ISSN No. 2456-4400
Int J Med Lab Res 2019, 4(1):55-63

IJMLR International Journal of Medical Laboratory Research

RESEARCH ARTICLE

DETERMINATION OF LC_{50} OF PHENOLIC COMPOUNDS (PHENOL & M-CRESOL) FOR A FISH, *LABEO ROHITA*

Vikash Gaur[1], Abhishek Mathur[2]

[1]*Department of Biochemistry, Himalayan University, Arunachal Pradesh, India*
[1]*Maulana Azad Medical College & Associated Hospitals, New Delhi*
[2]*National Centre of Fungal Taxonomy (NCFT), New Delhi & Institute of Transgene Life Sciences (ITLS), Dehradun, Uttarakhand, India.*

Received: 23 February, 2019/ Revision: 28 February, 2019/ Accepted: 8 March, 2019

ABSTRACT: Water pollution has become a global problem as various pollutants like heavy metals and toxic chemicals are discharged without prior treatment into the water. With the development of industrial production, a large volume of wastewater containing phenols was discharged into the aquatic environment. Moreover, chemical leakage further increased the emission of phenols into aquatic systems. Phenol and its methylated derivative (cresols) were selected due to their extensive use in industry and ecotoxicity to freshwater and marine organisms. This study focused on the ecotoxicity of phenol and m-cresol on aquatic systems. This paper emphasizes on the determination of 96hr LC_{50} value of phenol & m-cresol for the fish, Labeo rohita. The acute toxicity test was performed according to the standard methods in APHA and the value was calculated by probit analysis. The fish specimens were acclimatized in the laboratory conditions for 15 days. The stock solution of phenol & m-cresol was prepared and the fish fingerlings were treated with various concentrations ranging from 1 mg/l to 50 mg/l for 96 hours. The results showed that the median lethal concentration (LC_{50}) of phenol & m-cresol for the fish, Labeo rohita is 3212 & 2957 mg/l. The susceptibility of Labeo rohita to the lethal effect of phenol & m-cresol were dependent on duration as well as on concentration. The mortality of the fishes is directly proportional to the concentration

KEYWORDS: Phenol, Cresols Ecotoxicity, Biodegradation, Acute Toxicity, Labeo rohita, 96hr LC50.

INTRODUCTION:

Water pollution has become a global problem as various pollutants like heavy metals and toxic chemicals are discharged without prior treatment into the water bodies most commonly in developing countries. These toxic chemical due to their properties like long half life period, bioaccumulation, biomagnifications in the food chain and non-biodegradability are hazardous to the aquatic organisms and their consumers which on being exposed to these toxic chemical can suffer from immense health problems and risk of life[1-2]. Fishes have direct economic importance and are quite sensitive to the wide array of pollutants discharged in the aquatic ecosystems. Fishes are widely used to assess water quality of aquatic ecosystems because they serve as pollution bioindicators[3]. Fish may concentrate large quantities of toxic chemical from polluted aquatic environments[4]. The toxic chemical concentration in the body of fish depends upon feeding habits, trophic status, food availability,

Corresponding Author:
Vikash Gaur,
Department of Biochemistry, Himalayan University, Arunachal Pradesh, India

physico-chemical properties of water, metabolic rate of animal and toxicity of toxic chemical [5-6]. Labeo rohita is a commercial fish and widely preferred as edible fish in India. It is very important to evaluate edible organisms like Labeo rohita from toxicity point of view as health of human being is directly associated with it. During the present course of investigation acute toxicity tests of Phenolic compounds to determine 96 hr LC50 have been conducted on Labeo rohita, a fish having high nutritional value as well as a it serves as a good pollution indicator[7-9].

Phenol, a colorless-to-white solid with a characteristic odour, is the simplest monatomic phenol. Cresols, methylated derivatives of phenol, are composed of three isomers [meta-(m-), ortho-(o), and para-(p-)]. Phenolic compounds are extensively used as materials for organic synthesis and also used in different industries, such as pesticides, dyes, coatings, and oil refining (ASTDR, 2008a, 2008b; Michałowicz and Duda, 2007) and hence, they are ubiquitous in the wastewater from these industries (Jiang et al., 2006; Saravanan et al., 2008; Surkatti and El-Naas, 2017)[1-2-7-8].

