Statistical Analysis of Municipal Solid Waste Landfill Leachate Characteristics in Different Countries

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\section*{ABSTRACT}

This research was aimed to study municipal solid waste landfills leachate parameters for different sanitary landfill designs such as open dumping, anaerobic, and semi-aerobic with various ages in different countries. Landfill leachate characteristics such as pH, electrical conductivity (EC), turbidity, color, ammonia-nitrogen (NH\textsubscript{3}-N), biochemical oxygen demand (BOD), chemical oxygen demand (COD), biodegradability ratio, total solids (TS), total suspended solids (TSS), iron (Fe) and phenols and the age of landfills were used for examining in the statistical analysis. Application of statistical package for social sciences (SPSS) for statistical analysis for the mentioned parameters was another goal for this work. Results showed that leachates parameters such as turbidity, color, NH\textsubscript{3}-N, BOD, COD, TSS, Fe, and phenols were surpassed the standard limits for disposal. SPSS results presented that strong correlation ($r > 0.5$ at $P < 0.005$) discovered amongst NH\textsubscript{3}-N with BOD/COD, TS, and TSS; between BOD/COD with TS and TSS; among TS with TSS, Fe, and EC, and amid Fe and EC. The age of landfills generally hadn’t important statistical correlation with the aforementioned landfill leachate parameters; merely color approached to have a correlation with age ($r = -0.986$ at $P = 0.054$).

\section*{1. INTRODUCTION}

Sanitary landfill is the greatest public municipal solid waste (MSW) disposal technique due to such benefits as easy disposal process, low cost, and landscape-restoring result on holes from mineral workings. Though, the production of highly polluted leachate is a chief disadvantage of MSW landfilling system. Landfill leachate is liquid produced mainly by the infiltration of precipitation from an open landfill or through the cap of a completed landfill site. MSW landfill leachates may comprise large quantities of organic matters, ammonia-nitrogen (NH\textsubscript{3}-N), phenols, heavy metals, inorganic salts etc. (Renou et al., 2008; Bashir et al., 2010; Mauloolod and Aziz, 2016). Landfill leachate may be a threaten source for the soil,
groundwater and surface water sources, if not treated and carefully disposed to the natural environment (Aziz et al., 2015; Aziz and Maulood, 2015). Normally, the risks of the landfill leachate on the environment are found by comparing leachate parameters characteristics with the standards.

Matsufuji et al. (1993) and Yamamoto (2002) reported that in an anaerobic landfill, MSWs are dumped in an excavated site, which is filled with water in an anaerobic condition. Usually, anaerobic sanitary MSW landfills are known by its sandwich-shaped cover. In contrast, semi-aerobic (Fukuoka method) landfills have a landfill leachate collection pipes. The opening of the pipe is surrounded by air, and the pipe is covered with appropriate crushed stones. Moisture content in disposed MSW is low, and oxygen is provided to the MSW from the leachate collection conduit (JICA, 2005; Aziz et al., 2010). Age of landfill has a significant impact on the formed fresh landfill leachate. Age of landfill arranges the landfill leachate to young (< 5 years), intermediate (5 to 10 years) and matured/stabilized leachate (> 10 years) (Aziz et al., 2011). MSW landfill leachate characteristics such as pH, organic matters, nitrogen compounds, electrical conductivity (EC), color, solids etc. are changes with the age and types of landfills (Renou et al., 2008; Aziz et al., 2010; Mojiri et al., 2015; Aziz and Ali, 2018). Huge surface and cross-sectional areas of MSW landfill sites causes more production of landfill leachate to the surrounded areas.

Amount of disposed MSW in Erbil landfill site (ELS) - Iraq, Pulau Burung landfill site (PBLs) - Malaysia and Palestine were 2000 tons/day, 1800 tons/day, and 3605 tons/day, respectively (ARIJ, 2015; Kamaruddin et al., 2016; Aziz and Mustafa, 2018). High quantity of disposed MSW leads to increase in leachate production. Quantity of produced leachate at ELS-Iraq and PBLS-Malaysia were 158.68 m³/d and 69.201 m³/d, respectively (Maulood and Aziz, 2016; Aziz et al., 2002).

