# Influence of various Bleaching Agents on Bleaching of Cotton Knitted Fabrics

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**Summary**: Bleaching agents are one of the main contributors to the quality and cost of the bleaching. This paper attempts to optimize the quality and cost of the bleaching of cotton knitted fabrics by using various bleaching agents (sodium hydroxide, sodium carbonate, sodium bicarbonate, sodium borate, Urea, and sodium triphosphate) at different pH levels. The results revealed that varying pH level and different bleaching agents significantly influenced the bleaching properties (whiteness and bleaching loss) of the cotton knitted fabric

## Introduction

Bleaching is the important step in textile finishing. In modern preparation technologies the bleaching process is not only concerned with brightening of fabrics by the destruction of natural coloring matter but, it must frequently make a significant contribution toward preparation of subsequent dyeing, printing or chemical finishing. The bleaching agent is a material that lightens or whitens a substrate through chemical action [1,2]. The most commonly used bleaching agent is hydrogen peroxide which is used in batch, semi continuous and continuous bleaching process of cotton goods. Liquor to goods ratio, pH, hydrogen peroxide concentration, time and temperature are primary considerations for obtaining commercially viable results without damage to the nylon, acrylic, polyester or other fibres that may be present. Economics can be improved by preheating bleach baths and by bath recycling [2,3].

The alkalis control the pH to produce per hydroxyl ions, which are main bleaching ions, if pH is not controlled, the nascent oxygen is produced which damages the fabrics. Most commonly used alkalis in the bleaching process are sodium hydroxide, sodium carbonate, sodium bicarbonate, sodium borate, and sodium triphosphate. The bleach-ing of cotton fabric with hydrogen peroxide from an emulsion comprising water and perchloro-ethylene indicated that optimum quantity of water modified in a perchloroethylene resulted in effecttive bleaching with minimum degradation of fabric [4-6]. The influence of alkalis on whiteness and dyeing properties of fabric has also been reported [1,5,7]. However the influence of various alkalis on bleaching loss and whiteness with reference to pH and the cost of recipe has not been studied scientifically in Pakistan. This paper evaluates the performance of different alkalis to optimize the quality and coat of the bleaching process.

## Results and Discussion

### *Bleaching Loss*

The statistical analysis of variance and comparison of individual means for bleaching loss given in Table-1 and Table-2 respectively show that the effect of pH and bleaching agents on bleaching loss of cotton knitted fabrics is highly significant. While their interaction (PxA) remained non-signi-ficant. Duncan's multiple range test (Table-2) indi-cates that in case of different pH levels P1 (9.5), P2 (10.5) and P3 (11.5) the bleaching loss is 1.32, 1.29 and 1.07 percent respectively. It means that as the pH level increases the bleaching loss reduces and minimum-bleaching loss is obtained at maximum pH level P3 (11.5). The bleaching of the fabric obviously reduced the weight and consequently caused degradation of fabrics.

The individual comparison of means of bleaching loss (Table-2) regarding various bleaching agents viz. A1 (NaOH), A2 ($Na_2CO_3$), A3 ($NaHCO_3$), A4 ($Na_3PO_4$), A5 ($NaBO_4$) and A6 ($CO(NH_2)_2$), show that the minimum value of bleaching loss is obtained at A1 and maximum at A2 with their mean values as. 0.89 and 1.79 respectively. It is evident from results that the weight loss of cotton

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fabric after bleaching process is largely dependent on the types of alkalis used.

*Whiteness*

The statistical analysis of variance and comparison of individual means for whiteness (Table 1 and 2) indicate that the effect of pH (P) and bleaching agents (A) is highly significant, while their interaction remained non-significant. Duncan's multiple range test for the comparison of individual means (Table-3) shows that in case of different pH levels, minimum whiteness 62.47 is obtained at P1 (9.5), followed by P2 (10.5) and P3 (11.5) with their respective means 72.84 and 73.13. It is evident from the above results that by increasing the pH level, whiteness increases. It has been argued by Evans [3] that hydrogen peroxide could be used in most currently available hosiery equipment. Liquor-to-goods ratio, pH, hydrogen peroxide concentration, time, and temperature are primary considerations for obtaining commercially viable results without damage to the nylon, spandex, acrylic, polyester, or other fibres that may be present.

