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Review article

NONYLPHENOL : ITS TOXIC EFFECTS ON AQUATIC ORGANISMS

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ABSTRACT : Nonylphenol (NP) is analkylphenolic compound classified as an endocrine disrupter capable of interfering with the hormonal system of different aquatic organisms. It is mainly originated from degradation of Nonylphenol Ethoxylates. Due to its physical and chemical characteristics, it is persisted in sewage sludge and river sediments. In river water and sediments the concentration of NP is 4 µg/l and 1 mg/kg, respectively. The fate and occurrence of NP in the environment is clearly correlated with different anthropogenic activities like wastewater treatment, land-filling and sewage sludge recycling. Different types of aquatic vertebrates and invertebrates are trashily affected by the NP. The impact of the NP on the fish as follows: decrease in male fertility, altered sex ratio, reducing hatching rate. Also different types of alteration are occurred in haematological, biochemical and histopathological parameters. Due the bioaccumulation properties the human beings are dangerously affected by the NP.

Key words : Nonylphenol, toxic effects, aquatic organisms.

INTRODUCTION

Nonylphenol [4-(2, 4-dimethylheptan-3-yl) phenol] (NP) is a xenobiotic alkylphenolic compound which is used in the manufacturing of antioxidants, detergents, emulsifiers, solublizers, lubricating oil additives and herbicides etc. During alkylation process of phenol it is synthesised (OEHHA, 2009). NP is mainly used as surfactants which are composed of phenol bearing a 9 carbon-tail. Another major source of NP in the environment is the discharge of effluents from the sewage treatment plants (Soares *et al*, 2008). The major degradation product of Nonylphenol polyethoxylate (Nonylphenol) is gained significant environmental concern due to their estrogenic effects (Carrera *et al*, 2006).

Nonylphenol is a static compound with a boiling point between 293-297^{0}C and a melting point between -8 to 2^{0}C. The molecular formula for NP is $C_{15}H_{24}O$ and the chemical has a molecular weight of 220.35. Appearance of NP is light yellow and viscous liquid with phenolic smell Solubility of NP in water is very low near about 6mg/l at pH 7. The octanol-water partition coefficient (log K_{ow}) of NP is 4.48 so that the compound no readily soluble in the water, therefore it partitions favourably with the organic matter. When the pH becomes more alkaline then solubility of NP increases in the water. However, NP is easily dissolved in a various organic solvents. The compound has very low mobility and its capacity for spreading in the aqueous phase of soil and sediments is limited. It is semi-volatile organic compound having a capacity of water/air exchange. Henry's law constant of NP are 2.07×10^{-2} Pa and 8.39×10^{-1} Pa m^3/mol, respectively (Soares *et al*, 2008).

The compound is moderately soluble in the water and the half-life is more than 60 years. In aquatic environment the detection level of NP is 0.7 µg/l to 15 µg/l and in soil sediment 1 mg/kg respectively (Soares *et al*, 2008). Recently, NP gains much more attention due to its eco-toxicological consequence on the aquatic environment and its potential role as an endocrine disruptor and xenoestrogen due to its ability to act with estrogen like activity (Mergel and Maria, 2013).

FATE AND SOURCES OF NONYLPHENOL IN ENVIRONMENT

In surface water, sediment, ground water, soil and air the fate on NP is controlled predominantly by its physical and chemical properties and this in turn calibre its degradation. NP is a semi-volatile compound with the capacity of water-air exchange. Initially, it reaches to

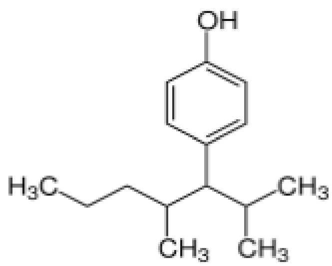

Fig. 1 : Structure of Nonylphenol [4-(2,4-dimethylheptan-3-yl)phenol] (NP)[$C_{15}H_{24}O$] (Soares *et al*, 2008).

the atmosphere then through the wet deposition it is transported to the aquatic and terrestrial environment. It is a photo degraded compound therefore, it can be degraded by the sun light in surface layer of water but its estimated half-life is more than 60 years in sediments. Through the action of aerobic and anaerobic microorganisms, biodegradation of NP can be achieved but it is restricted to oxygen supply. Under environmental condition microorganisms have been used to stimulate the outcome of nonylphenol. The degradation rate of (from high to low) NP through anaerobic microorganism is: sulphate reducing conditions > methanogenic conditions > nitrate reducing conditions (Soares *et al*, 2008).

