

The role of urban forest to reduce rain acid in urban industrial areas

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Abstract. Urban forest has many functions mainly on improving the quality of the urban environment. One of the functions is to increase pH and reduce dangerous chemical content. The aim of the research is to find out the role of vegetation density of urban forest around the industrial area in reducing the acid rain. The condition of land cover was classified into four classes which are dense, medium, sparse and open area. The water of the throughfall and stemflow was taken from each type of land cover except in the open area. Parameters measured in this study are water acidity (pH), anion content (SO_4^{2-} and NO_3^-), cation content (Ca^{2+} , Mg^{2+} , and NH_4^+) and electrical conductivity (EC). The results indicated that urban forest vegetation was able to increase the pH of rain water from 5.42 which is in an open area without vegetation to be 7.13 and 7.32 in dense and moderate vegetation cover by throughfall mechanism, respectively. Rain water acidity also decreased through stemflow mechanism with a pH ranged from 5.92 - 6.43. Urban forest vegetation decreased sulfate content (SO_4^{2-}) from 528.67 mg/l in open area to 44 - 118 mg/l by throughfall mechanism and ranged from 90 to 366.67 mg/l through stemflow mechanism. Urban forest vegetation significantly decreased the rainwater nitrate content from 27 mg/l to 0.03 - 0.70 mg/l through the mechanism of throughfall and between 1.53 - 8.82 mg/l through the stemflow mechanism. Urban forest vegetation also increased the concentration of cations (NH_4^+ , Ca^{2+} , Mg^{2+} , Na^+) compared with open areas. Urban forest vegetation showed increased the electrical conductivity (EC) from 208.12 $\mu\text{mhos/cm}$ to 344.67 - 902.17 $\mu\text{mhos/cm}$ through the through fall mechanism and 937.67 - 1058.70 $\mu\text{mhos/cm}$ through the stemflow mechanism. The study suggested that urban forests play a significant role in reducing rainwater acidity and improving the quality of rainwater that reached the soil surface.

1. Introduction

The development of industry and transportation within a region is a major contributor to pollutant emissions into the atmosphere which would lead to increase global temperature [1] and acid rain [2]. Acid rainfall is one of the biggest problems in different regions [3] with a very harmful impact on humans and the environment [4]. Acid rainfall occurs due to the amount of pollutant in the air that dissolves and is carried away by rainwater and then reaches the soil surface. The rain water will have a



low pH (< 5.6) and have a low quality. Acid rain impacts can erode buildings or are corrosive to construction materials, destroy biota life in water bodies.

Vegetation is known to neutralize acid rain through various mechanisms both physical and chemical. The gutation mechanism of the plants by removing the cations would raise the pH of the rainfall that reaches the soil surface. The physical mechanism of rainwater travel through the tree canopy interacts with the cation of the mutation processes would increase rain pH and electrical conductivity (EC). Because of the negative impact of acid rain, the reduction of rainwater acidity levels needs to be done to reduce the negative impact on the environment. The purpose of this study was to determine the role of urban forests in reducing acid rain that reached the surface of the soil around the industrial area.

2. Material and Methods

2.1. Study area

This research was conducted in the waste treatment area of an urban industrial zone in Medan City with an area of 2.0 ha which is 0.5 ha in the form of vegetation area (urban forest). The waste treatment area is surrounded by chemical industry, steel industry, and gas industry (Figure 1). The measurement plot was divided into 4 (four) types of land cover by *Swietenia mahagoni* vegetation. The plot consists of dense canopy cover with spacing of 4 meters ($3^{\circ}40'16.90''$ N and $98^{\circ}40'27.31''$ E), less dense canopy cover with a spacing of 6 meters ($3^{\circ}40'17.80''$ N and $98^{\circ}40'26.50''$ E). Also are sparse canopy cover with spacing Vegetation 7.5 meters ($3^{\circ}40'16.00''$ N and $98^{\circ}40'26.10''$ E) and open area without vegetation ($3^{\circ}40'16.38''$ N and $98^{\circ}40'26.65''$ E).

