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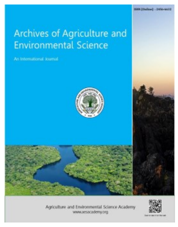

ORIGINAL RESEARCH ARTICLE

Assessment of rainwater quality in industrial area of rural Panipat (Haryana), India

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ABSTRACT

This study was conducted in Panipat industrial area for the evaluation rain water quality and indirectly the air pollution load created by industries in the vicinity. The rain water quality of first rain was assessed for the evaluation of air pollution load of region. Selected physico-chemical characteristics like temperature, pH (6.23-6.85), TDS (105-187 mg L^{-1}), DO (4.2-5.6 mg L^{-1}), Free CO_2 (0.8 mg L^{-1}), Pb (0.09 mg L^{-1}), Fe (0.085-0.132 mg L^{-1}), sulphate (121.2-131.8 mg L^{-1}), silica (3.51-7.26 mg L^{-1}), turbidity (11-19 NTU), total hardness (81-120 mg L^{-1}), chloride (3.20-6.75 mg L^{-1}), BOD (2-4 mg L^{-1}), and COD (14-31 mg L^{-1}) were detected for the evaluation of pollution load in rainwater. The present study revealed that the water quality of first rain was found highly polluted in comparison to second rain. The difference between first heavy rain and second rain was found significant and in favour of increasing air pollution in the industrial area. The trace amount of chloride, silica, lead, iron, sulphate, free carbon dioxide was found in first heavy rain of the region while in the second rain all these were found in very less quantity. The difference in the concentrations of pollutants in rainwater gives the basic idea about the air pollution load of the vicinity. In fact, this is a novel technique to monitor air pollution load of any particular area using rainwater quality monitoring.

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INTRODUCTION

In precipitation chemistry, a number of studies have been carried out in recent past because of awareness of the impact on the environment by acid rain particularly on human health (Sanderson *et al.*, 2006). Rainwater chemistry also enables to understand the relative importance of different sources of gaseous and particulate pollutants, which have been the subject of immense research in different parts of the world for the last 40 years (Balestrini *et al.*, 2000; Fornaro and Gutz, 2003; Hontoria *et al.*, 2003; Migliavacca *et al.*, 2004). Chemical characteristics of rainwater in urban areas are attributed to the local pollution sources, whereas in remote and rural areas, it provides the extent of impact of anthropogenic as well as natural sources (Al- Momani *et al.*, 2000; Sanusi *et al.,* 1996).
Rainwater is an important means of scavenging pollutants from the atmosphere, which can occur either in the gaseous or in the particulate phase. The composition of rainwater actually reflects the composition of the atmosphere through which it falls. More than 90% of the total amount of pollutants present in the atmosphere is lixiviated by wet deposition, being the predominant cleansing mechanism to remove pollutants from the air. Thus, rainwater can be a way to reduce the atmospheric load of pollutants, as well as a source of contamination for soil, water and terrestrial vegetation (Marcos *et al.,* 2014).
Both man-made and naturally originated dust particles with significant base cations influence the rainwater chemistry to a great extent. The acidity of rainwater is completely neutralized by cations prior to its fall on the ground surface (Ali *et al.,* 2004). Considering the importance of chemical transformations in polluted atmosphere as well as in precipitation, studies on rainwater quality monitoring

was undertaken during the monsoon season of 2008.

Panipat city is an industrial city with special reference to textile, pharmaceuticals, oil refinery and many other factories of daily needs products. These industries always imparts into environmental pollution in any form (Bharti, 2007a). A heavy load of gaseous pollutants emitted by the industries continuously, which remains in atmosphere for a long time and most part of these pollutants come down after a heavy rain. The researchers related to water pollution take not so more interest in the pollution load of air pollution and air pollution researchers never think about the rain water quality due to the different areas of relevant. But rain water monitoring is the best way to assess the air pollution load. With the help of a preliminary assessment of rain water quality it may be pointed out that how much pollution load the air occupy. Therefore, to know more about the air pollution of the region, that is the better way to check the rain water quality, the present investigation was carried out to study the physic-chemical characteristics of rainwater in industrial area of rural Panipat (Haryana), India.