Comparison of individual mean values for different bleaching agents (alkalis) reveals that the maximum witness (73.93) is produced at A5 ($NaBO_4$) followed by A4 ($Na_3PO_4$), A1 (NaOH), A2 ($Na_2CO_3$), A3 ($NaHCO_3$), and A6 ($CO(NH_2)_2$) with their respective means 71.55, 70.91, 70.00, 68.53 and 61.97respectively.All these values differ significantly for each other except A1 and A2.

Table-1: Analysis of variance for bleaching loss and whiteness of cotton fabrics.

| Sources of Variance | Degree of Freedom | F. Value | |
|---|---|---|---|
| | | Bleaching Loss (%) | Whiteness |
| P (pH) | 2 | 530.115** | 312.966** |
| A (Alkali) | 5 | 1418.023** | 71.041** |
| PxA | 10 | 0.0014 NS | 0.00314 NS |
| Error | 72 | | |
| *Total* | 89 | | |

** = Highly significant, NS = Non Significant

Table-2: Comparison between individual mean values for bleaching loss and whiteness

| pH Value | Mean Values | | Alkalis | Mean Values | |
|---|---|---|---|---|---|
| | Bleaching Loss (%) | Whiteness | | Bleaching Loss (%) | Whiteness |
| $P_1$ | 1.32a | 62.47b | $A_1$ | 0.89a | 70.91bc |
| $P_2$ | 1.29b | 72.84a | $A_2$ | 1.79f | 70.00c |
| $P_3$ | 1.07c | 73.13a | $A_3$ | 1.22d | 68.53d |
| | | | $A_4$ | 1.28e | 71.55b |
| | | | $A_5$ | 1.20c | 73.93a |
| | | | $A_6$ | 0.98b | 61.97e |

Note: Any two mean values not sharing a letter in common (within each column) differ significantly at $\alpha = 0.05$.

*Cost of recipe*

Per liter cost of each recipe (for bleaching) for all bleaching agents (alkalis) used in bleaching is depicted in Table-4. The different alkalis were used to maintain the pH levels at P1=9.5, P2=10.5, P3=11.5 which affected the cost of the bleaching process.

From the Table-3 it is clear that the minimum cost for the bleaching of knitted fabrics, was found in case of sodium bicarbonate as Rs1.75 cost per recipe at pH level of 9.5 followed by sodium hydroxide (Rs. 1.82/liter at pH 9.5) and sodium carbonate (Rs. 2.40/liter at pH 9.5) with slightly high costs. The maximum cost was found in case of sodium borate as Rs 35.15 at pH level 11.5. The variation in cost was due to the current market prices and the amount of bleaching agents used. These prices were for one liter solution, one liter solution of bleaching agent could bleach 100 gm of fabric.

From above all results it is clear that $NaHCO_3$ is most economical alkali with minimum cost per recipe (at pH 9.5). While the cost of NaOH is lower than other alkalis at pH of 10.5 and 11.5. It is also evident that minimum cost is found at pH level of 9.5, while slightly higher cost in incurred of pH level of 10.5, and at pH level of 11.5 the recipe becomes uneconomical.

Table-3: Cost per recipe (Rs/liter) for bleaching of cotton knitted fabrics.

| Bleaching Agents | pH 9.5 | pH 10.5 | pH 11.5 |
|---|---|---|---|
| NaOH | 1.82 | 2.57 | 3.07 |
| $Na_2CO_3$ | 2.4 | 4.75 | 6.1 |
| $NaHCO_3$ | 1.75 | 3.55 | 5.45 |
| $Na_3PO_4$ | 10.96 | 11.56 | 15.34 |
| $NaBO_4$ | 30.6 | 34.46 | 35.15 |
| $CO(NH_2)_2$ | 21.7 | 26.15 | 30.1 |

## Experimental

The research work was initiated in the Department of Fibre Technology, University of Agriculture Faisalabad, The processing of fabrics was done in Chand Textile Mills Faisalabad and the testing of these samples was conducted at Clariant Laboratory Ltd. Faisalabad, Pakistan. Single jersey cotton Knitted fabrics of 30" width having 42 wales and 55 courses per inch were used. The samples were scoured and then bleached by using different alkalis and pH levels. The recipe and the procedure of bleaching are given as under.