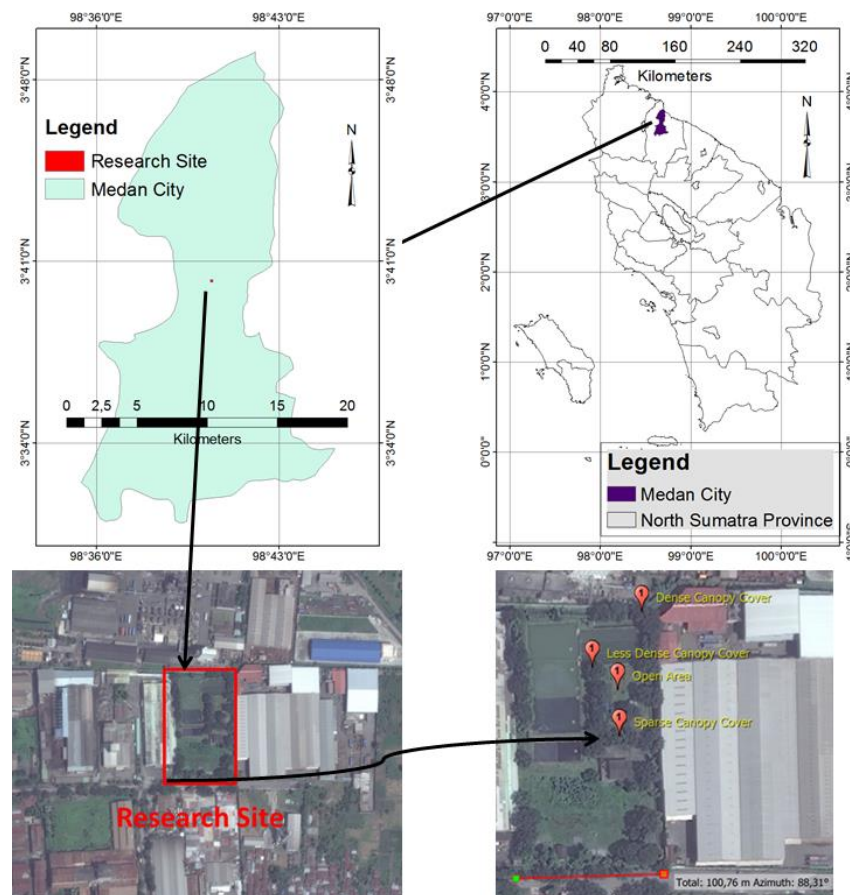


Figure 1. Research site.

2.2. Water collection and chemical analysis

The materials used in this study were a buffer with solutions of pH 4.0, buffer solution pH 10.0, buffer solution pH 7.0, distilled water EC 0.5-2 μ mhos/cm, and KNO₃, NaAsO₂ 0.5%. Also are sulfanilic acid, sulfuric acid, H₂SO₄, a reagent for ammonia test (ammoniac salicylate and cyanuric ammoniac). Others are sulfate reagent, 30% NaCl, calcium indicator solution and magnesium indicator, 1 M EDTA (disodium ethylene diamine tetraacetate, pH 8.0), 1 M EGTA (ethylene glycol bis(β -aminoethyl ether)-*N,N'*-tetraacetic acid), KCl 0.1, KCl 0.01, and KCl 0.5. The tools used in this research were ombrometer rainfall gauge, throughfall gauge, stemflow gauge, 0.45 μ m porous membrane filter, spectrophotometer, pH meter (mV meter), and EC meter.

Installation of throughfall and stemflow collector is carried out on all three types of land cover, whereas in open area only the ombrometer rain gauge type is installed. Water sampling was conducted on three rain events. The analyzed rainwater is derived from the bulk rainfall as control and rain water that has been through the mechanism of throughfall and stemflow. The parameters observed were pH, electrical conductivity (EC), anion content (SO₄²⁻, NO₃⁻), ammonia (NH₄⁺), and cation content (Ca²⁺, Mg²⁺, Na⁺). Ion analysis was done by spectrophotometric ion method using a spectrophotometer.