The current research was focused on the MSW landfill parameters, such as age of landfill site, type of landfills (open dumping, anaerobic landfill, semi-aerobic landfill, and fully aerated landfill) and characteristics of landfill leachate. pH, electrical conductivity (EC), turbidity, color, NH₃-N, biochemical oxygen demand (BOD), chemical oxygen demand (COD), biodegradability ratio (BOD/COD), total solids (TS), total suspended solids (TSS), iron (Fe) and phenols were used for illustrating quality of leachate for different MSW landfills. Statistical Package for the Social Sciences (SPSS) was applied to find statistical relations between mentioned parameters. In literature, a number of factors influences on the landfill leachate quality (Renou, 2008; Aziz et al., 2010). So far, determining descriptive statistics and correlations among landfill site and aforementioned landfill leachate characteristics using IBM SPSS was not conducted yet.

2. MATERIALS AND METHODS

2.1. Landfills

To show the effect of age and type of landfill on the quality of formed leachate, different MSWs were studied. The landfills were located in Malaysia, Iraq, and Palestine. In Malaysia, MSW landfills of Pulau Burung, Kulim, Kuala Sepatang, Sungai Patani, and Alor Pongsu were selected. While Erbil and Deir El-balalah MSW landfills were chosen in Iraq and Palestine, respectively. The landfills had various ages and designs. Studying MSW landfill leachate in Malaysia, Iraq and Palestine landfills are related to: 1) generation rate and characteristics of MSW are close to each others and all countries are located in Asia, 2) availability of information on the mentioned
landfills, and 3) commonly life style, climate and topography for the countries and especially for Erbil-Iraq and Palestine are close to each other. Details of landfills are shown in Table 1. Data from 15 various landfills were collected.

2.2. Landfill leachate

Characteristics of produced MSW landfill leachate at mentioned landfills were reported. The parameters of pH, EC, turbidity, color, \( \text{NH}_3-\text{N} \), BOD, COD, BOD/COD, TS, TSS, Fe, and phenols were collected at different MSW landfills. Table 1 illustrates the quality parameters for landfill leachates. In literature, data collection, transportation, and analyses were carried out according to (APHA, 2005).

2.3. SPSS program

SPSS is a complete system for analyzing collected data. It can obtain data from any type of file and use them to produce tabulated reports, plots of distributions and trends, charts, descriptive statistics, and complex statistical analysis. It is one of the best widespread statistical packages which can implement extremely complex data manipulation and analysis with easy instructions. SPSS is expert of handling huge quantities of data and can execute all of the analyses covered in the text and much more long produced by SPSS Inc., it was developed by IBM in 2009. The present version (23) is formally called IBM SPSS Statistics. Confidant products in the similar family are used for survey authoring and placement (IBM SPSS Data Collection), data mining (IBM SPSS Modeler), collaboration and deployment, and text analytics (Field, 2009). Statistical analysis for the quality parameters for the collected samples was carried out using IBM SPSS software. Descriptive statistics and correlations between wastewater samples were prepared.

3. RESULTS AND DISCUSSIONS

3.1. MSW landfills

Data on MSW characteristics is significant for the design of new waste management policy (Idris et al., 2004). Active MSW management and minimization strategy is practically difficult without dependable MSW data. Acceptable information on MSW characteristics is necessary to evaluate the influences of various MSW kinds and to appraisal the age of landfills. However, obtaining responsible and accurate data on MSW characteristics is not easy (Idris et al., 2004). A MSW landfill is a separated land that receives domestics, commercial, non hazardous … etc. wastes (https://www.epa.gov/landfills/municipal-solid-waste-landfills).

MSW landfills are simple, economical, and widely investigated disposal systems adopted all over the world. In a traditional MSW landfills, efforts are made to minimize moisture infiltration, which, in turn, leads to a longer decomposition time for the disposed MSW. Biodegradation of the MSW could be enhanced in different methods. Among some techniques, recirculation of landfill leachate and associated fluids within the landfill system (i.e., bioreactor landfills) was found to be effective method (Rajesh et al., 2016).