Moreover, leakage accidents further increased the possibility of the emission of phenols into the environment. Accidental spills of phenol, which happened in the Port of Gothenburg (Sweden) and Xin'an River (China), caused leakage of a significant amounts of phenol, posing a threat to water quality and aquatic systems (China Chemical Safety Association, 2011; HELCOM, 2002). Due to their high water-solubility (phenol, 8.28g/100mL; cresols, 2.15–2.60g/100mL), phenol and cresols can persistent a high concentration in aquatic environments (Wei et al., 2016). Water pollution in China is mainly caused by discharged wastewater from dozens of types of industrial pollution source (Zhou et al., 1991). Phenol and m-cresol, as priority pollutants of many industrial point sources, such as oil processing industry, insecticide factory, and chemical trades, have been named on the list of priority pollutants (68 substances) held by the China Environmental Priority Monitoring Research Group (Zhou et al., 1989). Currently, phenol has been named on a list of the top 20 chemicals likely to pose the highest risk of being involved in an HNS (hazardous and noxious substance) incident held by International Maritime Organization (IMO) (ITOPF, 2011).

Ayeni (2014) concluded that indiscriminate disposal of wastewaters into the aquatic environment and abrogation of the responsibility to manage industrial wastewater before point of discharge caused higher level concentrations of phenol in water systems. As for seawater, the concentrations of volatile phenols (including phenol and cresols) in Maoming onshore fishery (China) were greater than 10μg/L, and thus were classified as a Class IV pollutant according to Sea Water Quality Standard (SEBC, 1997). Moreover, accidental leakages of phenol and cresols, to sea or a river, may give rise to a significant increase of phenol and/or cresols concentrations in aquatic systems, causing high toxicity of phenols to aquatic organisms[2-5].

The physico-chemical properties of pollutants determine their behaviour upon entering the water (ITOPF, 2011). The Standard European Behaviour Classification (SEBC) codes enshrined a set of criteria for theoretical behaviour according to physico-chemical properties (i.e. physical state, density, solubility in water, and vapour pressure). Sink solids (density>seawater) with a solubility of 10% (or less) and sink liquids (density>seawater) with a solubility of 0.1–5% are classified as sinker (S) and sinker/dissolver (SD) by SEBC, respectively (Le Floch et al., 2012).

The physico-chemical properties of phenol and cresols were listed in Table 1: the properties of phenol, o-cresol, and p-cresol (with a density of 1.03–1.05g/cm3, and a solubility of between 2.15 and 8.28g per 100mL of water) indicate that they will, in theory, behave as S (ATSDR, 2008a, 2008b); however, m-cresol and mixed cresol (with a density of 1.03–1.038g/cm3 and a solubility of 2.27–2.59g per 100mL of water) will behave as SD (ATSDR, 2008b; CAFÉ database, 2017). Phenol is not expected to volatilize or be absorbed by sediments and suspended particulates in the aquatic environment (ATSDR, 2008a). Biodegradation and indirect reactions with photochemically produced hydroxyl radicals and peroxyl radicals are expected to be important transport mechanisms (ATSDR, 2008a). For cresols, volatilisation may be the dominant process (ATSDR, 2008b). Yet, these pathways may be influenced by environmental factors in situ[11-15].

The results of micro cosmo experiments conducted with seawater under simulated marine conditions

showed that volatilization was the dominant-attenuation type for phenol, o-cresol, and p-cresol, and photolysis dominated for m-cresol, with half-lives of 4.3–7.9 days for phenol and three isomers of cresol (Wang et al., 2017). The Henry's Law constant for m-cresol is the lowest (8.6× 10−7 atm·m3/mol) (Lyman et al., 1990), which indicates that the rate of evaporation of m-cresol inferior to the others. Experimental bio concentration factors (BCFs) of 0.28–39 indicated that phenol and the isomers of cresol would not bioconcentrate in aquatic organisms (ATSDR, 2008a, 2008b; NCBI, 2017); however, sound evidence could be concluded, from this review, that the effects of phenol and cresols showed high acute toxicity to aquatic systems (see below). Hence, the toxicity of phenol and cresols to aquatic organisms is more likely to be a direct effect rather than via their transfer through the food chain (Rocha et al., 2016)[16-21].