Occurrence of from Sewage Treatment plants

Treatment of nonylphenolic compounds is a very authentic factor in the prediction of the environmental fate of these compounds. Bench- scale experiments and batch tests have been widely performed to assess the behaviour of NP. The concentration of NP in municipal treatment plant effluents is more than 1 µg/l (OEHHA, 2009). Soares *et al* (2008) explained that temperature and oxygen are also very important factors in the fate of nonylphenol which has been demonstrated in the bench-scale activated sludge system. Analytical works on full-scale sewage treatment resulted frequent occurrence of NP as stable intermediate in sewage sludge with heavy load in treated industrial waste water or from urban area of higher population density. In same studyit was pointed out that 60-65% of the NP compounds of STW were released into the environment in the form of 19% nonylphenol carboxylate, 11% short nonylphenolethoxylates (1 and 2 ethoxylate group), 25% nonylphenol and 8% untreated compounds. In associated form with the sludge, NP was mainly released. The important pathway for NP removal from waste treatment plant is sorption of the sludge solids (Soares *et al*, 2008).

Exposure of Nonylphenol in river waters, estuaries, sediments and oceans

The concentration of nonylphenol is 0.89 µg/l, 1 µg/l, and 2.76 µg/l in freshwater, municipal treatment plant effluent and coastal water respectively. NP is deposited and persisted in sewage sludge, river sediments and other environmental compartments due to its physical and chemical properties. The fate of NP in aquatic environment is mainly correlated with the anthropogenic activities like waste water treatment, land filling and sewage sludge recycling (OEHHA, 2009). In most Asian countries the concentration of NP is very high in aquatic environment. In aquatic environment main sources of NP are domestic waste water, industrial waste water as well as surface run off. In the affected river the spatial variation of NP mainly depends on the distribution and properties of pollution sources. In aquatic environment, high concentration of NP is due to inadequate treatment of domestic waste water. The Kaoping River's tributaries were polluted with NP due to improper treatment of waste water which caused high risk in downstream of the river (Chen *et al*, 2010). Zhang *et al* (2009) found in their experiment that the main discharge point of NP in Jialu River was Zhenghou city from where the annual discharge of NP was 726 kg, which increased the NP level of this river up from 75.2 ng/l to 1520 ng/l (Zhang *et al*, 2009). Soares *et al* (2008) found that different types of factor such as temperature, flow rate, sedimentation rate, particle size, microbial activity etc. which affected the variation of NP in surface water. In summer season the microbial activity got increased which enhanced the degradation of nonylphenol ethoxylate (Soares *et al*, 2008). Mao *et al* (2012) reported that in summer season the NP also came from detergent, shower cream and plastic ware because in this season the use of those commodities was more than any other season.

Mao *et al* (2012) also reported that due to hydrophobic properties, NP of surface water got deposited in sediments which caused a preferential accumulation in sediment. The concentration of NP in sediments is more than 1mg/kg (Soares *et al*, 2008). According to Mao *et al* (2012) concentration of NP is 119, 100 µg/kg in Donghu Lake of China, which is referred as most contaminated sediment. Gong *et al* (2011) found that there was a positive correlation between NP and total organic carbon (TOC) of the sediment. In present condition some areas of Europe the concentration of NP in sediments were very high, like the maximum concentration of NP was 2830/kg in the sediment of Danube River (Miciæ and Hofmann, 2009). The NP concentration is more in the sediment of developing countries than the developed countries which is seen in Table no. 2 (Mao *et al*, 2012).

Occurrence of Nonylphenol in soil

According to CCME (2002) and Vikelsoe *et al* (2002) the occurrence of NP in soil is closely related with anthropogenic activities like as sewage sludge application, landfilling and accidental spillage. The activity that has gained much more attention is sewage sludge recycling to agricultural land. Jensen and Jepsen (2005) & Langford and Lester (2002) reported that according to a Danish study 66% of the total production of sewage sludge was recycled by the farmers in 2002 which raised the importance of investigating the occurrence and fate of contaminants such as NP. Falkenberg *et al* (2003) and Vikelsoe *et al* (2002) reported that the elevated concentration of NP have been found in soils exposed to high addition of sewage sludge (1.4-1.6mg/kg) and points of run-off (34-14 µg/kg) than unamended soils or soils fertilized with manure or with limited amounts of sewage sludge (0.01-0.98 µg/kg). According to Oman and Hynning (1993), NP has also been found in landfill leachates that were approaching anaerobic condition at concentrations ranging from <10 to 170 ìg/l. The occurrence of nonylphenol in soil is influenced by various factor such as: biodegradation, sorption and volatilization (Soares *et al*, 2008). He also reported that the rate of biodegradation mainly depends on bioavailability of NP to the soli microflora and availability of oxygen. Hollrigl-Rosta *et al* (2003) reported thatin dissolved organic matter (DOM) through non-specific lipophilic interactions NP conjugates with humic acid strongly which is fully regulated by the diffusion and are not completely reversible. They also reported that often stronger sorption is observed at pH value near the pK_a that's maximized interactions with soil matrix. Trocme *et al* (1988) found that the volatilization rate of NP from soil is very minimum. During a 40 days period of time volatilization rate of NP is 0.22% of 1g nonylpheno l/kg of soil. Vogel *et al* (2000) also found that the mobility of NP is very less in soil and consolidated with the soil particles. Almost 99% of the contaminant was found within 30 cm of the surface of soil after 730 days.