*Recipe*

| | | |
|---|---|---|
| Material | = | 100 % Cotton knitted fabric |
| Liquor ratio | = | 1: 50 |
| Detergent/wetting agent | = | Sandopan MRN |
| Bleaching Agents (Alkalis) | = | Variables (A) |
| Alkali Concentration | = | Variable (to obtain desired pH levels) |
| Temperature | = | 90 $^0$C |
| Time | = | 60 min. |
| pH | = | Variables(P) |

Table-4: Bleaching variables

| pH levels | Alkalis(A) |
|---|---|
| | A1= Sodium hydroxide(NaOH) |
| P1=9.5 | A2= Sodium carbonate($Na_2CO_3$) |
| P2=10.5 | A3= Sodium bicarbonate($NaHCO_3$) |
| P3=11.5 | A4= Sodium phosphate($Na_3PO_4$) |
| | A5= Sodium borate($NaBO_4$) |
| | A6= Urea $CO(NH_2)_2$ |

The scoured dry samples were put into the bleaching machine bath at about 40 $^0$C and then raised the temperature of bath up to 90 $^0$C (near boiling), maintaining this temperature for about one hour, the bath was allowed to cool and at low temperature the sample was taken out, rinsed first in hot and then in cold water. Finally the sample was hydro extracted and dried. After bleaching following tests were carried out.

*Bleaching Loss*

Bleaching loss means decrease in weight of the fabric due to the bleaching. To determine the bleaching loss, the samples, after scouring, were conditioned in the testing laboratory for 4 hours. After that the samples were weighed, and then the bleaching process was conducted, after bleaching the samples were washed, dried and again conditioned for 4 hours. The samples were again weighed. The bleaching loss percentage was calculated by the following formula.

$$\text{Percentage of bleaching loss} = \frac{W_o - W_1}{W_o} \times 100$$

Where

$W_O$ = weight of fabric before bleaching

$W_1$ = weight of fabric after bleaching.

*Whiteness*

The whiteness of the bleached and unbleached samples was checked with the help of "Macbeth, color-Eye 3100" apparatus.

*Statistic analyses:*

Duncan's Multiple Range test was also applied for individual comparison of means among various characteristics. This test is applied to analyze the statistical significance of individual treatments in order to check whether the treatments are statistically similar or not [8].

**Conclusions**

The study revealed that varying pH level and different bleaching agents significantly influenced the bleaching properties of cotton knitted fabric. The bleaching loss decreased with the increase of pH level. The alkali NaOH recorded minimum bleaching loss and in the case of whiteness of knitted fabrics the alkali $NaBO_4$ produced maximum whiteness. However cost wise $NaBO_4$ is most expensive. Alkalis NaOH and $Na_2CO_3$ performed equally better for fabric whiteness, but the cost of $Na_2CO_3$ is higher. Similarly higher pH level increased the whiteness but at the same time cost also increased. It is therefore suggested to use either NaOH or $NaHCO_3$ and maintaining the pH level 10.5 for optimum results.

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# Ambient Air Quality at Port Qasim in Karachi City

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**Summary:** The monitoring of ambient air quality along with various metrological parameters was carried out at the site of Port Qasim in Karachi (Pakistan). The study was conducted continuously for seven days and nights. Hourly average concentration of $O_3$ was found to be 12.01 ppb, $SO_2$ 2.42 ppb, CO 0.62 ppm, NO 2.35 ppb, $NO_x$ 11.26 ppb and $PM_{10}$ 123.49 $\mu g/m^3$. The maximum concentration of almost all of the pollutants were observed in the early morning period due to the stable atmospheric conditions prevailed during the night, being dispersed during the day due to the phenomena of thermal convection. The results obtained in the study have been discussed with reference to the permissible ambient air pollutant limits, recommended by World Health Organization (WHO).