MSW disposal techniques contain open dumping, incineration, sanitary landfill, grinding and discharge to sewer, composting, hog feeding, milling, dumping, compaction, reduction, and anaerobic digestion. Sanitary landfill is the greatest common urban MSW treatment method (Aziz et al., 2010). The landfill must be designed and operated so as to separate the MSW from the environment until it may be extracted safe over physical, chemical, and biological decay processes in the landfill. Generally, a sanitary landfill will be determined by the following: site selection, planned capacity, extensive site preparation,
Table 1: Characteristics of different landfill leachates

| No. | Site                  | MSWL Age Type                        | pH  | EC (µS/cm) | Turb. (NTU) | Color (Pt.Co.) | NH₃-N (mg/L) | BOD (mg/L) | COD (mg/L) | BOD/COD | TS (mg/L) | TSS (mg/L) | Fe (mg/L) | Phenols (mg/L) | References                                      |
|-----|-----------------------|--------------------------------------|-----|------------|-------------|---------------|--------------|-------------|------------|---------|-----------|------------|---------|----------------|------------------------------------------------|
| 1   | Pulau Burung-Malaysia | 18 Semi-aerobic                      | 8.28| 22100      | 180         | 3347          | 1568         | 243         | 2345       | 0.124   | 9925      | 837        | 3.4    | 6.7            | (Aziz et al., 2010)                             |
| 2   | Kulim-Malaysia        | 14 Anaerobic                         | 7.76| 8550       | 1936        | 4041          | 538          | 326         | 1892       | 0.205   | 6336      | 707        | 5.3    | 2.6            | (Aziz et al., 2010)                             |
| 3   | Pulau Burung-Malaysia | 18 Semi-aerobic                      | 8.7 | 23655      | 145         | 5545          | 2010         | 100         | 2615       | 0.038   | -         | 123        | -      | -              | (Bashir et al., 2010)                           |
| 4   | Pulau Burung-Malaysia | 19 Semi-aerobic                      | 8.36| 22360      | -           | 3615          | 1627         | 181         | 1819       | 0.1     | 9507      | 815        | 4.9    | 6.95           | (Aziz et al., 2015)                             |
| 5   | Kulim-Malaysia        | 15 Anaerobic                         | 8.02| 7660       | -           | 3029          | 562          | 71          | 1580       | 0.04    | 4832      | 553        | 3.82  | 1.54           | (Aziz et al., 2015)                             |
| 6   | Kuala Sepetang-Malaysia | Anaerobic                          | 8.66| 9680       | -           | 6398          | 564          | 257         | 1456       | 0.19    | 6615      | 693        | 3.43  | 1.56           | (Aziz et al., 2015)                             |
| 7   | Sungai Petani-Malaysia | Open dumping                      | 8.45| 3945       | 451         | 1690          | 532          | 269         | 1310       | 0.205   | 5723      | 710        | 6.03  | 169           | (Mojiri et al., 2015)                           |
| 8   | Erbil-Iraq            | 12 Anaerobic                         | 8.05| 10170      | 120         | 77000         | 930          | 32          | -          | -       | 18000     | 2000       | -     | -              | (Aziz and Maulood, 2015)                         |
| 9   | Pulau Burung-Malaysia | 20 Semi-aerobic                      | 8.5 | 17880      | -           | 4530          | 1170         | 75          | 2170       | 0.034   | -         | 197        | -     | -              | (Abu Amr et al., 2012)                          |
| 10  | Aler Pongsu Landfill Site (APLS) | anaerobic stabilized               | 8.29| 10788      | -           | 12475         | 1674         | 274         | 3125       | 0.088   | -         | 6483       | -     | -              | (Abu Amr et al., 2016)                          |
| 11  | Deir El-Balah Landfill Site (DBLS), Gaza, Palestine | anaerobic stabilized               | 8.24| 40800      | 537         | -            | 3400         | 1821        | 20448      | 0.9     | -         | -          | -     | -              | (Hilles et al., 2016)                           |
| 12  | Concentrated Landfill Leachate in Shanghai Laogang           | Covered and anaerobic              | 7.34| -          | -           | 2113          | 49           | 285         | 3018       | 0.09    | -         | -          | 15.7  | 5.11           | (Not Published)                                 |
| 13  | Sahom Landfill, Kampar, Malaysia >15 anaerobic stabilized |                         | 8.42| 10980      | 40.8         | 1450          | 3330         | 37          | 550        | 0.08    | -         | -          | 207   | -              | (Shehzad et al., 2016)                           |
| 14  | Papan Landfill, Ipoh, Malaysia >5 Anaerobic Intermediiate   |                         | 7.99| 21720      | 421          | 4200          | 700          | 1260        | 6650       | 0.24    | -         | -          | 410   | -              | (Bashir et al., 2016)                           |
| 15  | Batu Gajah leachate >10 Dump Site |                       | 9   | -          | 100          | 1069         | 330          | 131         | 561        | 0.23    | -         | 19         | -     | -              | (Not Published)                                 |
designed cell advance, full gas management, full leachate management, compaction, daily and final cover, fence and gate etc. A key component of separation is in the management and treatment of leachate. A number of processes can be applied to achieve isolation of leachate from the surrounding environment, depending on available resources. The systems range from prevention of leachate generation, to sophisticated leachate treatment methods, to controlled release of leachate into the environment (Liermann, 2009). In order to be designated a sanitary landfill, a disposal site should the following three common but basic situations: 1) compaction of the wastes, 2) daily covering of the wastes using soil or other material, and 3) control and prevention of negative impacts on the community health and on environment (e.g. odors, polluted water supplies, etc.) (UNEP, 2005). Advantages of sanitary landfills are: 1) Simple disposal method, 2) Low cost, and 3) Landscape-restoring effect on holes from mineral working. On the other hand, the shortcomings are the production of highly polluted leachate and emission of methane gas. Landfills are classified according to their structures (Table 2).
Table 2: Classification of landfill structures (Aziz, 2011)