Availability of NP in groundwater

The appearance of NP in aquifers is relatively attached to anthropogenic activities like as the discharge of STW effluent with concentrations averaging 790ng/l (Barber *et al*, 1988), in the vicinity of contaminated rivers 0.1-0.8mg/l (Ahel *et al*, 1996; Zoller *et al*, 1990), septic systems 1.2g/l (Rudel *et al*, 1998) but can also be due to agricultural activities 0.16-0.38 ìg/l (Latorre *et al*, 2003), landfill leachate and the discharge of industrial waste water <100-280ng/l (Ahel *et al*, 1991; Langwaldt and Puhakka, 2000) analysed that usually the removal of contaminants is very slowin ground water because the chemical and biological characteristics in aquifers are not suitable for degradation. Soares *et al* (2008) determined that the temperature of groundwater is in psychrophilic range and both the carbon sources and oxygen are limited that's why the microbial degradation rate of NP in groundwater is very slow. Ahel *et al* (1996) reported that occurrence of NP in groundwater is mostly affected by the variation in temperature. He also reported that during winter season the highest concentrations are observed. Montgomery-Brown *et al* (2003) found that the availability of oxygen is a very important factor during the permeation of NP to the aquifers.

Another important factor is hydrological characteristics of the sites. Prompt infiltration is observed at sites with highly permeable sediments. Mass transfer of NP is very low due to its low solubility (Barber *et al*, 1988) but its sorption is monitored by the organic carbon content of the sediment (Zoller *et al*, 1990).

Availability of NP in atmosphere and air

Dachs *et al* (1999) reported that in late 1990s first measurement of NP was initiated where the sample was taken from urban and coastal environment and found that unexpectedly high concentration on nonylphenol (2.2-70 ng/m^3) which mainly exceeded those of PCBs and PAHs. In another study Cincinelli *et al* (2003) found that NP in atmosphere was directly correlated with anthropogenic activities such as the operation of STW. Fries and Puttmann (2004) analysed that NP becomes conjugated with the aerosols produced by the aerator of the sewage treatment plants which lead to a decrease in air quality in the surrounding of the STW. They also found that through the wet deposition (rain and snow) the atmospheric NP can be returned to aquatic and terrestrial environment. In same study they also reported NP was found in the rain and snow of urban, suburban and rural area in Germany and Belgium where concentration of NP in rain water varied with the region of sampling such as: suburban areas-0.534 $\mu g/dm^3$, urban area-0.062 $\mu g/dm^3$ and rural area-0.099 $\mu g/dm^3$ respectively. Rudel *et al*. (2003) determined that in snow sample the mean value was found around 0.242 $\mu g/dm^3$, with higher value in the urban area 0.478 $ìg/dm^3$. They also found that NP has been identified in indoor environments in air and dust at concentration higher than outdoor value (air-110 ng/m^3 and dust-2.58 ìg/g). Soares *et al* (2008) reported that the occurrence and the fate of NP in the atmosphere are of considerable important.

Availability of NP in drinking water

Soares *et al* (2008) reported that Nonylphenol is identified in river water, ground water and other source of portable water at relatively high concentrations.

Table 1 : Distribution of nonylphenol in sewage water treatment (SWT).