## Introduction

Rapid growth of population has given rise to many day to day common problems, such as environmental degradation due to air pollution, pressure for land space, traffic congestion, lack of adequate drainage and waste disposal, and destruction of trees and green areas to accommodate the ever increasing urban development. Air pollution is an abnormal component of the natural environment and the environmental problems have acquired new dimensions now-a-days, resulting in the loss of biodiversity, threat of climatic change, rise in sea level, and depletion of stratospheric ozone layer. All of these after affects are the result of indiscriminate industrial activity and uncontrolled pollution. Rapidly increasing population, factories and processing industries, motor vehicles and other sources of emission of hazardous gases are adversely affecting the quality of air, especially in urban areas.

The major source of air pollution is the generation and ever increasing requirement of energy in diverse sectors of economy, which has its local, regional and global environmental impacts. The present worldwide consumption of commercial energy is about 8.3 billion tons of oil equivalents, out of which 86 % is produced by burning of fossil fuels i.e. coal, oil and gas [1]. The combustion of fossil fuels results in the emission of particulate matter, organic compounds and CO, $CO_2$, $SO_2$ and $NO_x$. The present global consumption of fossil fuels amounts to about 4.5 billion tons of coal, 3.4 billion tons of oil and 77.6 trillion cubic feet of natural gas, which all together results in the release of 24 billion tons of $CO_2$ annually in the ambient environment [2]. Pakistan uses annually about 3.6 million tons of coal, 15.9 million tons of oil and 598 billion cubic feet of gas, which on the whole is responsible for the emission of 90 million tons of $CO_2$ [3]. The figures as regards annual emission of other green house gases in Pakistan amounts to 4.6 million tons of $CH_4$, 3.0 million tons of CO, 0.5 million tons of $NO_x$ and 495 million cubic feet of natural gases and other ozone depleting substances, like chlorofloro-carbons, etc. used in manufacturing of foam and refrigeration purposes, etc. [4]. The main objective of this study was to assess the quality of ambient air in Port Qasim area, which is the second largest port of Pakistan and in coming days, going to cater the logistic need of industrial zones, being established near Karachi city and other areas of the country.

Ever growing concentration of air pollutants in the atmosphere at an alarming pace, not only damages the materials and agriculture, but also contribute to a variety of adverse effects on human health, ranging from respiratory diseases to change in the blood chemistry of living beings. Nitric oxide (NO) is not itself an irritant but in the presence of oxidants such as ozone ($O_3$), it is converted into $NO_2$, which irritates the respiratory system. It also reacts with the ozone resulting in the decrease of ozone levels at higher altitudes. This sort of depletion in $O_3$ levels may cause several types of skin diseases, as in this case human beings would be exposed to more intense ultraviolet radiation which would easily reach the earth. $SO_2$ is a corrosive gas and when inhaled,

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produces irritation and attack the lungs and respiratory system. CO is a toxic gas and its prolonged exposure, even at very low levels, may adversely affect the central nervous system. When inhaled, it reacts with hemoglobin of the blood stream to form carboxyhemoglobin. CO attaches to hemoglobin roughly about 220 times more strongly than oxygen, so small amount of CO in the air we breathe, may cause significant amount of our hemoglobin to be tied up as CoHb [5]. This CoHb reduces the transport of oxygen to the cells, causing nervous disorders. Higher concentration of carboxyhemoglobin in blood may also induce retention of cholesterol in the aorta [6]. Particulate matter, depending on the nature and size of the composing particles, may produce various types of environmental and health impacts. Particles with diameter between '3' to '15' μm are deposited in the upper respiratory system, whereas those between '1' and '5' μm are deposited in the lungs, and may cause various types of diseases, such as silicosis [7].

An assessment of the quality of ambient air, with continuous monitoring of major ambient air pollution components along with various metrological parameters, was carried out in Port Qasim area continuously for 7 days and nights. The monitoring site was located approximately one Km away from the main gate of Port Qasim and Steel Mill was about 2 Km in NW, KESC Thermal Power Plant and 300 MW Oil Fired Power Plant at about 5 Km in NE, Port Qasim Berth in SE, open sea in the South and Steel Mill conveyer belt was in SW direction of the sampling point.

