STUDY OF POLLUTION LAOD IN PAPER MILL EFFLUENTS AND ITS RECYCLING BY SUNDRY PLANTS AT HAYATABAD INDUSTRIAL ESTATE, PESHAWAR

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ABSTRACT

This study was initiated to explore the concept of recycling of paper mill effluents at Hayatabad Industrial Estate, Peshawar. The objective was to reduce pollution load of paper mill effluents via recycling of sundry plants. For this purpose a detail study was conducted at paper mills and sundry plants at Hayatabad Industrial Estate. The plants were examined for operation and sampled for waste water. Total 7 waste water samples were collected from selected points of Paper mills, Industrial drain and Sundry plants. Samples were analyzed for various physicochemical characteristics (colour, pH, EC, Alkalinity, Turbidity, TDS, TSS, COD and BOD5) by adopting standard methods for the examination of water and waste water. These samples were also investigated for micronutrients/heavy metals (Cr, Pd, Cd, Ni, Fe, Zn and Cu), using Atomic Absorption Spectrophotometer. The obtained results were compared with Pak-NEQS for industrial effluents. Results showed high limits of pH(8-8.2), EC(738-764uS/cm), Alkalinity(463-581mg/l), Turbidity(166-180NTU), TSS(967-1063.5mg/L), TDS(1673.3-1805.1mg/L), BOD5 (180.6-261.3mg/L) and COD (397-418.2mg/L) in effluents of paper mills. Among heavy metals Cd, Cr and Pd were observed above Pak-NEQS for industrial discharges with average range of 1-3, 2.1-3.2 and 1.01-2.3mg/L respectively. The effluents were recycled in sundry plants for manufacturing paper board/gatta. Analysis of recycled water reduced the levels of analyzed parameters upto low limits as pH(7.1-7.4), EC(336-345uS/cm), Alkalinity(425-580mg/L), Turbidity(140-154NTU), TDS(570-600mg/L), TSS(300-332mg/L), COD(210-200.3mg/L), BOD5 (125-132 mg/L). It was observed that huge quantity of waste water is generated during paper manufacturing and its direct discharge into receiving water is an emerging concern. While the study proved that pollution level of paper mill effluents can be discouraged by recycling of sundry plants. Therefore it is recommended to enhance the installation of sundry plants in proposed industrial estate.

Key Words: *industrial drain, paper mill effluents, permissible limit, recycling, water quality parameters.*

INTRODUCTION

Paper industry has an economic value in industrial sector. It is considered as the major consumer of natural resources (wood, water) and energy sources and therefore ranked as 6th largest pollution contributor to environment[1]. Demand of paper and paperboard is increasing each year and is more than 300 million tons of wood fiber products. It is estimated that nearly 50-60 m3 of water is consume to produce 1 ton of paper and around 240-260 chemicals[2]. These chemicals show significant responses to aquatic ecosystem. In paper manufacturing, large quantity of water is required for bleaching and pulping process[3]. In the result same quantity of waste water is generated which is called as black water and its discharge is a serious problem. This black water is rich in cellulose, suspended solids, resin acids, and oxidized and partially degraded lignin[4]. As paper mill effluents are rich in high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) therefore it can degrade water quality of receiving water and significantly harm the aquatic biota[5]. In addition, paper mill waste water is complicated mixtures of several compounds/ chemicals in which chlorinated phenols or pentachlorophenol are more toxicant[4]. High diversity of chemicals cause several disorders such as carcinogenic, endocrine, mutagenic effects on fish and diarrhea, headaches, nausea, vomiting and eye-irritation effects on humans[6]. Such type of waste water needs proper treatment before discharge.

The industries cannot retain the waste effluents treatment of longer time and it has to be discharged within a sensible time. Industries are in search of adopting techniques which are effective and environment friendly[7]. A workshop on Environment Friendly Techniques in Pulp and Paper Sector (2013), reported that alternative sources of conventional chemicals for paper and pulp industries have been introduced which are eco-friendly

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and available in markets[8].