Country	STW sampled	Sample source and NP concentration	Reference
Switzerland Germany	30	Sludge anaerobically stabilized:450-2530mg/kg Sludge aerobically stabilized:80-500mg/kg	Giger *et al* (1984)
Finland	29	Sludge anaerobically stabilized:640-2200mg/kg	Brunner *et al*.,1988
Switzerland	11	Primary effluent:43.5 ìg/l	Ahel *et al*.,1994a
Germany	149	Sludge:128.2mg/kg	Jobst,1995
Japan	40	Primary effluent:Nd Secondary effluent:0.35 ìg/l Final effluent:0.2 ìg/l	Fujita *et al*.,2000
USA	1	Sludge anaerobically stabilized:754mg/kg Heat treated sludge:496mg/kg Limed sludge:470mg/kg Composted sludge:64mg/kg	La Guardia *et al*., 2001
Italy	1	Sludge before anaerobic digestion 242mg/kg Sludge anaerobically stabilized:308mg/kg	Bruno *et al*.,2002
USA	1	Sludge anaerobically stabilized 1100-1800mg/kg	Pryor *et al*.,2002
Spain	2	Raw effluent:<1.5 ìg/l Primary effluent:1-2.3 ìg/l Final effluent:5.5-6.6 ìg/l	Farre *et al*.,2002
UK	1	Raw effluent:<0.02-0.1 ìg/l Final effluent:32-63 ìg/l	Sheahan *et al*.,2002
China	1	Final effluent :1.5 ìg/l Final sludge:0.0195mg/kg	Shao *et al*.,2003
Norway	17	Final effluent:0.05-1.31 ìg/l	Johnson *et al*.,2005
Japan	5	Raw effluent:0.1-0.9 ìg/l Final effluent:0.5-1.1 ìg/l	Nakada *et al*.,2006

Soares *et al* (2008).

Berryman *et al* (2004) found that in waste water treatment plants removing of NP was found to be very highly variable ranging from 11% to 99%. Petrovic *et al* (2003) observed that ozonation and activated carbon filtration with chlorination were able to remove 95 % of NP. They also found that concentration of NP in treated drinking water varied from 85 ng/l in Spain to 15 ng/l in Germany. Shao *et al* (2005) determined that in major city of south-western China, the NP removal rate of water treatment plant varied from 62% to 94%. In present condition the Drinking Water Safety has received significant attention to the NP concentrations in potable sources of water (Mao *et al*, 2012).

ORIGIN OF NP

Nonylphenol is an alkylphenolic compound consisting of a phenol ring and a nine-carbon chain on the para position (Fig. 1) (Soares *et al*, 2008). In normal condition, it is a viscous liquid with a light yellow colour and do not get mixed with the water. In industry during alkylation of phenol, the compound is produced. More than 22 isomers of 4-substituted monoalkylphenols are composed in final mixture (Thiele *et al*, 2004; Wheeler *et al*, 1997). Servor *et al* (2003) found that the direct discharge of NP was estimated to be 0.5% (96 tons)from the industrial sector in Canada (Servor *et al*, 2003).

However, the major source of NP to the environment is the degradation of Nonylphenolethoxylates (NPE) (Langford and Lester, 2002). In the chemical structure of an ethoxylate chain is present which follows a poisson distribution (Hager *et al*, 1998). Shao *et al* (2003) and Soares *et al* (2005) found that whenever the number of ethoxylate group got decreased, the recalcitrance of the compound got increased. Langford *et al* (2005 a,b); Mann and Boddy (2000) observed that the biodegradation of Nonylphenol ethoxylate in fundamental bench-scale study resulted in production of more recalcitrant compound than the parent compound. These products include nonylphenol di-ethoxylate (a major product) and mono ethoxylateas well as the carboxylic form of this compound. Corsi *et al* (2003) and Koh *et al* (2005) reported that no bench-scale study has been referenced to identify NP as a product of aerobic degradation of NPE but the field studies reported

Table 2 : Distribution of NP in river, ocean, estuaries and sediments in different countries.

Country	NP concentration	Reference
USA	River water:<1 ìg/l River sediments:<3000mg/kg	Naylor *et al*.,1992
Switzerland	River water:0.015-2.25 ìg/l River sediment:3520mg/kg	Ahel *et al*.,1994b
Canada	Lake and river water:0.01-0.92 ìg/l River sediment:0.17-72mg/kg	Bennie *et al*.,1997
Italy	River water:158 ìg/l	Davi and Gnudi 1999
Portugal	River and ocean water:<10 ìg/l	Azevedo *et al*.,2001
Germany	River water:0.0007-0.0044 ìg/l Estuaries:<0.03 ìg/l Marine sediment:0.01-0.153mg/kg	Bester *et al*.,2001
Japan	River water:0.051-1.08 ìg/l River sediment:0.5-13mg/kg	Isobe *et al*.,2001
Spain	River water:15 ìg/l River sediment:0.022-0.645mg/kg Ocean water:0.15-4.1 ìg/l Ocean sediment:0.008-1.05mg/kg	Petrovic *et al*.,2002a,b
Holland	Estuary water:0.031-0.934 ìg/l Estuary sediment:0.0004-1.08mg/kg	Jonkers *et al*.,2003
Korea	River water:0.0232-0.1876 ìg/l River sediment:0.0254-0.932mg/kg	Li *et al*.,2004
China	Lake water:1.9-32.8 ìg/l Lake sediment:3.5-32.4mg/kg	Wu *et al*.,2007