Table.1 Physic-chemical properties of phenol and cresols.26-27 Sources: ATSDR (2008a, 2008b) and CAFÉ database (2017).70-72

Chemical name	CAS No	Physical state	Density (g/cm3	Solubility in water (g/100mL)
Phenol	108-95-2	Solid	1.05	8.28
m-cresol	108-39-4	Liquid	1.03	2.27
o-cresol	95-48-7	Solid	1.05	2.60
p-cresol	106-44-5	Solid	1.03	2.15
Mixed cresol	1319-77-3	Liquid	1.030–1.038	2.59

The bioaccumulation of the highly toxic Phenolic compounds has been observed in various tissues of the fishes like scales, bones, gills, kidneys and liver13.The toxic effects of various chemicals may hinder the physiological and metabolic functions, rate of growth, reproductive efficacy and ultimately causes mortality in fishes[14]. Toxicity tests have been performed on fishes to evaluate the effect of toxicants on various aquatic organisms under laboratory conditions. To assess susceptibility and survival potential of the test organisms 96 hr LC50 tests of some particular toxicants have been conducted. The fingerling stage of fish is more reliable to conduct toxicity test of various waterborne toxicants[15, 16].

MATERIAL AND METHODS:

Chemicals and Reagents used for the study- The chemicals and reagents used for the study were of analytical grade and the diagnostic kits used in the study for biochemical testing were from standard diagnostics company.

Collection and maintenance of test fish - Labeo rohita (20-25g) were collected from the culture ponds of Yamuna river of Delhi region, India and were brought to artificial small ponds/ aquarium in Institute of Transgene Life Sciences,

Dehradun/Lucknow units. Further, these fishes were kept in large tanks where a continuous and gentle flow of fresh water was maintained & fishes were given bath for 2-3 minutes in 0.1% KMnO4 solution for the prevention of any disease. They were fed on a commercial diet ad libitum and were acclimated in tanks for a month before the experiment.

Experimental design for lethal toxicity study - The values of median lethal concentration (LC50) and median effect concentration (EC50) are usually used to characterize the toxicity of a chemical to a living organism. LC50 determinations were carried out by following semi-static acute toxicity test. For the experiment, 6 fishes were transferred to large experimental tubs, each containing 18 liters of dechlorinated tap water Eight phenol concentrations from 2700 mg l-1 (no mortality) to 3400 mg l-1 (100 % mortality) were chosen for the final 96 hour test to determine the 50 % lethal concentration (LC50) For m-cresol eight concentrations from 2500 mg l-1 (no mortality) to 3200 mg l-1 (100 % mortality) were chosen for the final 96-h test to determine the 50 % lethal concentration (LC50). Fishes transferred to tanks containing no toxicants were utilized as control. Water in the control tanks and water and toxicant in the experimental tanks were renewed daily to remove the debris, taking care to give

minimum disturbance to the fish[17,19,20]. The fishes were not fed during the entire exposure period. Fishes were checked for mortality at every 24 hours interval. The LC50 levels and 95% confidence limits were calculated using Probit analysis (Finney, 1971)[10]. The lethal toxicity experiments were repeated wherever necessary.

RESULTS AND DISCUSSION:

During the present investigation the 96hr LC50 of Phenol & m-cresol for the fish, Labeo rohita was found to be 3212 & 2957 mg/l respectively. [17-19-20]

Table 2: Acute toxicity range of phenol and m-cresol in L. rohita

Phenolic Compound (s)	Acute Toxicity Range (mg/l)
Phenol	3212
m-cresol	2957

The relation between the percentage mortality and the concentration of phenolics has been drawn (Table-2).

Figure-1. Shows the regression line between the probit kill of Labeo rohita and log concentration of phenolics

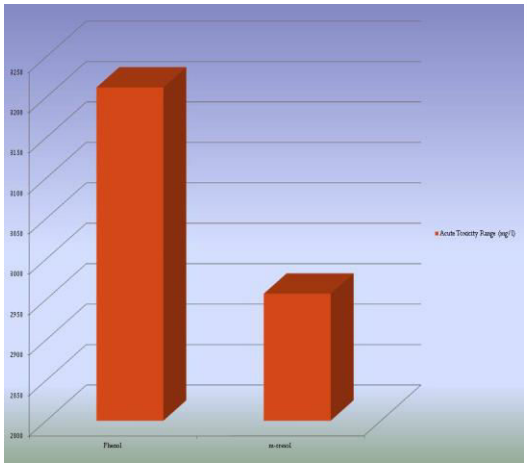

Figure 1: Acute toxicity range (LC50 values) of phenol and m-cresol in L. rohita

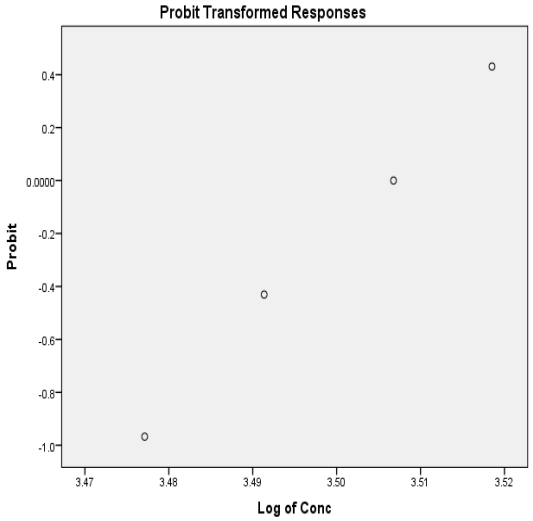

Figure 2: Regression line between the probit kill of Labeo rohita and log concentration of Phenol