Proper treatment and effective recycling can give solution to waste problem. The installation of waste water treatment plants is the scientific solution of this threat[9]. The situation is found worse in Pakistan in general and Province of Khyber Pakhtunkhwa in particular (KP), with improper treatment facility of industrial waste water[10]. The Hayatabad Industrial Estate, Peshawar discharge its untreated waste water with average of 304 cusecs/ day into Bara River which joins Kabul River. This river serves as a main source of water for drinking, irrigation and fishing but continues discharge of industrial wastes made this channel unsuitable for these activities[11].

Paper mill effluents can be treated by certain conventional methods such as physical, chemical and biological methods[6]. Due to lacking of treatment facility for industrial effluents, mitigation of this problem is required to reduce pollution load. Various regulations and standards have been proposed for industrial discharges by EPA to keep environment safe but they are not implemented effectively[12]. Therefore to reduce pollution load of waste water/effluents sundry studies have been directed[7]. This is the most encouraging effort to reduce pollution load of water bodies[13]. For HIE, treatment of paper mill effluents has become an essential requirement before their discharge into receiving water channels. Therefore remedial actions should be taken to lower this load from paper manufacturing industries.

METHOD AND MATERIAL

Background of the Study Area

Hayatabad Industrial Estate (HIE) is a famous industrial zone, considered as 3rd largest industrial estate in KP province, covering an area of about 868 acres. It is located on main Jamrud road in the west of Peshawar city[10]. According to Sarhad Development Authority, the current registered units in HIE are 389 by 2015[14]. Among these industries two big paper manufacturing industries have set up at Hayatabad Industrial Estate. The paper mills are fitted out with facilities to prepare paper from both sources such as virgin cellulose and recovered cellulose (waste paper). These mills generate huge quantity of waste water which are discharged directly into main drain called Malakandar Nala/ BudniNullah which further join river Kabul, apart 20km from industrial estate[15]. The paper mill effluents contain toxic chemical pollutants which are detoriating the water quality of river Kabul, making it unhealthy for fishing, animal watering and irrigation purposes[11]. There is no appropriate treatment facility inside the concerned industries to reduce pollution load of effluents. Therefore this problem is increasing day by day and becoming a serious threat for environment[16]. Apart from paper mills, two sundry plants have established at a distance of 2-3 km. These plants are connected via pipes to main industrial drain which carry heavy load of paper mill effluents. These plants have an efficient work in recycling of paper mill effluents. These units have large storage tanks where waste water of paper mills is stored for sedimentation. Effluents of Paper mills after settling in these tanks are processed for recycling. During processing some chemicals and paper waste is added to give the product in the form of paper board/gatta and make water clear upto certain level. This study was initiated to evaluate the industrial effluents of paper mills for pollution load and to encourage the role of sundry plants in reduction of pollution.

Data Collection

Data was collected during field survey. For this purpose five trips were arranged to visit paper mills and sundry plants at HIE, Peshawar. The paper mills are named as paper mill A and paper mill-B. Similarly sundry plants are mentioned by sundry plant A and B respectively. Interviews were conducted with industries mangers to gather information about processing, water usage, production capacity, effluents discharge and its handling etc.

Sample Collection

To check the quality of water, composite samples of waste water were collected from paper mills and sundry plants respectively. As the effluents of paper mills are discharged into industrial drain therefore this drain was also sampled for waste water characterization. Total 7 samples were collected from four main points 1) at sources (paper mills), 2) industrial drain/nullah, 3) water coming in and 4) water going out of sundry plants. Samples were taken in clean plastic bottles and

stored in laboratory at 4 C° in refrigerator for physico-chemical analysis.

Chemical Analysis

The collected waste water samples were analyzed for pH, Electrical Conductivity (EC), Alkalinity, Turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) according to standard methods for the examination of water and waste water[17]. Waste water samples were also tested for heavy metals Such as Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pd), Iron (Fe), Zinc(Zn) and Cobalt (Co) using atomic absorption Spectrophotometer model AAS-700 (table-1). The obtained results for each parameter were then compared with standard values recommended by Pak-NEQS for industrial effluents[18].

RESULTS AND DISCUSSION

Results have been presented in tabular form, table 2 to 6.