| No. | Type                        | Details                                                                                                                                                                                                 |
|-----|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Anaerobic landfill         | Disposed solid wastes are filled in dug areas of plane field or valley. The wastes are filled with water under anaerobic conditions.                                                                  |
| 2   | Anaerobic sanitary landfill| Anaerobic landfill with sandwich-shaped cover. Conditions of disposed wastes are similar to the conditions of Type 1.                                                                                   |
| 3   | Improved anaerobic sanitary landfill | This type has a leachate collection system at the bottom of the landfill site. Other parameters are the same as those of the anaerobic sanitary landfill. The conditions are anaerobic and moisture content is significantly less than that in the anaerobic sanitary landfill. |
| 4   | Semi-aerobic landfill      | The leachate collection pipe is larger than that of the improved sanitary landfill. The openings of the pipes are surrounded by air and the pipe is covered with small crushed stones. Moisture content in disposed solid waste is low. Oxygen is supplied to solid waste from the leachate collection pipe. |
| 5   | Aerobic landfill           | Aside from the leachate collection pipe, air supply pipes are attached and air is able to mix with the solid waste. Thus, the landfill becomes more aerobic than semi-aerobic. |

3.2 Characteristics of landfill leachate

Landfill leachates are produced when moisture mixes with refuse in the landfill; pollutants are dissolved into the liquid phase, after which they accumulate and then percolate. Leachates fluctuate from one landfill to another in the short- and long-terms periods because of differences in waste composition, hydrogeology, and climate. Enhancements in landfill engineering are intended to decrease leachate production and collection, as well as recover treatment prior to discharge (Visvanathan et al., 2000). Landfill leachates are regarded as wastewater that has the strongest environmental effect. The greatest important feature of leachates is the high concentrations of pollutants.