Table: 2 Model summery of phenol relation with mortality

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square	F Change	df1	df2	Sig. F Change	
1	.961[a]	.924	.905	89.410	.924	48.379	1	4	.002	1.929

a. Predictors: (Constant), mortality
b. Dependent Variable: Dose

Table: 3 ANOVA Model summery of phenol relation with mortality

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	386743.543	1	386743.543	48.379	.002[b]
	Residual	31976.457	4	7994.114		
	Total	418720.000	5			

a. Dependent Variable: Dose
b. Predictors: (Constant), mortality

Table : 4 Coefficient Model summery of phenol relation with mortality

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2708.686	61.389		44.123	.000
	mortality	128.743	18.510	.961	6.955	.002

a. Dependent Variable: Dose

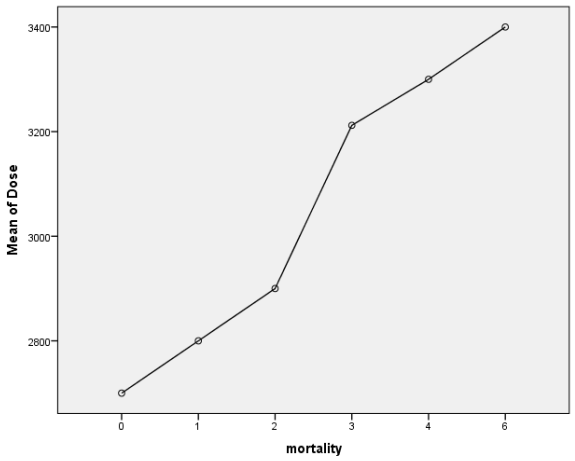

Figure : 3 Model summery of phenol relation with mortality

Carp (Cirrhinus mrigala) was the most sensitive freshwater organism with a 96h-LC50 of 1.555mg/L for phenol (Verma et al., 1984). Mortality of the freshwater fish Oncorhynchus mykiss was increased to 50% after a 96-h exposureto3.88mg/L m-cresol (Saglam and Ural, 2005). Among marine organisms, the opossum shrimp (Archaeomysis kokuboi) was the most susceptible to phenol, with a 96h-LC50 of 0.26mg/L (Kim and Chin, 1995). Pink salmon (Oncorhynchus gorbuscha) was the most sensitive to p-cresol in marine systems, with a 96h-LC50 of 3.36mg/L (Korn et al., 1985). LC50 or EC50 values for all organisms ranged from 0.26 to 1204.6mg/L (a 4633-fold range) for phenol, 3.88–196.78mg/L (a 51fold range) for m-cresol, 5.0–167.49mg/L (a33-fold range) for o-cresol, 1.4–110.66mg/L (a 79-fold range) for p-cresol, and 10-> 100mg/L (a>10-fold range) for mixed cresol.

LC50 or EC50 values for all organisms ranged from 0.26 to 1204.6mg/L (a 4633-fold range) for phenol, 3.88–196.78mg/L (a 51fold range) for m-cresol, 5.0–167.49mg/L (a33-fold range) for o-cresol, 1.4–110.66mg/L (a 79-fold range) for p-cresol, and 10-> 100mg/L (a>10-fold range) for mixed cresol.

According to the analysis of compiled data, the m-isomer of cresol was considerably less toxic than either the p-cresol or o-cresol for all of the organisms exposed to three isomers of cresol. This was inconsistent with the viewpoint of Benville and Korn (1977). The reason may be that the toxicity to an organism depends on the chemical structure and the bioavailability to the test organisms. The toxicity of the mixture is far more complex than a single substance. Synergistic and antagonistic effects are more likely to occur in mixture with two or three compounds (Backhaus, 2014). However, any certain conclusion could not be given according to the available study (Table 5) for the lack of toxicity data of individual cresol and mixed cresol to the same organisms.

