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The Coke Oven Effluent Channel of the Bhilai Steel Plant: Toxic Effects of its Wastewater on the Indian Murrel *Channa punctatus* Bloch

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ABSTRACT
The Bhilai Steel Plant is an integrated steel plant situated 30 kilometers (west) of Raipur, the capital of the state of Chhattisgarh (India). The waste generated in the coke ovens has a strong phenolic odour and contains a high amount of phenol, besides the presence of other toxic substances. A preliminary survey was conducted in five localities of the coke oven effluent channel, also known as Purena nala and gross effluent characteristics observed along with associated aquatic animals and plants growing in the embankment of the channel. Besides this, the LC_{50} of the waste water was also observed on the fresh water fish, *Channa punctatus* Bloch, for 24 to 96 h (short term exposure) and one month (long term exposure) using bioassay method. Percent mortalities of the fishes were also observed during short and long term exposures to lower and higher concentrations. The concentration of the effluent and duration of exposure were observed to have significant effects on organisms. Besides, some necrotic spots, lesions along with tail rotting were also observed.

Key words: Acute toxicity, phenolic industrial waste, lethal dose, *Channa punctatus* bloch

INTRODUCTION
Phenols are hydroxy-derivatives of aromatic hydrocarbons and are formed during the decomposition of organic materials under natural conditions. They are an important constituent of coal tar. The major portion of the phenol present in the environment is anthropogenic. Industrial pollution, particularly due to the iron and steel industry, leads to elevated levels of phenol in sediments and ground water (WHO Task Group, 1993) and needs to be taken care of.

Effects of pollutants on living organisms maybe be measured by toxicity tests (Reish and Oshida, 1987). The presence or absence of fish is a biological indicator of the degree of pollution (Boateng *et al.*, 2006). Razani *et al.* (1986) studied the chronic toxic effect of phenols on the Zebra fish, *Brachydanio rerio*. Angus (1986) studied phenol tolerance in populations of mosquito fish *Gambusia affinis* from industrially polluted and non polluted waters and reported that the median lethal concentration (LC_{50}) of phenol was significantly higher for mosquito fish from a stream that received coke-treatment wastewater from a steel plant than for the other two populations. Nair and Sherrif (1998) studied the acute toxicity of phenol on food consumption and growth of juvenile *Labeo rohita* (Ham.) and observed that fishes exposed to 5-10 mg L^{-1} phenol showed significantly lower mean wet weight gain, specific growth rate, food conservation efficiency. According to them the maximum allowable toxicant concentration for juvenile fishes was 3.16 mg L^{-1}.

The Bhilai steel plant is an integrated steel plant situated near Raipur, the capital of the state of Chhattisgarh (India). The metallurgy of iron ore takes place in the presence of coke which is used as a fuel and reducing agent in the blast furnace. This coke is obtained from bituminous coal which is converted in the coke ovens. Sinha (1999) studied the physico-chemical characteristics of this effluent generated from the coke oven batteries and reported it to be rusty brown in color and pungent phenolic odor. Besides, other parameters such as, total alkalinity, chloride ions, Total Dissolved Solids (TDS), chloride ions and sulphates etc. were also found to be far above normal levels. Although the Bhilai Steel Plant happens to be an important industry of Chhattisgarh, however, very few studies (Bakde and Poddar, 2011; Mishra and Niyogi, 2011) have yet been done on the effect of this phenolic industrial waste on food fishes. The present work is an attempt to understand the impact of a stressful phenolic environment on the food fish *Channa punctatus*.

MATERIALS AND METHOD

Preliminary survey of the effluent channel: A preliminary survey was conducted in five localities of the coke oven effluent channel, also known as Purena nala and gross effluent characteristics observed along with associated aquatic animals and plants growing in the embankment of the channel.

Waste water analysis: The wastewater was collected from the origin point of the effluent channel located at Purena (Bhilai 3) and was analyzed for its physicochemical characteristics by standard methods (APHA, 1975).