Leachate is the liquid percolation that drains through the waste in the landfill varies usually depend on MSW form and the MSW age (Christensen et al., 1994). Normally, the leachate can be categorized into three chief groups as shown in Table 3. The three main clusters are mostly inorganic matters, organic matters, and xenobiotic organic compounds. Leachate quality is meaningfully impact by the landfill age (Table 4).

Clearly, as landfill age increases, the biodegradable portion of organic contaminants in leachate decrease as an outcome of the anaerobic decomposition occurring in landfill site. Consequently, mature or stabilized leachate contains much more refractory organics than young leachate. In this respect, young landfill leachate (age < 5 years) is normally categorized by high BOD and COD concentrations, quite high amount of NH$_3$-N, high ratio of BOD/COD, and a pH value < 6.5. In contrast, stabilized landfill leachate (age>10 years) usually comprises high amount of NH$_3$–N, moderately high strength of COD, and a low BOD/COD ratio of less than 0.1. Regarding the parameters such as COD, BOD$_5$, NH$_3$-N, phenols, heavy metals etc. that surpassed the standards, it is recommended to treat the landfill leachate using physical-chemical and/or biological processes (Bashir et al., 2010; Aziz et al., 2011; Bashir et al., 2016). Commonly, leachate characterization varies with the climatic regions in addition to the landfill operational practices. The key factors that affect the leachate characteristics are: 1) Design and operation of the landfill and its age,
2) MSW composition, soluble or insoluble biodegradable or non-biodegradable, liquid or solid, organic or inorganic, and toxic or nontoxic, 3) Site hydrology, and 4) Availability of moisture and oxygen (Bagche, 2004). Aziz and Maulood (2015) recognized that produced leachate from Erbil landfill site-Iraq affected on groundwater and the surrounding soil; Improving/upgrading and design of sanitary MSW landfills are solutions for minimizing environmental pollution caused by landfill leachate.

Table 3: Pollutants in Leachate (Lee et al., 2010)

| Group of Pollutants In Leachate | Components |
|--------------------------------|------------|
| Organic matters               | Acids, alcohols, aldehydes and others usually quantified as COD (Chemical Oxygen Demand), BOD (Biochemical Oxygen Demand), DOC (Dissolved Organic Carbon), Other Volatile fatty acid and refractory compound include fulvic-like and humic like compounds |
| Inorganic matters             | Sulfate, chloride, ammonium, calcium, magnesium, sodium, potassium, hydrogen carbonate, iron and manganese and heavy metal like lead, nickel, copper, cadmium, chromium and zinc |
| Xenobiotic organic compounds  | Aromatic hydrocarbon, phenols, chlorinated aliphatics, pesticides and plastizers include PCB, Dioxin, PAH, etc. |

Table 4: Landfill leachate classification versus age (Ngo et al., 2008)

| Parameter                | Young           | Intermediate     | Old             |
|--------------------------|-----------------|------------------|-----------------|
| Age (years)              | <5              | 5 to 10          | >10             |
| pH                       | <6.5            | 6.5 to 7.5       | >7.5            |
| COD (mg/L)               | >10,000         | 4,000 to 10,000  | <4,000          |
| BOD$_5$/COD              | >0.3            | 0.1 to 0.3       | <0.1            |
| Organic compound         | 80% volatile fatty acids (VFA) | 5% to 30% VFA + humic and fulvic acids | Humic and fulvic acids |
| Heavy metals             | Low to medium   | Low              | Low             |
| Biodegradability         | Important       | Medium           | Low             |