Based on the classification criteria raised by the Joint Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP) (GESAMP, 2013), L(E)C50 values (mg/L) are divided into seven levels of eco-toxicological hazard:

non-toxic (L(E)C50> 1000),

practically non-toxic (100 <L(E)C50 ≤1000),

slightly toxic (10 <L (E)C50 ≤100),

moderately toxic (1 <L(E)C50≤10),

highly toxic (0.1 <L(E)C50 ≤1),

very highly toxic (0.01 <L(E)C50 ≤0.1), and

Extremely toxic (L(E)C50 ≤0.01).

According to this rating scheme, the LC50 or EC50 values the phenol was slightly toxic to moderately toxic to fish but significantly higher, indicating that the toxicity of phenol to aquatic creatures ranged from non-toxic to high. The toxicity of cresols to aquatic organisms is the same as with phenol. Overall, the toxicity of phenol and the isomers of cresol were at similar level in terms of effect on aquatic life forms.

For aquatic organisms, salinity may affect some aspects of the system (Rocha et al., 2016). Besides, salinity may affect the toxicity of some chemicals for species specificity, altered bioavailability, and physiological phenomena (Rocha et al., 2016). Therefore, the sensitivity of marine organisms to a chemical may be different from that in a freshwater system (Rocha et al., 2016; Duan et al., 2017b). For instance, the 96h-LC50 values of phenol were 27.32–53.64mg/L for marine diatoms.

Apart from salinity, other environmental factors, such as temperature (Oksama and Kristoffersson, 1979; Cowgill et al., 1985), dissolved oxygen (DO) (Gupta et al., 1983a) and hardness of water (Stephenson, 1983), also had an influence on the toxicity of a certain chemical to the same organism. When water temperature increased, the toxic effect of phenol was accelerated (Oksama and Kristoffersson, 1979). The toxicity of phenol decreased with the increase in DO levels due to a decrease in the susceptibility of fresh water fish (Notopterus notopterus)(Gupta et al., 1983a). Phenol was 1.3–1.6times more toxic in soft water than in hard for fresh water shrimp Gammarus pulex, while water temperature had no influence on the acute toxicity (Stephenson, 1983). Based on the discussion above, factors like organism species and growth stage, temperature and water quality, should be regulated to allow for comparing toxicity data obtained. In this case, toxicity data obtained from different labs will be well compared.

Hormesis is defined as a life-supporting beneficial effect caused by the cellular responses to single or multiple rounds of (mild) stress (Shushimita et al., 2016; Singh et al., 2012). Significant growth enhancements were observed at lower concentrations of phenol (≤ 15mg/L) for a marine diatom (Skeletonema costatum) by the authors (a manuscript in preparation). A similar phenomenon was reported at low concentrations of phenol (about 5–20mg/L) for some species of freshwater microalgae (Tadros et al., 1994). It was found that there was a positive relationship between the mortality and concentration levels; when the concentration level increased, the mortality rate increased as well. However, there was a negative relationship between the mortality time and concentration level; when the concentration level increased, the mortality time decreased. We employed Finney's probit analysis method of data evaluation for acute toxicity bioassay.

CONCLUSION:

It is concluded that some organisms become sensitive to high concentrations of some Phenolic compounds in the aquatic ecosystem and that causes deleterious effects on them. It helps us to determine the permissible limit of a toxicant in an ecosystem. Acute toxicity test reveals about the health of given aquatic ecosystem and eventually help us to propose policies to protect the aquatic ecosystem. It helps us to evaluate the environmental damage resulting from the pollutants and the establishment of water quality criteria to protect aquatic life

Acknowledgement

Authors are highly thankful to Director, Institute of Transgene Life Sciences (ITLS), Dehradun for making available all the necessary facilities to carry out this piece of research work.

REFERENCES:

1. Michałowicz J, Duda W. Phenols--Sources and Toxicity. Polish Journal of Environmental Studies. 2007 May 1;16(3).
2. Saha NC, Bhunia F, Kaviraj A. Toxicity of phenol to fish and aquatic ecosystems. Bulletin of Environmental Contamination and Toxicology. 1999 Aug 1;63(2):195-202.
3. Lopes PA, Pinheiro T, Santos MC, da Luz Mathias M, Collares-Pereira MJ, Viegas-Crespo AM. Response of antioxidant enzymes in freshwater fish populations (Leuciscus alburnoides complex) to inorganic pollutants exposure. Science of the total environment. 2001 Dec 3;280(1-3):153-63.
4. Olaifa FE, Olaifa AK, Adelaja AA, Owolabi AG. Heavy metal contamination of Clarias gariepinus from a lake and fish farm in Ibadan, Nigeria. African Journal of Biomedical Research. 2004;7(3).
5. Heath AG. Water pollution and fish physiology. CRC press; 1995 Sep 14.
6. Dallas HF, Day JA. The effect of water quality variables on riverine ecosystems: a review. Freshwater Research Unit, University of Cape Town; 1993.
7. Woodward DF, Brumbaugh WG, Delonay AJ, Little EE, Smith CE. Effects on rainbow trout