Water Consumption and Waste Water Generation for Manufacturing Process of Paper Mills and Sundry Plants

Excessive amount of water is used in paper manufacturing and large quantity of waste water is generated as a result. The daily consumption of water by paper mill-A is 2175.6 m^3 and paper mill-B is 2613.7 m3 for production rate of 300-400 tons and 400-500 tons paper/day respectively. The rate of waste water generation is 1936.4 and 2489.5 m^3/day by paper mill-A and B respectively (table-2). A fraction of this waste water is recycled in processing but the end water is unable to be recycled because of its high cellulose content and is directly discharged into outside nullah/drain. Filed survey revealed that both paper mills were lacking off treatment practices for waste water.

Table 1. Standard Water Quality Parameters Determination Methods and Instruments

S.No	Parameters	Determination methods and Instruments
1	Colour	Visual
2	pH, EC	pH meter, Conductivity Meter
3	TSS, TDS	Gravimetric method, dried at 105oC
4	Alkalinity	Titration of Sodium Carbonate solution against Sulfuric Acid solution, using Phenolphthalein and Methyl Orange indicators
5	Turbidity	Nephlometric
6	COD	Determination by Di-chromate Reflux method, through oxidation of sample with potassium Dichromate (K2Cr2O7) in sulfuric acid (H2SO4) solution followed by titration method
7	BOD5	5 days incubation by Reduction of dissolved Oxygen.
8	Heavy Metals	Determined by Atomic Absorption Spectrophotometer AAS (700)

The sundry plants have built to recycle paper mill effluents to manufacture board/gatta. These recycling plants have underground tanks with capacity to store 120-150 m^3 (120000-150000 liter) water. Sundry plant-A recycle waste water @120 m3for production rate of 5-6 tons board /day (1600 boards/day) and sundry plant-B recycle 150 m^3 waste water for 7 tons board/day (2000 boards/day), table-2.

Analytical Results of Paper Mills Effluents and Industrial Drain Waste Water

The waste water of paper mills was observed dark brown but it turned to brownish after joining the industrial drain/nullah. This change in colour was due to dilution of paper mill effluents after mixing with drain water. The pH of paper mill effluents ranged as 8- 8.2. Waste water of industrial nullah/drain showed pH as 7.6 (table-3). Electrical conductivity (637-764 uS/cm), alkalinity (581-918 mg/L) and turbidity (166-180 NTU) were observed higher for paper mill effluents and industrial drain water respectively (table-3). Pak-NEQS didn't show the allowable limits for these parameters. Higher value of EC in paper mills effluents is due to the presence

Table 2. Water Consumption and Waste Water Generation by Paper Mills and Sundry Plants

S.No	Industry Type	Production Capacity/ day (tons)	Production Capacity/ Annum(tons)	Water consumption/day (m3)	Waste water discharged/day (m3)
1	Paper Mill-A	300-400	45000-60000	2175.6	1936.4
2	Paper Mill-B	400-500	75000	2613.7	2489.5
3	Sundry plant-A Re-cycling of industrial waste water	5-6	200 (57600 crtns)	16	120
4	Sundry plant-B Re-cycling of industrial waste water	7	250 (90000 crtns)	20	150

of dissolved salts such as alkaline phosphate, sulphate etc[19]. The trend of TDS was observed high in effluents of paper mill-B (1805.1mg/L), followed by paper mill-A (1673.3 mg/L) and then industrial drain water as 652 mg/L respectively. TDS in paper mill effluents arise from chemicals, used for sizing and then their mixing with pulp for internal size. The analyzed samples were observed within the permissible limit (3500mg/L). However high concentration of TDS increases the chances of turbidity and water density and reduces the solubility of gases such as oxygen[19]. Total Suspended load (TSS) ranged as 967, 1063.5 and 388 mg/L in effluents of paper mill-A, paper mill-B and industrial drain respectively. TSS was observed high, crossing the permissible limit (150mg/L). BOD5 and COD were observed with 80.6-289.4 mg/L and 397-418.3 mg/L respectively (table-3). In 2002, Khan and Noor also reported high limits of TSS, TDS, BOD and COD in industrial effluents of Hayatabad Industrial Estate[20]. So, their effect on surface water is an emerging concern. Literature revealed that discharged effluents of paper mill contain different chemicals. Therefore paper mill is associated with pollution problems including high TDS, TSS, BOD5, COD etc[21].