3. Results and Discussion

The results will be discussed in three subsections; they are pH value and electrical conductivity (EC), the content of anion SO₄²⁻ and NO₃⁻, and the content of NH₄⁺, Ca²⁺, Mg²⁺, and Na⁺ cations.

3.1. pH value and electrical conductivity (EC)

With the base of acid rain pH <5.6 [1], the existence of urban forest vegetation tends to increase the pH of rainwater reaching the soil surface. Throughfall tends to contribute higher in reducing rainwater acidity than stemflow (Figure 2). Plant with dense and less dense canopy cover characteristics contributes to a higher pH increase than vegetation with spare density. The results of this study reaffirm that plant can reduce acidity acid rain through the mechanism of throughfall and stemflow[5, 6] Rain water pH increased from 0.50 to 1.01 through the stemflow mechanism and 1.23 to 1.90 through the through fall mechanism compared to bulk precipitation.

The mechanism of rainwater distribution through stemflow and throughfall tends to increase electrical conductivity (Figure 2). Different with pH, stemflow provides a higher electrical conductivity (EC) increase compared to throughfall. The enhanced range of electrical conductivity of water through the stemflow is 4.5 to 5.1 times compared to the electrical conductivity of bulk precipitation respectively. While the water through the through fall there is an increase in electrical conductivity of about 1.7 to 3.5 times that of bulk precipitation. The higher density vegetation tends to increase the electrical conductivity. One of the sources that Increase in EC value due to dissolved deposits attached to the leaves and stems of the plant. The higher the EC content in water represents the more pollutants in the atmosphere[7].

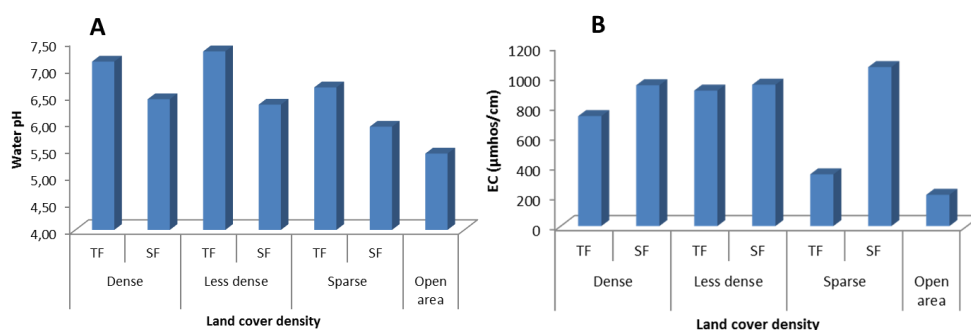


Figure 2. Enhancement of water pH (A) and increase the EC (B) through stemflow (SF) and throughfall (TF) mechanisms.

3.2. The content of anion SO_4^{2-} and NO_3^-

The anions content of SO_4^{2-} and NO_3^- in the vegetated areas decreased variable. The mechanism of throughfall gives a greater reduction in SO_4^{2-} and NO_3^- anion content than the stemflow mechanisms of all vegetation density types. While between land cover types there is no decreasing trend of SO_4^{2-} and NO_3^- (Figure 3). Although the presence of vegetation can decrease the content of SO_4^{2-} and NO_3^- anions, the levels of anions content are still very high[8]. SO_4^{2-} and NO_3^- are derived from the burning of fossil fuels[7] in which the study sites are obtained from factories and motor vehicles.