fry of a metals-contaminated diet of benthic invertebrates from the Clark Fork River, Montana. Transactions of the American Fisheries Society. 1994 Jan 1;123(1):51-62.
8. McKim JM. Evaluation of tests with early life stages of fish for predicting long-term toxicity. Journal of the Fisheries Board of Canada. 1977 Aug 1;34(8):1148-54.
9. American Public Health Association, American Water Works Association. Standard methods for the examination of water and wastewater. American public health association; 1989.
10. Finney DJ. Probit analysis. ed.
11. Abdullah SA, Javed MU, Javid AR. Studies on acute toxicity of metals to the fish (Labeo rohita). Int. J. Agr. Biol. 2007;9:333-7.
12. Javid AR, Javed MU, Abdullah SA. Nickel bio-accumulation in the bodies of Catla catla, Labeo rohita and Cirrhina mrigala during 96-hr LC50 exposures. Int. J. Agric. Biol. 2007;9:139-42.
13. Adhikari S. Effect of calcium and magnesium hardness on acute copper toxicity to Indian
14. major carp, Labeo rohita (Hamilton) and catfish, Channa punctatus (Bloch). Aquaculture Research. 2003 Oct;34(12):975-80.
15. NEKOUBIN H, GHAREDAASHI E, IMANPOUR MR, MONTAJAMI S. Determination of LC50 of Lead Nitrate and Copper Sulfate in Caspian Roach (Rutilus rutilus caspicus). Walailak Journal of Science and Technology. 2012;9(4):333-40.
16. Shah SL, ALTINDAĞ A. Effects of Heavy Metal Accumulation on the 96-h LC_50 Values in Tench Tinca tinca L., 1758. Turkish Journal of Veterinary and Animal Sciences. 2005 Mar 18;29(1):139-44.
17. Witeska M, Jezierska B. The effects of environmental factors on metal toxicity to fish(review). Fresenius Environmental Bulletin. 2003;12(8):824-9
18. Gaur V, Raina V, Jain R, Mathur A. 2016. Proceedings of International Conference on Recent Advances in Biotechnology & Nano biotechnology (Int- BIONANO-2016), pp. 101-115.
19. Singh A, Jain DK, Kumar P. Determination of LC50 of cadmium chloride in Heteropneustes fossilis. GERF Bull Biosci. 2010;1(1):21-4.
20. Gaur V, Mathur A. Effect of Phenolic compounds on atp'ases and metabolic profile of labeo rohita. RAPCS Proceeding 2017 pp: 49-60
21. Gaur V, Mathur A. Evaluation of antioxidant profile of Labeo rohita in stress condition after exposure to phenolic compounds. Int. J. Sci. Res. Pub. 2017;7(6):423-34.
22. Saarikoski J, Viluksela MA. Relation between physicochemical properties of phenols and their toxicity and accumulation in fish. Ecotoxicology and environmental safety. 1982 Dec 1;6(6):501-12.
23. Ghosh TK. Effect of phenol pollution on aquatic life. Environment and Ecology. 1983;1(1):1-3..
24. Alex A, Verma OP, Mathur A, Sharan A, Varshney PK. Evaluation of changes in metabolic parameters and enzymes involved in metabolic pathways in Clarias batrachus after exposure to phenolic compounds. Asian Journal of Biomedical and Pharmaceutical Sciences. 2013 Jun 12;3(21).
25. Gad NS, Saad AS. Effect of environmental pollution by phenol on some physiological parameters of Oreochromis niloticus. Global Veterinaria. 2008;2(6):312-9.
26. Arutchelvan V, Kanakasabai V, Elangovan R, Nagarajan S, Muralikrishnan V. Kinetics of high strength phenol degradation using Bacillus brevis. Journal of Hazardous Materials. 2006 Feb 28;129(1-3):216-22.
27. ATSDR, 2008 a. Toxicological Profile for Phenol. Agency for Toxic Substances and Disease Registry.
28. ATSDR, 2008 b.Toxicological Profile for Cresols. Agency for Toxic Substances and Disease Registry.
29. Avilez IM, Hori TS, de Almeida LC, Hackbarth A, Neto JD, da Cunha Bastos VL, Moraes G. Effects of phenol in antioxidant metabolism in matrinxã, Brycon amazonicus (Teleostei; Characidae). Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology. 2008 Aug 1;148(2):136-42.
30. Ayeni O. A preliminary assessment of phenol contamination of Isebo River in south-western Nigeria. Greener J. Phys. Sci. 2014;4(2):30-7..
31. Basha KM, Rajendran A, Thangavelu V. Recent advances in the biodegradation of phenol: a review. Asian J Exp Biol Sci. 2010;1(2):219-34.