Analytical Results of Waste Water after Recycling by Sundry Plants

The colour of paper mill effluents changed into light brownish colour after recycling of sundry plants. This effect was due to sedimentation of solids in storage tanks. The recycled water was not completely cleared and needs extra treatment to make it non-objectionable. Moreover a changing behavior of pH was observed for effluents coming in and going out of sundry plants. The pH values were 7.7-7.9 for waste water coming in sundry plants. After recycling the pH dropped to slightly alkaline range of 7.1 and 7.4 (table-4). This change was due to settling of solids and precipitation of lignin components in storage tanks of sundry plants. For pH, Pak-NEQS limit is 6-10 and the obtained results were observed

Table 3. Analytical results of Paper Mills Effluents

S. No	Point of Sample	Colour	pH	EC uS/cm	Alkalinity mg/L	Turbidity NTU	TDS mg/L	TSS mg/L	COD mg/L	BOD mg/L
1	Paper Mill-A	Dark Brown	8.2	738	581	178	1673.3	967	418.2	261.3
2	paper Mill-B	Dark Brown	8	764	463	180	1805.1	1063.5	397	180.6
3	Industrial Drain (Nullah)	Brownish	7.6	637	918	166	652	388	373	289.4

within permissible limit (table- 4). The EC, alkalinity and turbidity were observed in low range of 445-536uS/cm, 425-580mg/L and 140-154mg/L respectively (table-4). TSS in paper mill effluents was observed above the permissible limit. Therefore cost effective treatment is required to reduce TSS and TDS is a major challenge for paper mills. Their concentrations were extensively reduced after recycling of sundry plants as 570-600mg/L for TDS and 300-332mg/L for TSS respectively (table-4). The comparative results of these parameters for incoming

Table 4. Results of Recycled Waste Water

S. No	Point of Sample	Colour	pH	EC uS/ cm	Alkalinity mg/L	Turbidity NTU	TDS mg/L	TSS mg/L	COD mg/L	BOD_5 mg/L
1	Water coming in Sundry plant-A	Dark brownish	7.7	648	927	171	671	380	377	278
2	Water going out Sundry plant-A	Light brownish	7.1	445	580	140	600	332	210	125
3	Water coming in Sundry plant-B	Dark brownish	7.9	679	906	185	655	350	369	284.3
4	Water going out Sundry plant-B	Light brownish	7.4	536	425	154	570	300	200.3	132.5
5	NEQS	NA	6-10	NA	NA	NA	3500	150	150	80

waste water and outgoing recycled water showed that sundry plants decreased their intensity to low level.

The contents of BOD5 (278-284.3mg/L) and COD (369-377mg/L) found high before recycling. This is attributed to tannins (an organic substance in barks and plant tissues) and chemicals, present in paper mill effluents which absorb more light and heat and tend to retain less oxygen. Such type of waste water has significant effects on aquatic flora and fauna when it is discharged without treatment 22. The contents of BOD5 and COD were reduced to 125-132.5mg/L and 210-200.3 mg/L (table-4).

Concentrations of Heavy Metals in Paper Mills Effluents

Table 5. Heavy Metals Concentrations of Paper Mills Effluents

S. No	Point of Sample	Fe mg/L	Zn g/L	Cu mg/L	Co mg/L	Cr mg/L	Cd mg/L	Ni mg/L	Pb mg/L
1	Paper Mill-A	0.01	0.05	0.03	0.001	2.11	0.1	0.01	1.01
2	Paper Mill-B	0.02	0.04	0.02	0.002	3.2	0.3	0.03	1.5
3	Industrial Drain (Nullah)	0.04	0.05	0.01	0.001	2.6	0.2	0.5	2.3

The distribution pattern of heavy metals in effluents of paper mills was Cr>Pd>Cd>Ni>Zn>Fe>Cu>Co (table-5). Among heavy metals Cr, Cd and Pd showed high values for untreated waste water. The recorded values of Cd, Cr and Pd were higher than the standards fixed for theses metals while other metals were observed within their permissible limits (table-5). These findings favor the work of Khan et al, 2002 who studied heavy metals in effluents of paper mill for the concerned industrial estate[23].