Some researchers have carried out several evaluation studies of rainwater quality characteristics in various part of World including Canada (Christopher *et al.*, 2009), Spain (Ramon *et al.*, 2011), Iran (Saeedi and Pajooheshfar, 2012), Ghana (Cobbina *et al.,* 2013), Brazil (Marcos *et al.,* 2014), Nigeria (Olowoyo, 2011; Achadu *et al.,* 2013), Pakistan (Chughtai *et al.,* 2014; Brahman *et al.,* 2014), North India (Shukla and Sharma, 2010; Mishra *et al.*, 2012), West India (Meena *et al.*, 2014), East & North-East India (Chakraborty and Gupta 2014). Khurana (2017) suggested basic treatment technology for the rainwater and utilize it for drinking purpose after removing the impurities. He described about rainwater quality and how rain can be purified to meet WHO drinking water guidelines using an innovative multi-stage water purification technology. Therefore, to know more about the air pollution of the region, that is the better way to check the rain water quality, the present investigation was carried out to study the physic-chemical characteristics of rainwater in industrial area of rural Panipat (Haryana), India.

MATERIALS AND METHODS

Site description: Panipat (29.25°N, 77.02°E) is about 90 km to the north of Capital of India (Delhi) and 1100 km away from the nearest coast of Arabian Sea. Three large industrial hubs (Thermal power station, fertilizer plant and an oil refinery and pipelines) besides 34 medium and 2898 small-scale industries (textile, chemical, paper mill, dyeing, processing units, handloom, etc.) are located there. Sampling site was at Dadlana, a small village 18 km away from Panipat and very close to Panipat Refinery (Figure 1).

Sample collection: The samples of the rain water at the first occurrence of the rain (R_1) was collected from a open roof of a resident at Dadlana village in June 2008 during the first heavy rain of the Panipat region and the samples of the rain water (R_2) during the second occurrence of the rain was collected from the same location when the second rain occurs in July 2008.

Figure 1. *Satellite view of the study area at Panipat (Haryana), India*

Rainwater samples were collected on event basis with a rain collector placed about 10 m above ground. The bottles as well as funnels in the collector were cleaned by triple distilled water twice daily in the morning and evening to avoid dry deposition of gaseous and particulate species. Collected samples were then stored in small polythene bottles, also cleaned by triple distilled water and adding Thymol (<2mg) for preventing biological degradation of the samples. Both the samples were refrigerated at 4°C in the laboratory till all ionic components were analyzed. The pH and conductivity were measured immediately after collection of samples, while the remaining samples were immediately referred to the QC laboratory of IOCL, Panipat for the analysis of different physico-chemical parameters viz., temperature, pH , total solids (TS), dissolved oxygen (DO), carbon dioxide (CO_2), lead (Pb), iron (Fe), sulphate, silica, turbidity, hardness, chloride, biochemical oxygen demand (BOD), and chemical oxygen demand (COD) of the rain water.

Chemical analysis: Concentrations of selected chemical species and physico-chemical variables were measured by standard analytical methods (APHA, 2012) and Laboratory manual of IOCL. The pH was measured with a digital pH meter (Elico make, Model L1-120) using reference (KCL solution) and glass electrodes standardized with pH 4.00 and 9.2 reference buffers before and after pH determination. Conductivity was also measured with a digital EC-TDS analyzer (Elico, model CM-183). All the parameters were analyzed according to standard methods as per the APHA (2012).

RESULTS AND DISCUSSION

The observations finding of both rainwater samples were found quite interesting, while comparing in a systematic manner. The findings of the present research work are depicted in Tables 1-3 as physical, chemical and parameters of biological importance, respectively.

Physico-chemical variables: The conductivity of first rain (285 µmho cm^{-1}) was found quiet higher than the second rain water (195), while total dissolved solids, suspended solids and turbidity was also found high in first rain i.e. 187, 9 and 19 mg L^{-1}, respectively. All these differences in physical properties of waters of two rains were observed due to the presence of high quantity of dust particles in air of the region. The particles were probably settle down with the first rain and contributed into rainwater quality characteristics accordingly. Additionally, the first rain washes away the deposited particulate matter of the rooftop and other surfaces of the premises and collects all settled particulate matter into the rainwater on very first event.

Total Hardness, chloride, silica and sulphate contents in first rainwater sample were measured significantly high (120, 6.75, 7.26 and 131.8 mg L^{-1}, respectively), while in the water sample of second rain, these parameters were found significantly lower. The differences in all major physico-chemical characteristics of both samples are clearly indicating the heavy air pollution load in the atmosphere, which was lowered by first heavy rain of the premises.

