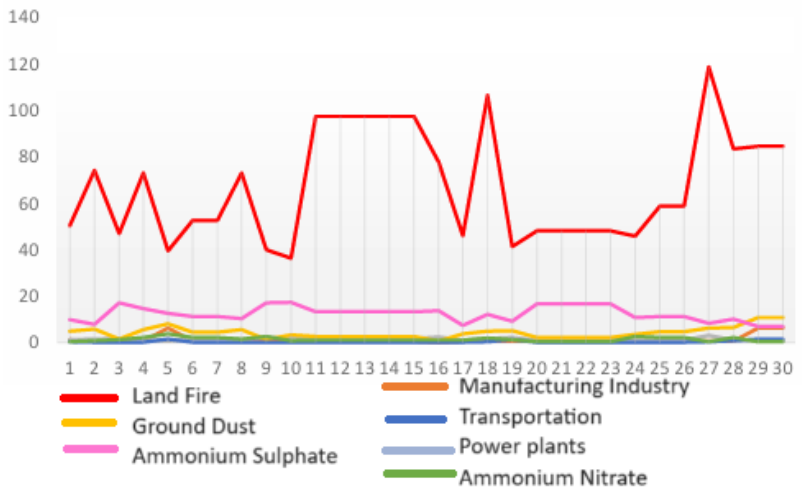

Fig. 4 Graph of contribution of air pollution sources per day

4. Conclusions

Monitoring carried out in September 2015, October 2015 on PM10 concentrations in the Sukajadi monitoring area showed that the average value was still above the national PM10 quality standard (150 µg/m3), with the highest daily value of 569 µg/m3 on 23 October 2015 and the highest hourly value was at 15.30 on September 14 2015, namely 898.8 µg/m3. So, PM10 in this area is very dangerous. The composition of all PM10 samples collected for 3 months shows that K and SO4- are the most dominant chemical species with contents of 2.62 µg/m3 and 10.58279µg/m3, respectively. Application of the CMB 8.2 model to PM10 concentrations produces PM10 contribution values including 76.45% of land fires, 15.44% of secondary particles, 4.8% of soil dust, electricity generation of 1.56%, and industrial and transportation sources of 1.31% and 44%. respectively.

This study provides a insight into the alarming contribution of land fires as the dominant source of PM10 pollution in the Sukajadi area, with a significantly high percentage (76.45%) compared to other sources. The integration of PM10 chemical composition analysis with the CMB 8.2 model presents a novel application in identifying and quantifying specific pollutant sources. This research also highlights the unprecedented peak hourly PM10 concentration of 898.8 µg/m^3, which is among the highest ever reported for the region, underscoring the need for immediate mitigation strategies. Furthermore, the study reveals the dominance of potassium (K) and sulfate (SO_4^{2-}) as primary chemical species, suggesting strong associations with biomass burning and secondary atmospheric processes, offering a fresh perspective on source apportionment in areas severely affected by land fires.

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