### Results and Discussion

Table-1 shows hourly average concentration for the respective hours of the week days of different air pollutants like $O_3$, $SO_2$, CO, NO, $NO_x$ and $PM_{10}$ at the selected site in Port Qasim area. Table-2 shows hourly average concentrations of various meteorological parameters and Table-3 gives the calculated 1h and 24h Time Weighted Average (TWA) concentration of $O_3$, $SO_2$, CO, NO, $NO_x$ and $PM_{10}$ along with their permissible ambient air quality limits as per guidelines, recommended by the World Health Organization [8].

Table-1 shows that hourly average concentration of (i) $O_3$, $SO_2$, NO and $NO_x$ were found to be in the range of 2.4 to 28.12, 0.78 to 5.32, 0.98 to 5.48 and 4.61 to 17.45 ppb respectively, with total hourly average values of 12.01, 2.42, 2.35 and 11.26 ppb respectively, (ii) CO in the range of 0.15 to 1.23 ppm with average value of 0.62 ppm, and (iii) $PM_{10}$ in the range of 68.68 to 191.68 $\mu g/m^3$, with average value of 123.49 $\mu g/m^3$.

Table - 1: Evaluated Hourly Average Concentration of Ambient Air Pollutants recorded at Port Qasim

| Time | $O_3$ ppb | $SO_2$ Ppb | CO ppm | NO ppb | $NO_x$ ppb | $PM_{10}$ $\mu g/m^3$ |
|---|---|---|---|---|---|---|
| 1:00 AM | 3.30 | 1.13 | 0.15 | 4.78 | 15.48 | 142.80 |
| 2:00 AM | 2.91 | 1.82 | 0.35 | 4.52 | 14.58 | 126.88 |
| 3:00AM | 2.40 | 1.25 | 0.49 | 4.23 | 14.83 | 161.90 |
| 4:00AM | 4.16 | 1.58 | 0.50 | 2.78 | 14.45 | 135.28 |
| 5:00AM | 4.98 | 1.18 | 0.43 | 2.75 | 12.80 | 124.98 |
| 6:00AM | 4.68 | 2.63 | 0.58 | 1.92 | 12.65 | 138.43 |
| 7:00AM | 3.05 | 4.90 | 0.63 | 1.75 | 11.58 | 191.68 |
| 8:00AM | 5.51 | 3.80 | 0.68 | 1.53 | 10.28 | 144.85 |
| 9:00AM | 8.13 | 5.32 | 0.43 | 2.50 | 13.15 | 130.28 |
| 10:00AM | 12.94 | 3.50 | 0.32 | 1.63 | 9.13 | 122.10 |
| 11:00AM | 15.58 | 2.08 | 0.45 | 1.33 | 7.33 | 128.05 |
| 12:00AM | 21.10 | 2.20 | 0.90 | 1.53 | 7.90 | 119.13 |
| 1:00PM | 23.98 | 3.28 | 0.72 | 1.25 | 5.73 | 94.35 |
| 2:00PM | 28.12 | 3.65 | 0.56 | 0.98 | 5.00 | 84.73 |
| 3:00PM | 24.43 | 2.75 | 0.72 | 1.00 | 4.61 | 68.68 |
| 4:00PM | 21.26 | 2.91 | 0.91 | 1.98 | 5.70 | 80.45 |
| 5:00PM | 19.95 | 2.18 | 1.10 | 1.79 | 7.13 | 73.03 |
| 6:00PM | 18.48 | 2.34 | 1.23 | 1.58 | 8.70 | 82.10 |
| 7:00PM | 15.23 | 1.98 | 1.12 | 1.40 | 11.68 | 128.88 |
| 8:00PM | 11.02 | 1.41 | 0.90 | 1.75 | 14.35 | 129.23 |
| 9:00PM | 10.53 | 1.53 | 0.70 | 2.48 | 16.38 | 133.03 |
| 10:00PM | 9.02 | 1.62 | 0.50 | 2.63 | 15.05 | 122.88 |
| 11:00PM | 8.60 | 1.20 | 0.35 | 2.93 | 14.35 | 146.35 |
| 12:00PM | 8.90 | 0.78 | 0.20 | 5.48 | 17.45 | 153.75 |
| Average | 12.01 | 2.42 | 0.62 | 2.35 | 11.26 | 123.49 |
| maximum | 28.12 | 5.32 | 1.23 | 5.48 | 17.45 | 191.68 |
| minimum | 2.40 | 0.78 | 0.15 | 0.98 | 4.61 | 68.68 |