3.3 Statistical analysis by IBM SPSS

IBM SPSS was used for analyzing landfill leachate data shown in Table 1. Effect of age of landfill site, and characteristics of landfill leachate (such as pH, EC, turbidity, color, NH$_3$-N, BOD, COD, BOD/COD, TS, TSS, Fe and phenols) were studied. Descriptive statistics for landfill parameters are illustrated in Table 5. Results revealed that mean static
values for age of landfill, pH, EC, turbidity, color, NH$_3$-N, BOD, COD, BOD/COD, TS, TSS, Fe, and phenols were 16.54545 years, 8.27067, 16176 µS/cm, 436.75556 NTU, 3418.91667 Pt Co, 1265.60000 mg/L, 357.46667 mg/L, 2237.76923 mg/L, 0.18314, 1058.00000, and 27.63714, respectively. The mean static value for age of 16.54545 years indicated that landfills are in methane formation phase and mature/stabilized leachate, Table 4 (Tchobanoglous and Kreith, 2002; Ngo et al., 2008; Aziz, 2011; Aziz and Maulood, 2015). pH and COD mean static values for landfill leachate confirm that the leachates are old, Table 4. According to Malaysian standards for disposal of wastewater, turbidity, color, NH$_3$-N, BOD, COD, TSS, Fe, and phenols mean static values were exceeded the permissible limits (Environmental Quality Regulation, 2009). Based on Iraqi standards for disposal of wastewater to water sources, color, NH$_3$-N, BOD, COD, TSS, Fe, and phenols were surpassed the standards (IES, 1993). Therefore, the produced landfill leachates require treatment processes prior disposal to the natural environment. Based on the BOD/COD value of 0.18314, physical-chemical treatment methods are suitable for treatment of produced landfill leachates (Bashir et al., 2010; Aziz et al., 2011; Mojiri et al., 2015; Aziz and Ali, 2018). Range, standard deviations and variance of landfill leachate parameters are given in Table 5. Standard deviation can be calculated by taking square root of variance. Wide variety for standard deviations and range are reflects of MSW characteristics, age and structure of landfill, location and weather. BOD/COD and pH have smallest figures for standard deviations and range. This is due to closing of BOD/COD and pH values from the mean. Table 6 shows the correlations among landfill leachate parameters. A Pearson product-moment correlation coefficient was carried out to examine the relationship between age of landfill, pH, EC, turbidity, color, NH$_3$-N, BOD, COD, BOD/COD, TS, TSS, Fe, and phenols. Pearson’s correlation coefficient requires only that data are interval for it to be an accurate measure of the linear relationship between two variables (Utts and Heckared, 2007; Field, 2009). It can be noticed from Table 6 that probability (P) values for relation of NH$_3$-N with BOD/COD, TS, and TSS were 0.002, 0.042, and 0.008, respectively. Pearson correlation coefficient for NH$_3$-N with BOD/COD, TS, and TSS were -1, 0.992, and 1, respectively. Positive relationship means higher scores on variable 1 are associated with higher scores on variable 2. While, negative relationship means higher scores on variable 1 are associated with lower scores on variable 2 and vice versa. In some cases, no predictable relationships occur between variable 1 and variable 2. Correlation coefficient (r) from 0.5 to 1 and from -1 to -0.5 regard as strong relation (DeCoursy, 2003; Soong, 2004). Consequently, a strong r found between NH$_3$-N with BOD/COD, TS, and TSS. Additionally, BOD/COD had a strong r with TS and TSS as well at P values of 0.043 and 0.006. The P values for correlation amongst TS with TSS, Fe, and EC were less than 0.05. The r figures between TS with TSS, Fe, and EC were 0.988, -0.991, and 0.994, respectively. A strong relation between TS with TSS, Fe, and EC was detected. In addition, a strong relation between Fe and EC was obtained; r between Fe and EC was -1.0.

4. CONCLUSIONS

MSW Landfills leachate parameters in different deigned landfills with various ages were studied. Some landfill leachate such as turbidity, color, NH$_3$-N, BOD, COD, TSS, Fe, and phenols were exceeded the standard limits for disposal. SPSS outcome revealed that strong correlation (r > 0.5 at P < 0.005) found
Table 5: Descriptive statistics for landfills using SPSS