Determination of lethal concentration: To determine the LC_{50}, in all six concentrations of the effluent (10, 30, 50, 70, 90 and 100%) were taken for experimentation after dilution by tap water. Laboratory acclimatized fishes, 20 in each concentration, were exposed to these dilution percentages of the Effluent with one set maintained along as control and percent mortality calculated by the formula-Number of fishes dead X 100/Total number of fishes exposed. Similarly, 20 fishes each, were also exposed to different concentrations (10,12,14,16,18 mg L^{-1}) of commercially available phenol solution for 24 h and the LC_{50} determined by Probit analysis (Finney, 1971). The corresponding Probit values for each concentration were used further for calculating LC_{50}. Accordingly, the LC_{50} for effluent was calculated to be 70% (Table 2) and Phenol to be 14 mg L^{-1}. Hence, sublethal concentration ranges comprising of low (0.01, 0.015, 0.02, 0.025%), respectively designated as E1, E2, E3, E4 and higher ranges comprising of 10, 20 and 30% and designated as E10, E20, E30, respectively in case of effluent were selected further for short and long term exposure experiments.

Exposure of fishes to toxicants and percent mortality: The amount of phenol present in effluent was estimated to be 5.6 mg L^{-1} and a stock phenol solution was prepared amounting to the same concentration. This was subsequently diluted with tap water so as to have the afore mentioned concentrations (0.01, 0.015, 0.02, 0.025%), respectively designated as P1, P2, P3, P4 and 10, 20 and 30% and designated as P10, P20, P30, respectively.

Acclimatization: Live, healthy fishes belonging to the same age group were collected from local streams and acclimatized under normal laboratory conditions for 15 days. They were then separated into 7 groups of 16 fishes each.

Short term exposure: Short term exposures to various concentrations of the Phenolic Effluent along with Normal tap water as control was done in 20 L glass aquaria for a period of 7 days and day to day observations on mortality made at different time points viz., 24, 48, 72, 96, 120, 144 and 164 h. Uniform feeding and aeration of the tanks was done throughout the experiment.

Long term exposure: Long term exposure of fishes to 10, 20, 30% concentrations of effluents was done for a duration of 4 weeks and observations on its toxic effects made at weekly intervals.

RESULTS AND DISCUSSION

The observations made in the preliminary survey of the five localities of the coke oven effluent channel, also known as Purena nala is depicted in Table 1. The channel starts from its source at Purena, Bhilai 3 and after traveling an approximate distance of 15 km through meadows and villages, ends up in the river Kharoon, a tributary of the river Mahanadi. This place is inaccessible, being camouflaged between trees and guarded by barbed wire and is situated in the out skirts of a small town Kumhari, about 15 km west from Raipur city, the capital of Chhattisgarh. The river Kharoon obviously is very important, since it caters to the needs of water and fish for Raipur and adjoining cities like Charoda, Bhilai etc. The waste water flowing through the channel was found to be blackish-brown in color with floating oil and intense phenolic odor. The soil texture of the embankment, particularly near the origin at Purena, appeared to be oily black. The vegetation mainly comprised of grasses (Fig. 1). The entire course of the channel was traced to be traveling through the villages Sirsa (Somni), Nardhi and Aundhi (Fig. 2-4) before reaching the river mouth at Kumhari (Fig. 5). About 40 villagers were interviewed with the help of a questionnaire to gather information on the effect of the effluent on the humans and animals living there and using the water for their daily chores (Table 1). Accordingly, the local villagers avoided using the wastewater since it was reported to cause an itching and burning sensation in the skin accompanied by reddish papule like dermatitis.