Table-1 further shows that maximum concentration of ozone was 28.12 ppb, NO 5.48 ppb and $NO_x$ 17.45 ppb. Ozone is generated by two processes, (i) the down wind mixing of stratospheric ozone and (ii) as a result of chemical reactions involving the absorption of solar radiation by nitrogen dioxide ($NO_2$) in the presence of volatile organic compounds and carbon monoxide [9]. Stationary sources contribute approximately 40% of the total man made ozone emission [10]. From Table-1, it may also be seen that the ozone concentration was found to be the maximum in the mid afternoon, and it may be due to the photochemical dissociation of $NO_2$ during the day time period when it was found to be at its maximum level. The correlation in the formation of ozone is evident, as the solar energy gradually increases the balance between NO, $NO_x$ and $O_3$ shift in favour of ozone production. The ozone level increases with the increase in sunlight and decreases in the evening time, as the ultraviolet

Table - 2: Hourly Average Concentration of Meteorological Parameters recorded at Port Qasim

| Time Hrs | Wind Speed m/sec | Wind direction deg | Humidity % | Temperature °C | Barometric Pressure mbars | Solar Energy W/sqcm |
|---|---|---|---|---|---|---|
| 1:00AM | 1.35 | 158.88 | 85.55 | 21.33 | 1014.18 | 2.60 |
| 2:00AM | 1.83 | 135.25 | 83.63 | 22.13 | 1014.45 | 2.55 |
| 3:00AM | 1.83 | 219.00 | 82.73 | 21.28 | 1013.75 | 1.98 |
| 4:00AM | 1.88 | 171.88 | 82.68 | 21.05 | 1013.45 | 2.00 |
| 5:00AM | 2.48 | 182.50 | 82.00 | 20.93 | 1013.70 | 1.80 |
| 6:00AM | 2.53 | 214.00 | 82.45 | 20.63 | 1014.08 | 1.95 |
| 7:00AM | 2.48 | 203.38 | 83.23 | 20.40 | 1014.65 | 5.38 |
| 8:00AM | 2.00 | 198.75 | 82.85 | 20.85 | 1015.35 | 101.25 |
| 9:00AM | 2.25 | 265.00 | 73.83 | 24.38 | 1016.08 | 307.45 |
| 10:00AM | 3.45 | 299.38 | 60.53 | 28.18 | 1016.58 | 497.80 |
| 11:00AM | 4.65 | 303.88 | 49.45 | 30.63 | 1016.53 | 643.28 |
| 12:00AM | 4.95 | 299.25 | 46.28 | 31.68 | 1015.25 | 717.03 |
| 1:00PM | 5.20 | 299.38 | 44.35 | 32.18 | 1014.60 | 715.23 |
| 2:00PM | 5.50 | 284.50 | 43.30 | 32.00 | 1013.43 | 639.50 |
| 3:00PM | 5.73 | 297.13 | 43.05 | 31.63 | 1012.95 | 568.13 |
| 4:00PM | 6.13 | 309.88 | 42.58 | 31.45 | 1012.68 | 410.20 |
| 5:00PM | 5.88 | 304.50 | 46.93 | 30.53 | 1012.65 | 201.60 |
| 6:00PM | 4.90 | 309.38 | 51.25 | 29.40 | 1012.93 | 33.60 |
| 7:00PM | 3.70 | 217.38 | 60.08 | 27.80 | 1013.48 | 2.18 |
| 8:00PM | 2.88 | 172.63 | 64.43 | 26.55 | 1013.83 | 1.70 |
| 9:00PM | 2.38 | 168.63 | 63.38 | 25.83 | 1014.58 | 2.90 |
| 10:00PM | 1.88 | 204.00 | 67.05 | 24.80 | 1014.95 | 3.05 |
| 11:00PM | 2.05 | 183.88 | 71.68 | 23.83 | 1015.08 | 3.30 |
| 12:00PM | 2.03 | 166.25 | 73.88 | 23.18 | 1014.95 | 3.40 |
| Average | 3.33 | 232.03 | 65.30 | 25.94 | 1014.34 | 202.91 |
| Maximum | 6.13 | 309.88 | 85.55 | 32.18 | 1016.58 | 717.03 |
| Minimum | 1.35 | 135.25 | 42.58 | 20.40 | 1012.65 | 1.70 |