| Parameters | N Statistic | Range Statistic | Minimum Statistic | Maximum Statistic | Sum Statistic | Mean Statistic | Mean Std. Error | Std. Deviation Statistic | Variance Statistic |
|------------|-------------|-----------------|-------------------|-------------------|---------------|----------------|-------------------|--------------------------|-------------------|
| Age (year) | 11          | 13.000          | 10.000            | 23.000            | 182.000       | 16.54545       | 1.114888          | 3.697665                 | 13.673            |
| pH         | 15          | 1.660           | 7.340             | 9.000             | 124.060       | 8.27067        | 0.104688          | 0.405453                 | 0.164             |
| EC (µS/cm) | 13          | 36855.000       | 3945.000          | 40800.000         | 210288.000    | 16176.00000    | 2754.747075       | 9932.381831              | 98652208.830      |
| Turb. (NTU)| 9           | 1895.200        | 40.800            | 1936.000          | 3930.800      | 436.75556      | 196.489960         | 589.469879               | 347474.738        |
| Color (Pt. Co.) | 12    | 5329.000        | 1069.000          | 6398.000          | 41027.000     | 3418.91667     | 476.061182         | 1649.124311              | 2719610.992     |
| NH₃-N (mg/L) | 15  | 3351.000        | 49.000            | 3400.000          | 18984.000     | 1265.60000     | 263.785515         | 1021.636908              | 1043741.971     |
| BOD (mg/L)  | 15          | 1789.000        | 32.000            | 1821.000          | 5362.000      | 357.46667      | 129.466336         | 501.420962               | 251422.981       |
| COD (mg/L)  | 13          | 6100.000        | 550.000           | 6650.000          | 29091.000     | 2237.76923     | 430.278207         | 1551.390138              | 2406811.359     |
| BOD/COD    | 14          | 0.866           | 0.034             | 0.900             | 2.564         | 0.18314        | 0.058502           | 0.218894                 | 0.048            |
| TS (mg/L)   | 7           | 13168.000       | 4832.000          | 18000.000         | 60938.000     | 8705.42857     | 1707.137270        | 4516.660671              | 20400223.620    |
| TSS (mg/L)  | 13          | 6464.000        | 19.000            | 6483.000          | 13754.000     | 1058.00000     | 472.972095         | 1705.325140              | 2908133.833     |
| Fe (mg/L)   | 7           | 12.300          | 3.400             | 15.700            | 42.580        | 6.08286        | 1.646498           | 4.356224                 | 18.977           |
| Phenols (mg/L) | 7  | 167.460         | 1.540             | 169.000           | 193.460       | 27.63714       | 23.576213          | 62.376796                 | 3890.865        |

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Table 6: Person correlations and significant values for data sets using SPSS