Table 1: A preliminary survey report of the Coke oven effluent channel (Purena Nala)

			Aquatic animal		
Locality	Subjects interviewed	Effluent characteristics	Occurrence	Characteristics	Plants growing
Purena (source)	9	Blackish brown color. Phenolic odour. Oily. No human use.	Nil	Not applicable	Sugarcane, Grasses Paddy
Sirsa (Somni)	8	Blackish brown color. Phenolic odour. No human use.	Tilapia, Carps	Flesh with phenolic taste. Heavy mucous secretion. Skin heavily pigmented (black)	Grasses
Nardhi	7	Blackish brown color. Phenolic odour. No human use.	Turtles	Protective hard Carapace	Grasses
Aundhi	7	Blackish brown color. Phenolic odour. No human use.	Turtles	Protective hard Carapace	Bamboo Paddy
Kumhari (rivermouth)	9	Diluted No human use	Snakeheads Tilapia Carps	Fishes few in number, appear normal in behavior.	Sugarcane Grasses

Fig. 1: Coke oven effluent channel (origin point) at Purena (Bhilai-3). Note the oily black soil texture, grasses growing and distant slag dumps

Fig. 2: Coke oven effluent channel at Purena (Purena Nala)

Fig. 3: Coke oven effluent channel at Sirsa

Fig. 4: Coke oven effluent channel at Nardhi

Fig. 5: River mouth at Kumhari

No fishes were reported to be present in the channel near Purena, although some hybrid and exotic fishes like Carps and Tilapia were reported to exist in the channel passing through village Sirsa (Somni). These fishes were ill grown, blackish, with heavy mucus secretion and reddish papules on their surface. They were complained of being unpalatable, indigestible with intense phenolic odor in their flesh. The embankment of the channel in this place consisted of members of the grass family only. Although fishes were absent, but in a few instances, animals with hard carapaces such as, Turtles could be found in the channel at Nardhi and Aoundhi villages. The presence of a hard carapace possibly gave a selective advantage to the turtles over fishes in the protection against the toxic effects of effluent. The villagers also complained that *Channa punctatus* although present a few years back had vanished from the channel presently. During heavy rains the wastewater was reported to enter into a fish farm situated in Nardhi and responsible for heavy casualties of fishes. At this place the phenolic wastewater was being used for irrigation of Paddy by the local villagers. At Kumhari, the water being diluted upon meeting the river Kharoon, a few fishes like, Snakeheads, Carps and Tilapia were visible. Inevitably, all these factors raise questions on the toxic effects of the effluent on the aquatic life dwelling in the river.

Determination of LC_{50} of effluent by Probit analysis was calculated to be 70% and for Phenol to be 14 mg L^{-1} which are depicted in Table 2. No mortalities of fishes were observed in the first 24 h during short term exposures. Mortality of fishes started after 48 hours of exposure initially ranging between 5-10% (Table 3). Long term exposure to 30% of effluent showed the onset of necrotic spots in the head region in the first week after exposure which extended to the ventral region as large lesions in the second week. Onset of tail rotting started in the 3rd week and extended to the whole caudal region in the 4th week (Fig. 6-9).

Phenol and phenolic compounds are stressful environmental factors which because of their lipophilic properties present a threat against the natural environment and also to human health (Hori *et al*., 2006). According to Schaperclaus *et al*. (1991), the primary damages caused by phenolic waters on fisheries resources are acute toxicity effects causing mortality of fish (>3-5 mg L^{-1}); movement of fish away from toxicity site (>0.2 mg L^{-1}) and impaired fish taste (>0.1 mg L^{-1}). Southgate *et al*. (1932) conducted an investigation into the causes of death of Salmon and Sea trout smolts in the estuary of the river Tees, famous as Salmon river and found that pollution of its water by effluents from iron and steel industry was responsible for the heavy mortality of fishes. Tupholme (1933) also reported death of fishes exposed to cyanides present in coke oven effluents. The present author agrees with Schaperclaus *et al*. (1991) that the absence of fishes near the origin of the channel at Purena is possibly due to heavy mortality of fishes due possibly to high concentrations of phenol. Presence of exotic and hybrid fishes, like Tilapia and Carps in the channel at Somni reflects the better adaptability potential of these fishes to survive environmental stress. It may be assumed that possibly these fishes have moved out of the mortality zone at Purena and proceeded to Somni. Presence of ill grown fishes possibly reflects the effect of phenolic effluent on growth of fishes (Saha *et al*., 1999). Phenols have been reported to cause blanching, burning sensation followed by numbness and corrosion (burn and gangrene)in skin after single exposure.