radiation from the sun declines. Ozone level is often elevated in down wind direction of the emitter, because of the time lag involved in the photochemical process and NO scavenging in the polluted atmosphere [11].

The maximum average concentration of $SO_2$ was found to be 5.3 ppb and minimum average concentration 0.7 ppb, whereas total average concentration was 2.42 ppb. Maximum concentration of $SO_2$ was found at about 9:00 AM, which gradually decreases thereafter during the day time. The main source of $SO_2$ at Port Qasim is the oil fired Power Plant, which consumes about 480,000 tons per annum of furnace oil. 80 % of the city's consumption of furnace oil is being used in power generation at port Qasim and it has been estimated that 32,000 tons/annum of $SO_2$ is produced from Power Plant [12]. An environmental data was not available for this Power Plant; however, it has been known that the installation was designed for the use of furnace oil and oil containing 3.5 and 2.7 % sulphur respectively. Sulphur dioxide is readily oxidized into sulphur trioxide in the atmosphere by photochemical or catalytic processes. In the presence of moisture, sulphur trioxide is converted into sulphuric acid or a sulphate salt which further precipitates out of the atmosphere, where it lasts only for a few days and its maximum residence time is four days. $SO_2$ may cause irritation, reduction of visibility and respiratory diseases. Healthy persons may experience broncho-construction at 1.6 ppm of $SO_2$ within a few minute exposures, throat irritation at 8 – 12 ppm, eye irritation at 10 ppm and immediate cough at 20 ppm. Exposure to 400 – 500 ppm of $SO_2$, even for a few minute is dangerous to life. Normally urban air contains 0.001 – 0.02 ppm $SO_2$ [13].

The maximum hourly average concentration of CO was found to be 1.23 ppm and minimum 0.15 ppm during the daytime, whereas its total average concentration was 0.62 ppm. The level of CO is very low during the day and increases during the night due to the phenomena of thermal convection. Natural production of CO, mainly by volcanic and biological action in swamp area, was estimated to be 75 x $10^6$ tons per year and by man made emissions it is 274 x $10^6$ tons per year, mainly emitted from vehicular exhaust and other combustion sources. CO is present in small concentration in the atmosphere with a lifetime of 2 – 4 months [13]. Further it has back ground concentration of 0.1 ppm and residence time of 3 days [14].

Table - 3: Evaluated Time Weighted Average Concentration of Air Pollutants recorded at Port Qasim and TWA limits recommended by the World Health Organization

| S. No. | Pollutants | TWA Limits recommended by WHO | TWA values recorded at Port Qasim | Duration |
|---|---|---|---|---|
| 1 | $SO_2$ | 350 $\mu g/m^3$ | 6.2 $\mu g/m^3$ | 1 hr |
| 2 | CO | 30 $mg/m^3$ | 0.79 $mg/m^3$ | 1 hr |
| | | 10 $mg/m^3$ | 1.02 $mg/m^3$ | 8 hr |
| 3 | $O_3$ | 150 – 200 $\mu g/m^3$ | 23.7 $\mu g/m^3$ | 1 hr |
| | | 100 – 120 $\mu g/m^3$ | 37.0 $\mu g/m^3$ | 8 hr |
| 4 | $NO_2$ | 400 $\mu g/m^3$ | 17.0 $\mu g/m^3$ | 1 hr |

Anthropogenic suspended particulate matter emissions have been estimated to be about 116,000 tons per year. The inventory shows that stationary industrial sources account for 59% of the anthropogenic SPM emissions. Heating boilers and house hold stoves, contribute to about 34% of all SPM emissions [15]. The maximum concentration of $PM_{10}$ was found to be 191.68 $\mu g/m^3$ and minimum 68.68 $\mu g/m^3$ whereas its average concentration was 123.49 $\mu g/m^3$. A significant relationship may be observed between $PM_{10}$ and different metrological variables.

