Environmental heat stress enhances crystallization in urine

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Abstract. Over the past several decades, agriculture and plantations have been used as the main livelihood of most of the Karanganyar residents. However, these two sources of living are now replaced by industrial areas that employ thousands of people in that district. The development of this industry triggers multiple environmental impacts, including ecosystem and temperature changes. In consequence, there is an increase in air temperature that can cause a variety of diseases, especially in the workplace. According to the International Labour Organization (ILO) data in 2013, one worker dies every 15 second due to a work accident and 160 workers are suffering from the occupational disease. In Indonesia, the incidence of crystallization in urine is actually still unknown, but it is estimated that there are 170,000 cases annually. A high temperature or called heat stress is one among many factors causing this disease to appear. The workers in the textile industry, especially in the Finishing Department Kusumahadi Co. Ltd that exposed heat stress from the finishing machines and inadequate ventilation. This hot working climate causes the human body to adapt in the form of body cooling mechanism or called sweating. This adaptation can cause an increase in sweat production and decrease the production of urine. If it is not followed by consuming the recommended amount of water intake, it can result in the precipitation of body salts that, in a long time, will cause crystallization in urine. The research used the analytic observational designs for a cross-sectional study. There were 34 samples collected from 57 finishing workers. The data were analyzed using Spearman correlation test. The results showed that heat stress (p=0.015) and water intake (p=0.034) has a significant correlation with crystallization in urine.

1. Introduction
Karanganyar is a regency in the Indonesian province of Central Java. Considered as one of the fastest growing industrial areas, the development of the industry in this region triggers multiple environmental impacts, including ecosystem and temperature changes. As a result, there is an increase in temperature from year to year. Over the past several decades, agriculture and plantations have been used as the main livelihood of most of the Karanganyar residents. However, these sources of living are now replaced by industrial areas that employ thousands of people in that district. Of course, these developments have both positive and negative impacts on humans and the environment. The negative impact that can be clearly seen is the change in weather and temperature in this region. The old Karanganyar city, known for its cold temperatures, is now becoming a hot environment. On the other hand, there are several positive impacts such as an increase in the income of the community, the opening of job vacancy and the increasing of development in Karanganyar. One of the popular industries that recruit lots of workers in Karanganyar is a textile industry. The textile industries in Indonesia develop significantly and play an important role in the economic growth in the society. According to Statistic Center Bureau, the textile industry hires 1.47 million people in 2011. It increases by 4.78% of the total labor from the previous year (around 1.4 million people). According to
the International Labour Organization (ILO) data in 2013, one worker dies every 15 second due to a work accident and 160 workers are suffering from occupational disease [1].

In the textile industry, the prevention of disease at work is very important as the company's effort to improve the work productivity, because if there are many workers suffer from disease complaints, the greater money and time will be wasted for the process and cost of treatment [2]. The production process on textile industry generates heat as the result of a series of production processes that comes from the equipment, ventilation, or human factor. Hot working climate causes the human body to adapt in the form of body cooling mechanism or called sweating [3]. Urine crystallization happened as a result of human excess dehydration. The relatively high of fluid discharge will affect the balance and concentration of body fluids, so the body fluid will decrease (dehydrated), followed by concentration and formation of urine crystals [4]. Currently, urinary infection becomes a hot issue as it affects millions of people in the world. In many countries especially America, Europe, and Asia, the data of total disease caused by urinary infection increase two times in the last three decades [5].

This study was conducted at Kusumahadi Santosa Corporate, Karanganyar. This company is engaged in the export of textile apparel and its production includes weaving, finishing, printing, and dying. Finishing department is where the fabric undergoes the refinement process from grey to ceramic color. In its every process, heavy machinery are used and heat dominates the room. Poor layout and ventilation cause air circulation to be hampered and then the working place becomes hotter. Based on the heat pressure measurement, it was found that the average heat pressure on finishing room was 30.65°C and it exceeds the maximum standard defined by the Ministry of Manpower. On the other hand, most workers complained about the heat in their working environment. They were often thirsty and having a high intensity of sweat and a small amount of urine. This study was aimed at determining the relationship between the heat pressure and water consumption with the urine crystallization in the workers from the finishing department at Kusumahadi Santosa Co. Ltd.

2. Subject and Method
This study was an analytic observational study with a cross-sectional approach. A simple random sampling technique was employed to collect the sample. This study was conducted in the finishing department at Kusumahadi Santosa Co. Ltd. There were totally 57 workers as the population of this study, whereas the samples used in this study were 34 respondents. The heat pressure was measured using a Questremp Heat Stress Monitor. The total water consumption was the average of water consumption in a day and a night by workers from the finishing department at Kusumahadi Santosa Co. Ltd. Urine crystallization indicated the existence of crystal in the worker's urine who were exposed to the heat pressure and less water consumption. The laboratory urine examination showed that there was a positive result with urine crystal in the form of calcium oxalate crystal, uric acid crystal, and amorphous phosphate crystal. The data were then analyzed using SPSS version 16.0 with correlation bivariate test of Spearman rank.