Table 2: Determination of LC_{50} of effluent by Probit analysis

Concentration of effluent (%)	Total No. of fishes exposed	No of dead fish at 96 h	Mortality (%)	Probit value
0	20	0	0	0
10	20	2	10	3.72
30	20	4	20	4.16
50	20	7	35	4.62
70	20	11	55	5.16
90	20	14	90	5.29
100	20	17	85	6.04

Table 3: Percent mortality during short term exposure of *C. punctatus* to low and high concentrations of effluent

Hours	0.1 (%)	0.15 (%)	0.2 (%)	0.25 (%)	10 (%)	20 (%)	30 (%)
24	Nil	Nil	Nil	Nil	Nil	Nil	Nil
48	Nil	5.0	Nil	5.0	Nil	Nil	5.0
72	Nil	Nil	5.0	5.0	5.0	5.0	5.0
96	Nil	5.0	Nil	5.0	Nil	5.0	10.0
120	Nil	5.0	Nil	Nil	10.0	5.0	5.0
144	5.0	Nil	5.0	5.0	5.0	10.0	5.0
168	10.0	10.0	5.0	5.0	5.0	5.0	5.0

Fig. 6: Presence of necrotic spots in the head region of the fishes, one week after exposure

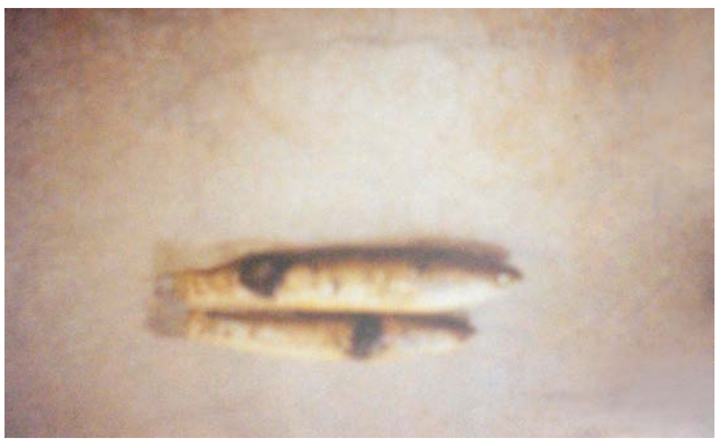

Fig. 7: Presence of large necrotic spots on the outer surface, in the second week after exposure

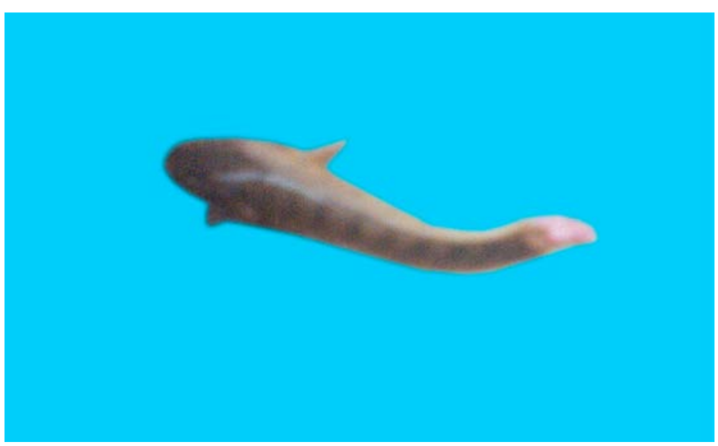

Fig. 8: Onset of tail rotting near the caudal fin during 3rd week after exposure

Fig. 9: Showing the entire caudal end rotten (4rth week)

Repeated exposures cause dermatitis (WHO, IPCS and UNEP, 1994). Presence of reddish papules on the surface of fishes reflects corrosive effect of the cokeoven effluent. Presence of unpalatable, indigestible fishes with intense phenolic odour in their flesh obviously reflects organoleptic and bioaccumulative properties of the phenol present in the effluent. While, black color of the fish tegument helps the fish to blend with the black phenolic effluent environment, heavy mucus secretion is possibly to counter the irritating effects of effluent.