|                  | BOD (mg/L) | pH   | Color (Pt. Co.) | NH-N (mg/L) | COD (mg/L) | BOD/COD | TS (mg/L) | TSS (mg/L) | Fe (mg/L) | Age (year) | EC (µS/cm) | Phenols (mg/L) | Turb. (NTU) |
|------------------|------------|------|-----------------|-------------|------------|----------|-----------|-----------|-----------|------------|-----------|----------------|--------------|
| Pearson Correlation |            |      |                 |             |            |          |           |           |           |            |           |                |              |
| BOD (mg/L)      | 1.000      | -853 | 483             | -738        | -237       | 741      | -644      | -755      | 533       | -622       | -555      | -232           | 986          |
| pH              | -853       | 1.000 | -869            | 276         | -306       | -281     | 149       | 300       | -013      | 940        | 038       | 076            | -928         |
| Color (Pt. Co.) | 483        | -869 | 1.000           | 235         | 736        | -730     | 359       | 210       | -483      | -986       | 461       | -964           | 622          |
| NH-N (mg/L)     | -738       | .276 | 235             | 1.000       | .831       | -1.000   | 992       | 1.000     | -965      | -069       | 971       | -486           | -615         |
| COD (mg/L)      | -237       | -306 | 736             | 831         | 1.000      | -828     | 896       | 816       | -948      | -613       | 940       | -890           | -072         |
| BOD/COD         | -741       | -281 | -2.30           | -1.000      | -828       | 1.000    | -991      | -1.000    | 963       | 0.064      | -970      | 481            | 619          |
| TS (mg/L)       | -644       | 1.49  | 359             | 0.992       | 0.896      | 0.991    | 1.000     | 0.988     | 0.991     | 0.198      | 0.994     | 0.95           | 0.409        |
| TSS (mg/L)      | .755       | 0.300 | 210             | 1.000       | 0.816      | -1.000   | 0.988     | 1.000     | -0.958    | -0.044     | 0.965     | -0.463         | -0.365       |
| Fe (mg/L)       | .533       | -0.013 | -0.483        | 0.965       | -0.948     | 0.963    | -0.991    | 0.958     | 1.000     | 0.330      | -1.000    | 0.693          | 0.385        |
| Age (year)      | -0.622     | .940  | -0.986         | -0.069      | -0.613     | 0.064    | -0.198    | 0.044     | 0.330     | 1.000      | -0.306    | 0.906          | -0.744       |
| EC (µS/cm)      | -0.555     | .038  | 0.461           | 0.971       | -0.970     | 0.994    | 0.965     | -1.000    | 0.306     | 1.000      | -0.681    | -0.409         | -0.409       |
| Phenols (mg/L)  | -2.326     | .706  | -0.964         | -0.486      | -0.890     | 0.481    | -0.595    | 0.463     | 0.699     | 0.906      | -0.681    | 0.100          | -0.391       |
| Turb. (NTU)     | .986       | -0.928 | 0.622         | -0.615      | -0.072     | 0.619    | -0.507    | -0.635    | 0.385     | -0.744     | -0.409    | -0.391         | 1.000        |
| Sig. (1-tailed) |            |      |                 |             |            |          |           |           |           |            |           |                |              |
| BOD (mg/L)      | . -175     | .156  | .165            | 0.411       | 0.401      | 0.409    | 0.452     | 0.403     | 0.496     | 0.111      | 0.488     | 0.250          | 0.122        |
| pH              | .175       | .156  | .165            | 0.411       | 0.401      | 0.409    | 0.452     | 0.403     | 0.496     | 0.111      | 0.488     | 0.250          | 0.122        |
| Color (Pt. Co.) | .340       | .165  | .411            | .424        | .237       | 0.426    | 0.383     | 0.433     | 0.339     | .054       | .348      | .086           | 0.286        |
| NH-N (mg/L)     | .336       | .411  | .424            | .188        | .002       | 0.042    | 0.008     | 0.085     | 0.478     | 0.077      | .339      | .289           | 0.289        |
| COD (mg/L)      | .424       | .401  | .237            | .188        | .190       | 0.146    | 0.196     | 0.103     | 0.290     | 0.111      | .151      | .477           | 0.477        |
| BOD/COD         | .373       | .409  | .426            | .002        | .190       | .087     | 0.044     | 0.093     | .393      | .008       | .254      | .374           |             |
| TS (mg/L)       | .277       | .552  | .383            | .042        | .146       | .043     | .050      | .044      | .436      | .035       | .297      | .331           |             |
| TSS (mg/L)      | .228       | .403  | .433            | .008        | .196       | .006     | .050      | .093      | .486      | .085       | .347      | .281           |             |
| Fe (mg/L)       | .321       | .496  | .339            | .085        | .103       | .087     | .044      | 0.093     | .393      | .008       | .254      | .374           |             |
| Age (year)      | .286       | .111  | .054            | .478        | .290       | .480     | .436      | .486      | .393      | .401       | .139      | .233           |             |
| EC (µS/cm)      | .313       | .488  | 348             | .077        | .111       | .078     | .035      | 0.085     | 0.008     | 0.401      | .262      | .366           |             |
| Phenols (mg/L)  | .426       | .250  | .086            | .339        | .151       | .340     | .297      | .347      | .254      | .139       | .262      | .372           |             |
| Turb. (NTU)     | .053       | .122  | .286            | .289        | .477       | .288     | .331      | .281      | .374      | .233       | .366      | .372           |             |
between NH3-N with BOD/COD, TS, and TSS, among BOD/COD with TS and TSS, amongst TS with TSS, Fe, and EC, and between Fe and EC. The age of landfills commonly hadn’t significant statistical correlation with the mentioned landfill leachate parameters; only color neared to have a correlation with age ($r = -0.986$ at $P = 0.054$).

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