3. Result
This study was conducted in Karanganyar, Indonesia. The respondents in this study were the workers from the finishing department at PT. Kusumahadi Santosa. Table 1 showed the result of a measurement of four spots at the finishing department of PT. Kusumahadi Textile. The data showed that there were three spots that exceeded the maximum level of The Minister of Work and Transmigration Regulation Number 13 in 2011 (about 28°C). Table 2 showed the characteristics of the risk factor of worker's urine crystallization. Most of them showed that the respondents had a high risk of urine crystallization including age, work periods, heat pressure, and water consumption. Table 3 showed that heat pressure and water consumption had a close relationship with urine crystallization. Coefficient correlation level of heat pressure (r) was 0.415 as moderate correlation level. As there was a positive relation (+), it can be known that the higher the respondents received the heat pressure, the higher urine crystallization that they formed. On correlation test between water consumption, an obtained correlation coefficient level (r) of -0.352 showed that the relationship between each variable
was low and indicated the opposite correlation between each variable (-). Therefore, it can be known that the higher the respondents consumed the water, the lower urine crystallization that they formed.

| Table 1. Results of pressure heat measurement at 4 points location of finishing section. |
|-----------------------------------------------|
| Measurement Location | Wet ball in temperature index(°C) | Explanation |
|----------------------|----------------------------------|-------------|
| Point A              | 31.25                            | Exceeded the threshold value |
| Point B              | 31.66                            | Exceeded the threshold value |
| Point B              | 31.87                            | Exceeded the threshold value |
| Point B              | 27.85                            | Below the threshold value |

| Table 2. Distribution of respondents with crystallization in urine. |
|---------------------|-----------------|----------|
| Variable            | Category        | Frequency| Percentage |
| Age                 | 30 – 39         | 16       | 47.1 |
|                     | ≥ 40             | 18       | 52.9 |
| Work period         | 5-9             | 15       | 44.1 |
|                     | ≥ 10             | 19       | 55.9 |
| Body mass index     | Thin            | 3        | 8.9 |
|                     | Normal           | 25       | 73.5 |
|                     | Fat              | 6        | 17.6 |
| Heat pressure       | ≥ threshold value| 27       | 79.4 |
|                     | < threshold value| 7        | 20.6 |
| Water consumption   | ≤ 3 liter/day    | 30       | 88.2 |
|                     | > 3 liter/day    | 4        | 11.8 |
| Urine crystallization| Positive       | 17       | 50 |
|                     | Negative        | 17       | 50 |

| Table 3. Bivariate analysis of crystallization in urine using Spearman rank test |
|-----------------------------------------------|
| Risk factor for Crystallization in Urine | P value | Correlation coefficient (r) |
| Age                                      | 0.507   | 0.118             |
| Work period                              | 0.315   | -0.178            |
| Body mass index                          | 0.760   | 0.054             |
| Heat pressure                            | 0.015   | 0.415             |
| Water consumption                        | 0.034   | -0.352            |

4. Discussion
Age is one of the internal factors causing of urolithiasis 1 of 2 people per 1000 population [6]. The age of labors in this research starts from 30 years old. According to the results of this research, the percentage of the respondents whose their age ≥ 40 years are about 52.9%. The research sample is chosen from the 30-year-old worker because in that age, the body decreases its ability to protect itself from heat pressure. The ability to tolerate heat will decrease, as the workers get older. The condition is very real when the age reaches 40 years. In this age, the body's ability to cool down through the evaporation of sweat becomes slower [7]. It showed that the respondent of this research, in the finishing department of PT. Kusumahadi Santosa is observed from the age, the experienced reduction
in heat stress protection, and the slower evaporation of sweat. It is the same with the research from Morocco showing that urolithiasis happens as the age increase to above 48 years old because the body resistance to adapt to the hot environment will slow down and decrease at that age. Thus, the prevalence of urine crystal incidence will increase because the body's ability of elderly people in returning body temperature to normal will be slower. [8]. The statistical test result on labor age variable shows that there is no significant relationship between age and the occurrence of urine crystallization, seen from the number of p-value = 0.507. In this study, it is known that age does not contribute to urine crystallization.