Govindarajalu (2003) studied the health status of villagers, agriculture and the livestock population of Noyyal river basin and found almost all the 31 sampled villages were affected by the industrial effluent. Health problems such as skin allergy, respiratory infections, general allergy, gastritis and ulcers were the common diagnosis by the medical team. In the present work, similar complaints of itching and burning sensation in the skin accompanied by reddish papule like dermatitis in animals have also been reported by the local villagers after usage of the wastewater for bathing of animals or washing clothes. Oily black texture of the soil and presence of only grass family reflects soil degradation.

Hematological parameters may be considered useful as health indicators of fish during changing environmental conditions. Mishra and Niyogi (2011) studied the daily changes in the hematological parameters (TEC,TLC and gm% Hb) of *Channa punctatus* (Bloch) upon short term exposure to low and high concentrations of this phenolic effluent. Commercially available Phenol in the same concentration was taken as a reference for comparison. Fishes adapted to environmental change by significant augmentation in their TEC, TLC and Hb (g dL^{-1}) up to 120 h followed by a tendency to resume back normal conditions thereafter. Bakde and Poddar (2011) exposed *Cyprinus carpio* Linn. (1758) and observed that various concentrations of the same effluent altered the acidic and alkaline phosphatase activity in the liver, gills and gonads. Khewar (2011) observed higher activity of ALAT in liver tissue of treated fishes in the first two weeks after exposure opined it to be due to stress caused by exposure to phenolic effluent, since stress in general is known to elevate amino transferase activities to cope up with augmentation in energy demand. Decline in ALAT and ASAT activities from the 3rd week onwards was indicative of liver damage.

According to the national recommended water quality criteria phenol has been listed as a priority pollutant with an organoleptic effect criterion of 300 $\mu g\ L^{-1}$ (United States Environmental

Protection Agency, 2009). It is very toxic to fish and has a unique quality of tainting the taste of fish, if present in marine environments at 0.1-1.0 ppm (Kirk and Othmer, 1982; Neff, 2002). Hence, it is beyond doubt that dumping of this phenolic wastewater of the Purena Channel into the river Kharoon may have deleterious consequences and must be taken care off.

CONCLUSION

The cokeoven effluent of the Bhilai Steel Plant contains a very high amount of phenol (5.6 mg L^{-1}) which is far higher than the OEC (organoleptic effect criterion) of phenol (0.3 mg L^{-1}) according to the National Recommended Water Quality Criteria (United States Environmental Protection Agency, 2009). Besides, it not only causes toxic effects on fishes in the form of lesions, hematological and enzymatic changes, but is also responsible for large scale mortality of fishes. Hence, dumping of this effluent into the river Kharoon which caters to the needs of Raipur city and suburbs will not only be responsible for degradation of the water quality, but will also lead to severe ecotoxicological effects.

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REFERENCES

APHA, 1975. Standard Methods for the Examination of Water and Wastewater. 14th Edn., American Public Health Association, Washington, DC., USA., Pages: 1193.

Angus, R.A., 1986. Phenol tolerance in populations of mosquito fish from polluted and non polluted waters. Trans. Am. Fish. Soci., 112: 794-799.

Bakde, C. and A.N. Poddar, 2011. Effect of steel plant effluent on acid and alkaline phosphatases of gills, liver and gonads of *Cyprinus carpio* Linn. (1758). Int. J. Environ. Sci., 1: 1305-1316.