It may be seen in Table-2, that during the monitoring period, hourly average values of various metrological parameters, like wind velocity was recorded in the range of 1.35 to 6.13 m/sec, wind direction 135.25 to 309.88 deg, humidity 42.58 to 85.55 %, temperature 20.4 to 32.18 $^0C$, barometric pressure 1012 - 1016 mbars and solar energy 1.70 to 717.03 W/sq m.

Meteorological conditions play an important role in the dispersion of pollutants. Low wind speeds usually accompany inversion, and in this case there is very little dispersion of pollutants, so these pollutants accumulate and produce high degree of pollution. Port Qasim has relatively leveled topography and its climate is influenced by the water body. The presence of significant body of water can lead to micro-climatological effects and to on shore and off shore diurnal wind pattern. Thermal inversion is also one of the factor influencing the transport and dispersion of air pollutant emissions. The wind speed increases with the increase in temperature and decrease in the humidity. That is why; average speed of wind during night the time is less than 3 m/sec. Therefore, pollution generated in this area may accumulate during the night time beneath a very stable atmospheric level, a few hundred meters high, and is then further carried down to the ground in the morning. These results in Table I further show, that the maximum concentration of $SO_2$ and $PM_{10}$ has been observed in the morning time, whereas that of CO in the evening and NO and $NO_x$ the in the midnight.

The level of concentrations of $O_3$, $SO_2$, CO, NO, $NO_x$ and $PM_{10}$ in the ambient air recorded at Port Qasim are presented in Table-3, along with their Time Weighted Average (TWA) limits provided in WHO guidelines [8]. The Table shows that the concentrations of these pollutants in the ambient air are within the permissible limits of WHO guidelines for ambient air quality. However, it is presumed that in future, after the area will be fully industrialized, the level of the air pollutants may increase and may result in a variety of adverse health effects.

## Experimental

The monitoring of ambient air quality has been carried out using Air Pollution Monitoring Mobile Laboratory (Environmental SA; France). This Laboratory is fitted with UV Photometric Ozone Analyzer (Model $0_341M$), NO and $NO_x$ Analyzer (Model AC31M), UV Fluorescent $SO_2$ Analyzer (Model AF21M) and Gas Filter correlation CO Analyzer (Model CO11M) for the analysis of $O_3$, NO and $NO_x$, $SO_2$ and CO in the ambient air and Ambient Suspended Particulate Beta Gauge Monitor (Model MPSI 100) for monitoring particulate matter. The laboratory is also equipped with meteorological sensors mounted on a telescopic mast. These advanced technology instruments are microprocessor regulated and define a homogenous and coherent range. An Intelligent Data Logger (SAM32) fitted in the Lab. records spot concentrations at every second and accumulates them to provide 15-minute averages. The logger also monitors instrument alarm and diagnostic functions and control daily instrument zero/span response checks. The NO, $NO_x$ and $SO_2$ analyzers were regularly calibrated by using $NO_2/SO_2$ permeation tube oven and Zero Gas Generator. The Ozone Analyzer has its own ozone generator for span gas. CO Analyzer was calibrated using certified standard CO span gas supplied by M/S Alphagaz, France. The SCANAIR software, fitted in the Lab. was used for acquisition, editing and recording logical and analogical data from SAM 32.

Monitoring of ambient air quality at Port Qasim site was carried out continuously for seven days and nights, in the winter season in the month of November. The data was collected continuously for $O_3$, $SO_2$, CO, NO, $NO_x$ and $PM_{10}$ from mid night of the beginning day to the mid night of the following day (i.e. 168h). The 15 minute average recorded data was analyzed for hourly average concentration for the respective hours of the week, and also for the Time weighted Average concentration of $O_3$, $SO_2$, CO, NO, $NO_x$ and $PM_{10}$. During various measurements, metrological data was also collected for different metrological parameters, like wind speed, wind direction, humidity, temperature, barometric pressure and solar flux.

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