32. Benville Jr PE, Korn S. THE ACUTE TOXICITY OF SIX MONOCYCLIC AROMATIC CRUDE OIL COMPONENTS TO STRIPED BASS {MORONESAXATIUS) AND BAY SHRIMP (CR A GO FRA N CISCO RU M) л.
33. Cai W, Li J, Zhang Z. The characteristics and mechanisms of phenol biodegradation by Fusarium sp. Journal of Hazardous Materials. 2007 Sep 5;148(1-2):38-42.
34. Cairns J, Buikema AL, Heath AG, Parker BC. Effects of temperature on aquatic organism sensitivity to selected chemicals.
35. Call DJ, Brooke LT, Lu PY. Uptake, elimination, and metabolism of three phenols by fathead minnows. Archives of environmental contamination and toxicology. 1980 Nov 1;9(6):699-714.
36. Chen, B., Guo, H., Su, R., Su, J., 1999. Analysing the quality of sea water from Meizhou Bay. J. Huaqiao Univ. (Nat. Sci.) 20 (4), 403–406 (in Chinese).
37. Chen HR, Zhu LZ, Yang K, Ge F, Chen YY. Concentration and pollution characteristics of phenolic compounds in Qiantang River. China Environmental Science. 2005;25(6):729-32.
38. Clemens HP, Sneed KE. Lethal doses of several commercial chemicals for fingerling channel catfish.
39. Colgan PW, Cross JA, Johansen PH. Guppy behavior during exposure to a sub-lethal concentration of phenol. Bulletin of environmental contamination and toxicology. 1982 Jan 1;28(1):20-7.
40. Dalela RC, Rani S, Rani S, Verma SR. Influence of pH on the toxicity of phenol and its 2 derivatives pentachlorophenol and dinitrophenol to some fresh-water teleosts. Acta Hydrochimica et Hydrobiologica. 1980 Jan 1;8(6):623-9.
41. DeGraeve GM, Geiger DL, Meyer JS, Bergman HL. Acute and embryo-larval toxicity of phenolic compounds to aquatic biota. Archives of environmental contamination and toxicology. 1980 Sep 1;9(5):557-68.
42. Duan W, Meng F, Lin Y, Wang G. Toxicological effects of phenol on four marine microalgae. Environmental toxicology and pharmacology. 2017 Jun 1;52:170-6.
43. Ertürk MD, Sacan MT, Novic M, Minovski N. Quantitative structure–activity relationships (QSARs) using the novel marine algal toxicity data of phenols. Journal of Molecular Graphics and Modelling. 2012 Sep 1; 38:90-100.
44. Fernando R, Salibián A, Ferrari L. Assessment of the pollution impact on biomarkers of effect of a freshwater fish. Chemosphere. 2007 Jul 1;68(8):1582-90..
45. Gupta AB, Srivastava AK. Phenol induced changes in the carbohydrate metabolism of the Indian catfish Heteropneustes fossilis. Environmental biology of fishes. 1984 Apr 1;10(3):221-4.
46. Gupta PK, Mujumdar VS, Rao PS, Durve VS. Toxicity of phenol, pentachlorophenol and sodium pentachlorophenolate to a freshwater teleost Lebistes reticulatus (Peters). Acta hydrochimica et hydrobiologica. 1982;10(2):177-81.
47. Gupta, S., Dalela, R.C., Saxena, P.K., 1983b. Influence of temperature on the toxicity of phenol and its chloro-and nitro-derivatives to the fish Notopterus notopterus (Pallas). CLEAN–Soil Air Water 11 (2), 187–192.
48. Hickey CW, Blaise C, Costan G. Microtesting appraisal of ATP and cell recovery toxicity end points after acute exposure of Selenastrum capricornutum to selected chemicals. Environmental Toxicology and Water Quality. 1991 Nov;6(4):383-403.
49. Hodson PV, Dixon DG, Kaiser KL. Measurement of median lethal dose as a rapid indication of contaminant toxicity to fish. Environmental Toxicology and Chemistry: An International Journal. 1984 Apr;3(2):243-54.
50. Kopperman HL, Carlson RM, Caple R. Aqueous chlorination and ozonation studies I. Structure-toxicity correlations of phenolic compounds to Daphnia magna. Chemico-biological interactions. 1974 Oct 1;9(4):245-51.
51. Kotresha D, Vidyasagar GM. Isolation and characterisation of phenol-degrading Pseudomonas aeruginosa MTCC 4996. World Journal of Microbiology and Biotechnology. 2008 Apr 1;24(4):541-7.
52. Lovell CR, Eriksen NT, Lewitus AJ, Chen YP. Resistance of the marine diatom Thalassiosira sp. to toxicity of phenolic compounds. Marine Ecology Progress Series. 2002 Mar 20; 229:11-18.
53. Martínez-Gómez C, Vethaak AD, Hylland K, Burgeot T, Köhler A, Lyons BP, Thain J, Gubbins MJ, Davies IM. A guide to toxicity assessment and monitoring effects at lower levels of biological organization following