Respondents in this study are workers with the service period of 5 years. The period of work of respondents that mostly appear is ≥ 10 years, with a percentage of 55.1%. Longer working lives are likely to result in the accumulation of the effects of exposure to the hazard. Heat exposure on workers can generally be overcome naturally by the body through the process of acclimatization of the body to heat temperature. However, this form of body adjustment can also affect the normal functioning of the body, so that the body can slowly accumulate the negative effects of heat exposure such as an increase in expenditure [9]. Urinary tract stones tend to recur, with the average recurrence occurs 50% in 5 years and 70% in 10 years. So the identification of the first cause of the stone is important for the prevention of further kidney damage[10]. This shows that the respondents in this study had a 70% increased risk of urinary tract stones if they had already worked for 10 years. Based on the statistical test, the relationship between working period and urine crystallization shows that there is no significant relationship that can be seen from the value of p = 0.315. This means that the increase of urine crystallization can happen to the worker after working on the heat pressure with the working period of more than 15 years.

It is very difficult to determine that one of the causes of urinary crystal formation is a body mass index since diet can also affect the formation of urine crystals in the body[11]. In this study, 25 workers (73.5%) belong to in the normal nutritional status category, whereas three people (8.8%) are in the thin category, and 6 people (17.65%) are in the fat category. The production of heat in the body is related to the body weight and body mass. Overweight BMI may increase the risk of heat-related disorders (heat-related disorder) because the fat layer that they have is thicker than people with a normal BMI.

The symptoms may include light head, pounding, and dehydration. People are said to experience excess weight based on certain criteria that are determined by calculating Body Mass Index (BMI)[12]. Body mass index of most respondents in this study was in a normal status; hence, there were no risks of the formation of urine crystallization. Based on the statistical test results, there is no significant relationship between body mass index with urine crystallization. This can be seen with the value of p = 0.760 (p > 0.05). Therefore, it can be concluded that body mass index in this study does not contribute to the urine crystallization.

The pressure of heat in the workplace can be caused by various sources, including from the heat of the sun, inadequate ventilation and the use of heat removing apparatus. The research in China showed that workers exposed to the heat have a 4-fold risk than workers who are not exposed to the heat[13]. Based on the statistical test results, there is a significant relationship between heat pressure and urine crystallization. It can be seen from the value p = 0.015, with correlation strength (r) = 0.415. The interpretation of the test results showed that the higher the exposure to heat received by the workers, the higher the risk of urine crystallization. This is reinforced by the research conducted by Mulyani stating that workers exposed to high temperatures have a risk of urinary tract stones up to nine times greater than the other workers who are not exposed to heat[14]. As the workforce is under the influence of a hot working environment, the sweating rate becomes maximal. With this condition, the body will experience a lot of loss of mineral salts, causing the body to dehydrate[15]. The hot environment affects the amount of fluid and electrolyte of the body that is one of the factors of the stone formation. Physiologically, the mechanism of dehydration begins with the expenditure of sweat to cool the body. The relatively high fluid release will affect the fluid balance in the body. It is followed by urine concentration so that urine supersaturation will occur. Urine supersaturation is an
important cause since there is an increase in the concentration of salts that triggers the formation of calcium crystals, uric acid, or phosphate[16]. It showed that the respondents in this study, who worked under the hot work environment, had increased the expenditure of sweat, dehydration, reduction of urine volume and marked with positive laboratory test results.

The average drinking water consumption of respondents was mostly ≤ 3 liters. Moreover, based on statistical test results, there is a significant relationship between drinking water consumption and urine crystallization. It can be seen from the value p = 0.034 with the value of correlation coefficient (r) of -0.352, which means the direction of the opposite correlation between variables. It can be concluded that consuming >3 liters of water can lower the formation of urine crystallization. Kidney stones can be formed due to the body's response to the environmental and/or metabolic risk factors [17] It is supported by the research conducted in French showing that the respondents who drink water more than 3 liters per day can reduce the incidence rate of crystals formed in the urethra by 55% [18]. The low urine volume and significant environmental factors, as well as the low fluid intake or direct fluid loss, will increase the risk of stones by increasing urine saturation from rock-forming salts. In addition, drinking water consumption is essential in the process of preventing urinary tract stones [19]. If a person lacks in drinking water, the supersaturation of urinary stone forming material can occur [20]. For people with a chronic dehydration, the pH of urine likely tends to fall. Meanwhile, the density of the urine rises. The supersaturation of uric acid rises and causes the attachment of uric acid crystals. A lack of water consumption results in a calcium deposition in the renal pelvis due to the incoming fluid imbalances. It results in a decrease in the amount of urine volume. The consumption of adequate drinking water can prevent urine from becoming concentrated or colorful [20].

5. Conclusion
There is a significant relationship between the heat pressure and drinking water consumption with urine crystallization. To prevent the crystallization of urine in the workers of finishing department, the company should take control in reducing the heat pressure exposed to labor by building the natural ventilation and adding the exhaust fan so that the indoor heat can flow outside the room. In addition, the availability of drinking water in the company is also very important to keep the labor hydrated and prevent the formation of urine crystallization. Moreover, a worker who has urine crystals in the urinary tract should immediately be examined at the nearest hospital for the immediate treatment in order to prevent the formation of kidney stones

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