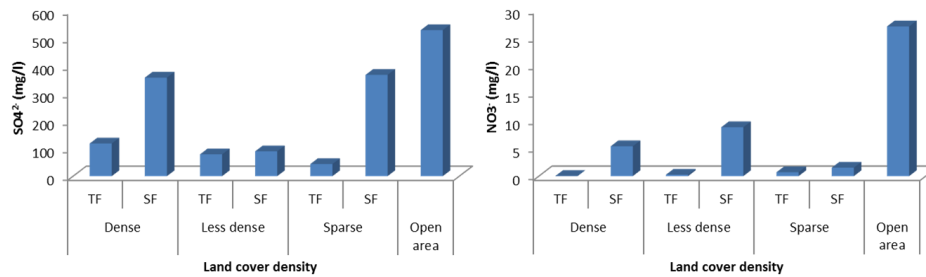


Figure 3. Decrease in SO_4^{2-} and NO_3^- content of rain water through stemflow (SF) and throughfall (TF) mechanisms.

3.3. The content of NH_4^+ , Ca^{2+} , Mg^{2+} , and Na^+ cations

The presence of vegetation increases the content of NH_4^+ , Ca^{2+} , Mg^{2+} , and Na^+ cations through both throughfall and stemflow mechanisms. The increase of cation content of NH_4^+ , Ca^{2+} , Mg^{2+} , and Na^+ in stemflow for all vegetation density types was higher than cations from **throughfall** mechanism (Figure 4). The results of this study are in line with other studies in which stemflow consistently increases the cation content[4].

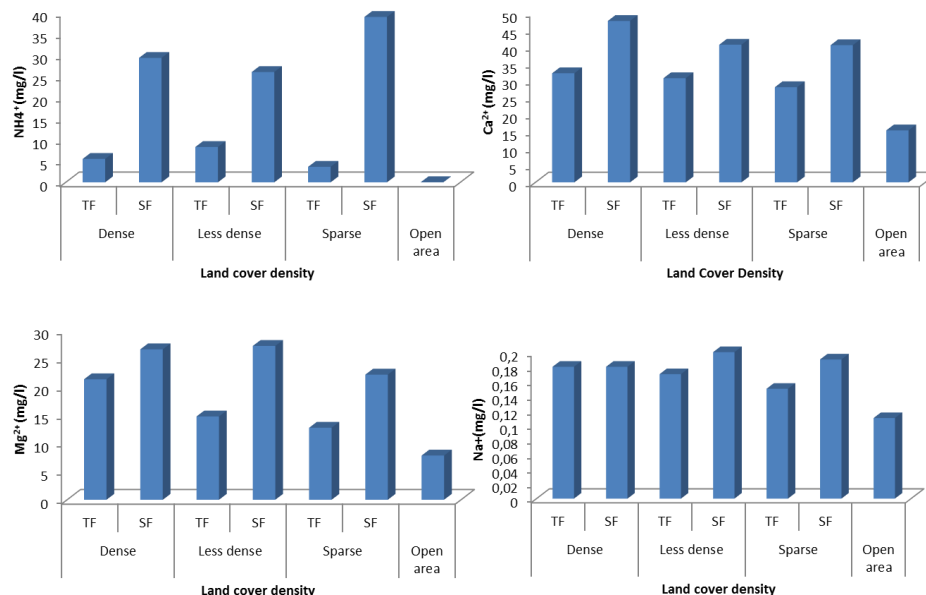


Figure 4. Increase in NH_4^+ , Ca^{2+} , Mg^{2+} , and Na^+ cations content of rain water through stemflow (SF) and throughfall (TF) mechanisms

4. Conclusion

Water acidity measurements show that bulk rainfall that reached the soil surface has higher acidity (lower pH) compared to water that has through the mechanisms of throughfall and stemflow. The existence of urban forest vegetation in an urban industrial zone would increase the pH. The mechanism of throughfall and stemflow also increases the EC and NH_4^+ , Ca^{2+} , Mg^{2+} , and Na^+ cations and decreases the anion content of SO_4^{2-} and NO_3^- .

Acknowledgments

The authors gratefully acknowledge that this study was partly supported by Environmental Agency of North Sumatra Province especially for the chemistry material and tools in Environmental Laboratory.

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