Concentrations of Heavy Metals in Recycled Waste Water

For sundry plants, waste water before recycling showed higher concentrations of heavy metals as compared to after processing/recycling. The level of Cd was reduced below its permissible level (0.03-0.05 mg/l). Cr and Pd were lower down in their concentrations by recycling of sundry plants (table-6). In industrial effluents heavy metals are of special concern and have poisoning effects to water body[9]. Environmental effects have been attributed to chemicals use in paper making because of interaction of these chemicals with each other and with biota/ecosystem in which effluents are being discharged[24]. Due to such hazardous pollutants/metals, its direct discharge into water drain should be controlled. Otherwise the expected damage to environment would be remarkable. The study revealed that the magnitude

Table 6. Heavy Metals Concentrations of Recycled Waste Water

S. No	Point of Sample	Fe mg/L	Zn mg/L	Cu mg/L	Co mg/L	Cr mg/L	Cd mg/L	Ni mg/L	Pb mg/L
1	Water coming in Sundry plant-A	0.03	0.04	0.02	0.002	4.4	0.2	0.01	1.9
2	Water going out Sundry plant-A	0.01	0.03	0.001	0	3.2	0.03	0.002	1.2
3	Water coming in Sundry plant-B	0.04	0.06	0.01	0.001	3.5	0.3	0.1	2
4	Water going out Sundry plant-B	0.03	0.04	0.001	0	3.04	0.05	0.01	1.6
5	Pak-NEQS	-	-	1	-	1	0.1	1	0.5

of pollution load in paper mill effluents can be reduced upto some level by Sundry plants. Therefore, installation of sundry plants should be encouraged in the proposed industrial estate.

CONCLUSION AND RECOMMENDATIONS

Discharge of paper mills was rich in TDS, TSS, BOD5, COD and heavy metals such as Cd, Cr and Pd. Paper mills were observed with no treatment facilities for waste effluents and their direct discharge into water channel is not environment friendly. There is need to use substitute of conventional chemicals with eco-friendly chemicals for paper manufacturing. After recycling of sundry plants, the paper mill effluents showed reduction in TDS (570-600mg/L), TSS (300-332mg/L), BOD (125-132.5mg/L) and COD (210-200.3 mg/L). The contents of heavy metals were reduced upto allowable limits. From the results it is concluded that sundry plants performed well by depressing high limits of pollutants upto low level. Therefore, it is recommended to encourage the establishment of sundry plants in proposed industrial estate. In addition, study on potentially carcinogenic compounds such as pentachlorophenol[25] should be conducted in the near future.

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REFERENCES

1. *Monte, M.C., Fuente, E. Blanco, A. and Negro, C., 2009. "Waste Management from Pulp and Paper Production in the European Union", Waste Management, 29: 293-308.*

2. *Hawkins, S.A., Billiard, S.M. Tabash, S.P. Brown R.S. and Hodson, P.V., 2002. "Altering Cytochrome P4501A Activity Affects Polycyclic Aromatic Hydrocarbon Metabolism and Toxicity in Rainbow Trout (Oncorhynchus mykiss)", Environmental Toxicology and Chemistry, 21: 1845-1853.*

3. *Zahrim, A.Y. Melissa, L. Gilbert and Janaun, J., 2007. "Treatment of Pulp and Paper using Photo-Fenton's Process", Journal of Applied Science, 7(15): 2164-2167.*

4. *Chandra, R., Raj, A. Yadav, S. and Patel, D. K., 2009. "Reduction of Pollutants in Pulp Paper Mill Effluent Treated by PCP-degrading Bacterial Strains", Environmental Monitoring and Assessment, 155: 1–4.*

5. *Raj, A., Kumar, S. Haq, I. and Singh, S.K., 2014. "Bioremediation and Toxicity Reduction in Pulp and Paper Mill Effluent by Newly Isolated Ligninolytic Paenibacillussp", Ecological Engineering, 71: 355-362.*

6. *Sharma, R., Chandra, S. Singh,A. and Singh, K., 2014. "Degradation of Pulp and Paper Mill Effluents", Institute of Integrative Omics and applied*