Boateng, J.O., F.K. Nunoo, E.H.R. Dankwa and M.H. Ocran, 2006. Acute toxic effects of deltamethrin on tilapia, *Oreochromis niloticus* (Linnaeus, 1758). West Afr. J. Applied Ecol., 9: 1-5.

Finney, D.J., 1971. Probit Analysis. 3rd Edn., Cambridge University Press, Cambridge, London.

Govindarajalu, K., 2003. Industrial effluent and health status-A case study of Noyyal river basin. Proceedings of the Third International Conference on Environment and Health, December 15-17, 2003, Chennai, India, pp: 150-157.

Hori, T.S.F., I.M. Avilez, L.K. Inoue and G. Moraes, 2006. Metabolical changes induced by chronic phenol exposure in matrinxa *Brycon cephalus* (teleostei: characidae), juveniles. Comp. Biochem. Physiol. Toxicol. Pharmacol., 143: 67-72.

Khewar, V., 2011. Effect of steel plant effluent on transaminases of *Channa punctatus* (Bloch). M.Sc. Thesis, Pt. RSU, Raipur.

Kirk, R.E. and D.F. Othmer, 1982. Encyclopaedia of Chemical Technology. Vol. 17, 3rd Edn., Wiley, New York, ISBN: 9780471020707, pp: 1-26.

Mishra, A. and P.A. Niyogi, 2011. Hematological changes in the Indian murrel (*Channa Punctatus* bloch) in response to phenolic industrial wastes of the bhilai steel plant (Chhattisgarh, India). Int. J. Res. Chem. Environ., 1: 83-91.

Nair, J.R. and P.M. Sherrif, 1998. Acute toxicity of phenol and long-term effects on food consumption and growth of juvenile Rohu *Labeo rohita* (Ham.) under tropical conditions. Asian Fish. Sci., 10: 179-187.

Neff, J.M., 2002. Phenols in Ocean. In: Bioaccumulation in Marine Organisms: Effect of oil well Produced Water, Neff, J.M., (Ed.). Chapter 12, Elsevier Ltd, UK., pp: 203-214.

Razani, H., K. Nanba and S. Murachi, 1986. Chronic toxic effect of phenols on the Zebra fish, *Brachydanio rerio*. Bull. Jap. Soc. Sci. Fish, 52: 1553-1558.

Reish, D. L. and P.S. Oshida, 1987. Manual of methods in aquatic environment research-Part 10 short-term static bioassays. FAO Fisheries Technical Paper, Rome, pp: 64.

Saha, N.C., F. Bhunia and A. Kaviraj, 1999. Toxicity of phenol to fish and aquatic ecosystems. Bull. Environ. Contam. Toxicol., 63: 195-202.

Schaperclaus, W., H. Kulow and K. Schreckenbach, 1991. Fish Diseases. Vol. 2, Amerind Pub. Co., USA., ISBN: 9788170870562, Pages: 1398.

Sinha, S., 1999. Industrial effluents and organisms inhabiting it. Ph.D. Thesis, Submitted to Pt Ravishankar Shukla University, Raipur, CG., India.

Southgate, B.A., F.T. K. Pentelow and R. Bassindale, 1932. An investigation into the causes of death of salmon and sea trout smolts in the estuary of the river Tees. Biochem. J., 26: 273-284.

Tupholme, C.H.S., 1933. Death of fish from cyanides in coke-oven effluents. Chem. Eng. News, 11: 211-212.

United States Environmental Protection Agency, 2009. National recommended water quality criteria. http://www.epa.gov/ost/criteria/wqctable/

WHO Task Group, 1993. Environmental health criteria for phenols: A monograph. On Behalf of the International Program on Chemical Safety, IPCS A Joint Venture of the UNEP, ILO and WHO.

WHO, IPCS and UNEP, 1994. Phenol Health and Safety Guide. WHO, Geneva, Pages: 88.