marine oil spills in European waters. ICES Journal of Marine Science. 2010 Mar 25;67(6):1105-18.
54. McLeay DJ. A rapid method for measuring the acute toxicity of pulpmill effluents and other toxicants to salmonid fish at ambient room temperature. Journal of the Fisheries Board of Canada. 1976 Jun 1;33(6):1303-11.
55. Oruc EO, Sevgiler Y, Uner N. Tissue-specific oxidative stress responses in fish exposed to 2, 4-D and azinphosmethyl. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology. 2004 Jan 1; 137(1):43-51.
56. Pickering QH, Henderson C. Acute toxicity of some important petrochemicals to fish. Journal (Water Pollution Control Federation). 1966 Sep 1:1419-29.
57. Phipps GL, Holcombe GW, Fiandt JT. Acute toxicity of phenol and substituted phenols to the fathead minnow. Bulletin of environmental contamination and toxicology. 1981 Jan 1;26(1):585-93
58. Ruesink RG, Smith JR LL. The relationship of the 96-hour LC50 to the lethal threshold concentration of hexavalent chromium, phenol, and sodium pentachlorophenate for fathead minnows (Pimephales promelas Rafinesque). Transactions of the American Fisheries Society. 1975 Jul 1; 104(3):567-70.
59. Stephenson RR. Effects of water hardness, water temperature, and size of the test organism on the susceptibility of the freshwater shrimp, Gammarus pulex (L.), to toxicants. Bulletin of environmental contamination and toxicology. 1983 Oct 1;31(4):459-66.
60. Stoilova I, Krastanov A, Stanchev V, Daniel D, Gerginova M, Alexieva Z. Biodegradation of high amounts of phenol, catechol, 2, 4-dichlorophenol and 2, 6-dimethoxyphenol by Aspergillus awamori cells. Enzyme and Microbial Technology. 2006 Sep 4;39(5):1036-41.
61. Tallur PN, Megadi VB, Ninnekar HZ. Biodegradation of p-cresol by immobilized cells of Bacillus sp. strain PHN 1. Biodegradation. 2009 Feb 1;20(1):79-83.
62. Tatem HE, Cox BA, Anderson JW. The toxicity of oils and petroleum hydrocarbons to estuarine crustaceans. Estuarine and Coastal Marine Science. 1978 Apr 1;6(4):365-73.
63. Verma SR, Rani S, Dalela RC. Synergism, antagonism, and additivity of phenol, pentachlorophenol, and dinitrophenol to a fish (Notopterus notopterus). Archives of environmental contamination and toxicology. 1981 May 1;10(3):365-70.
64. Verma SR, Rani S, Tyagi AK, Dalela RC. Evaluation of acute toxicity of phenol and its chloro-and nitro-derivatives to certain teleosts. Water, Air, and Soil Pollution. 1980 Jan 1;14(1):95-102.
65. Zhong W, Wang D, Xu X, Luo Q, Wang B, Shan X, Wang Z. Screening level ecological risk assessment for phenols in surface water of the Taihu Lake. Chemosphere. 2010 Aug 1;80(9):998

Cite of article: Gaur V, Mathur A; Determination of lc_{50} of phenolic compounds (phenol & m-cresol) for a fish, *labeo rohita* . Int. J. Med. Lab. Res. 2019, 4(1):55-63

CONFLICT OF INTEREST: Authors declared no conflict of interest
SOURCE OF FINANCIAL SUPPORT: Nil