Biotechnology, 5 (3): 6-12

7. *Singh,Y.P. Dhall, P. Mathur, R.M., Jain R.K. and Thakur V.V., 2011. "Bioremediation of Pulp and Paper Mill Effluent by Tannic Acid Degrading Enterobacter SP", Water Air Soil Pollution, 218: 693-701.*

8. *Environment Friendly Techniques in Pulp & Paper Sector. 2013. State Level Workshop Report. Hotel Fortune, Vapi (Gujarat). pp 1-21*

9. *Hussain, N. and Khan, A. A., 2003. "Industrial Wastewater Treatment for Protection of Environmental Pollution", Pakistan Journal of Environmental Science, 3(1):1-10*

10. *Tariq, M., Ali, M. and Shah, Z., 2006. "Characteristics of Industrial Effluents and their Possible Impacts on Quality of Underground Water", Soil & Environment, 25(1): 64-69*

11. *IUCN, 1996. "An Integrated Development Vision, International Union for the Conservation of Nature, Pakistan", Sarhad Programme, Government of the North West Frontier Province (NWFP), Planning and Development Department, Peshawar.*

12. *Obaid-ur-Rehman, Kazmi, S. J. H. and Alam, A., 2012. "Mismanagement of Solid Waste & its Impact on the Environment of Peshawar City", International Journal of Learning & Development, 2 (4):182-188*

13. *Sandstrom, O. and Neuman, E., 2003. "Long-term development in a Baltic Fish Community Exposed to Bleached Pulp Mill Effluent", Aquatic Ecology, 37: 267-276.*

14. *Sarhad Development Authority (SDA), PIA Building, Arbab Road, Peshawar.*

15. *Jan, F.A., Ishaq, M, Ihsanullahb, I. and Asim. S.M., 2010. "Multivariate Statistical Analysis of Heavy Metals Pollution in Industrial Area and Its Composition with Relatively Less Polluted Area: A Case Study from the City of Peshawar and District Dir Lower", Journal of Hazardous Material, 176 (1-3):609-616.*

16. *Nafees, M., Shah, W. Khan, H. and Zahidullah, 2010. "Study of Paper Mill For Water Recycling, Hayatabad Industrial Estate Peshawar", Journal of Science and Technology University Peshawar, 34 (1):29-36*

17. *Arnold, E., 1992. "Standard methods for the examination of water and wastewater". 18th edition, American public health association Washington, DC, 209-269 Method 4500-H+B. pH value/electrometric method. Pp 209-269.*

18. *NEQS, 1993. National Environmental Quality Standards. Gazette of Govt. of Pakistan.*

19. *Bangash, F.K. and Alam, S., 2004. "Extent of Pollutants in the Effluents of Hayatabad Industrial Estate, Peshawar", Journal of the Chemical Society of Pakistan, 26(3):271-278*

20. *Khan, S. and Noor, M., 2002. "Investigation of Pollutants in Wastewater of Hayatabad Industrial Estate Peshawar", Pakistan Journal of Agriculture Sciences, 2: 457-461*

21. *Hossain, K. and Ismail, N., 2015. "Bioremediation and Detoxification of Pulp and Paper Mill Effluent": A Review, Research Journal of Environmental Toxicology, 9 (3): 113-134*

22. *Mishra, A., Tripathi, C.P.M. Dwivedi, A.K. and Dubey, V.K., 2011. "Acute Toxicity and Behavioral Response of Freshwater Fish, Mystusvittatusexposed to Pulp Mill Effluent", Journal of Environmental Chemistry and Ecotoxicology, 3: 167-172.*

23. *Khan, S., Khan, A. M. and Khan. M.N., 2002. "Investigations of Pollutants Load in Waste Water of Hayatabad Industrial Estate, Peshawar, Pakistan", Pakistan Journal of Applied Science, 2(4): 457-461.*

24. *Hewitt, L.M., Parrott J.L. and McMaster, M.E., 2006. "A Decade of Research on The Environmental Impacts of Pulp and Paper Mill Effluents in Canada: Sources and Characteristics of Bioactive Substances", Journal of Toxicology and Environmental Health, 9: 341-356.*

25. Rahman, R.A., Zahrim, A.Y. and A. Abu-Bakar, 2007. "Choroorganics in Paper mill Effluent: Identification and Removal by SBBR", Journal of Applied Science, 7 (15):2160-2163