Metallic variables: Heavy metals like Fe and Pb were found 0.132 and 0.09 mg L^{-1} in first rain, while 0.085 and traces in second rain. Metals are chiefly associated and/or part of suspended particulate matter and finally contribute into air pollution of a particular area. Out of these suspended and deposited metals, a few metals may be toxic to living organisms at different concentrations (Bharti, 2007b). Tiwari *et al.* (2008) also highlighted the similar changes in the chemical composition of rainwater in industrial area of Panipat City.

Biologically important variables: Some parameters related to human health were also analyzed in which DO (4.2 mg L^{-1}), free carbon (0.8 mg L^{-1}) dioxide, BOD (4 mg L^{-1}) and COD (31 mg L^{-1}) were found in first rain and in second rain 5.6 mg L^{-1}, Nil, 2 mg L^{-1} and 14 mg L^{-1}, respectively. Free mineral acidity is generally determined in the water used in industries, but in first rain water FMA was detected slightly, while second rainwater was found free from FMA and free carbon dioxide. P. alkalinity, total phosphate, H_2S, ammonia and cyanide were not detected in both first and second rain in the industrial area of Panipat city. Reduction in the concentration of free CO_2 in the second rain water sample indicates that the rain helps to absorb the atmospheric carbon di-oxide to a great extent. This phenomenon is already well established method among the gas absorbing method in the initial stages of bench scale studies.

Table 1. Physical characteristics of rainwater at Panipat (Haryana), India.

Parameters	First rain (R_1)	Second rain (R_2)
Temperature (ºC)	30±1.33	28±0.22
Conductivity (µmho cm^{-1})	285±25.33	195±22.67
TDS (mg L^{-1})	187±17.67	105±13.33
TSS (mg L^{-1})	9±1.33	4±1.33
Turbidity (NTU)	19±3.33	11±2.67

Values given in the table are the mean ±SD of three replicates.

Table 2. Chemical characteristics of rainwater at Panipat (Haryana), India.

Parameters	First rain	Second rain
pH	6.23±0.67	6.85±0.67
M. Alkalinity (mg L^{-1})	60±8.33	46±6.33
P. Alkalinity (mg L^{-1})	Nil	Nil
Total Hardness (mg L^{-1})	120±14.33	81±11.67
Ca Hardness (mg L^{-1})	48±5.33	32±4.67
Mg Hardness (mg L^{-1})	72±11.33	49±8.67
Cl^- (mg L^{-1})	6.75±1.33	3.20±0.41
SiO_2 (mg L^{-1})	7.26±1.67	3.51±0.82
Fe^+ (mg L^{-1})	0.132±0.023	0.085±0.012
T. SO_4 (mg L^{-1})	131.8±14.67	121.2±12.33
T. PO_4 (mg L^{-1})	ND	ND

Values given in the table are the mean ±SD of three replicates.

Table 3. Characteristics of biological importance of rainwater.

Parameters	First rain	Second rain
DO (mg L^{-1})	4.2±1.33	5.6±1.83
F-CO_2 (mg L^{-1})	0.8±0.033	ND
BOD (mg L^{-1})	4±1.67	2±1.33
COD (mg L^{-1})	31±8.33	14±6.67
H_2S (mg L^{-1})	NIL	NIL
Pb (mg L^{-1})	0.09±0.01	Traces
NH_3 (mg L^{-1})	ND	ND
CN^-(mg L^{-1})	ND	ND
FMA (mg L^{-1})	2±0.67	NIL

Values given in the table are the mean ±SD of three replicates.

Conclusions

The present research data indicated the heavy air pollution just before the first heavy rain, which causes the pollutants in rainwater because rainwater always free from environmental pollutants and other contaminants. So, the findings cleared that the air pollution of the area is the main cause of rainwater pollution. Industries of the premises are the root cause of all type of air pollutants in atmosphere as well as in rainwater. This evaluation method may be used as a novel assessment technique for air quality monitoring and pollution load assessment too. Additionally, there is a need for a paradigm shift in the way we use rain. There is enough rain to meet at least drinking water needs and it must be used for drinking purpose. Rainwater use for drinking purposes will promote the use of a decentralized and low cost source of water, under user control. It will go a long way in meeting the Millennium Development Goals and achieving household and community level clean drinking water, in a sustainable manner. The rainwater can be treated by applying appropriate technology to remove the impurities.

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