Soares *et al* (2008).

the occurrence of NPE in well-aerated environment which hinders the process of degradation of NPE in bench scale experiment. Temperature is also a strong stimulator in the process of biodegradation of NPE (Manzano *et al*, 1999). In same study it was found that the biotransformation of these compounds is 2-10 times higher at 22.5^{0}C than at 13^{0}C. The degradation of NPE in anaerobic condition is very scarce (Scrimshaw and Lester, 2002). Soares *et al* (2005) reported that NP is the major product of degradation; it does not undergo further transformation and is sharply adsorbed onto the sludge solids.

TOXICOLOGICAL EFFECT OF NP ON DIFFERENT AQUATIC ORGANISMS

In the environment NP is a virtually ubiquitous contaminant. The occurrence of NP has been reported all over the world in water, sediment, air and soil (Mao *et al*, 2012). NP is very toxic to wide variety of marine and freshwater vertebrate and invertebrate species. Its toxicity mainly affects the reproductive system and endocrine system. It also affects growth, behaviour, respiration and osmoregulation. It has been found that NP affects various indicators of reproduction in aquatic organisms at concentration ranging from 0.13ìg/l up to the mg/l range (OEHHA, 2009).

Haematological indices

According to Satyanarayanan *et al* (2011) when *Clarias gariepinus* was exposed to 250 µg/l concentration of NP, the levels of haemoglobin (Hb) and haematocrit (HCT) got significantly increased ($p<0.05$). It also has been found that when the dose was increased up to 750 µg/l then the level of Hb and HCT got drastically reduced.

Satyanarayanan *et al* (2011) found that a significant increase ($p<0.05$) in RBC count was occurred in NP treated *Clarias gariepinus* (250 and 500 µg/l). In other hand when the concentration of NP was increased up to 750 µg/l then the RBC count considerably got decreased, showing a higher decrease at 1000 µg/l NP exposure.

With respect to the WBC count, Satyanarayanan *et al* (2011) noted that, irrespective of the toxicants and their concentration, there was a gradual significant increase throughout the experiment.

During their experiment Sayeda and Hamdy (2018) observed occurrence of apoptosis in the erythrocytes of the NP treated fish sample *Clarias gariepinus*.

Biochemical indices

Satyanarayanan *et al* (2011) found that the level of total serum bilirubin was significantly higher in all the concentrations of NP in *Clarias gariepinus*. The maximum increase of total serum bilirubin was found in 1000 ìg/l concentration of NP.

According to Satyanarayanan *et al* (2011) the toxic effect of NP asserted a reduction in the level of serum protein in the body of *Clarias gariepinus*. The maximum reduction of serum protein occurred in the 1000 ìg/l concentration.

On the other hand Satyanarayanan *et al* (2011) found that the level of serum glucose significantly increased at all the concentrations of NP in *Clarias gariepinus*, showing the lowest increase at 250 µg/l and the highest increase at 1000 µg/l.

Schwaiger *et al* (2000) found a highly significant elevation of the mean corpuscular volume (MCV) and mean corpuscular haemoglobin (MCH) in juvenile Common carp (*Cyprinus carpio*). They also found that the corpuscular haemoglobin concentration (MCHC) got significantly decreased.

Table 3 : Effect of NP on different fish species.

Species	**Exposure (ìg/l)**	**Effect**	**Reference**
Flounder (*Psetta flesus*)	333	↑ vitellogenin (an egg yolk precursor protein levels expressed in female fish)	Kirby *et al*.,2007
Cod (*Gadus morhua*)	30	↓ glucuronidation of estradiol	Martin-Skilton *et a*l., 2006
	29	↑ plasma vitellogenin	Larsen *et al*., 2006
Medaka (*Oryzias latipes)*	5.4	↓Hepatic vitellogenin levels (♂)	Ishibashi *et al*.,2006
	61	↓ Fecundity & fertility,	
	30-100	↑ female/male ratio, mixed sex characteristics	Balch and Metcalfe, 2006
	101	↓ reproduction	Kang *et al*., 2003
Rainbow trout (*Oncorhynchus mykiss*)	0.28-0.75	↓ embryo development & survival	Lahnsteiner *et al*., 2005
	0.13	↓ semen volume	
	1.05	↑ liver vitellogenin	Ackermann *et al*., 2002
	10.2	↑ liver zona radiate protein	
	6	↑ liver vitellogenin	Thorpe *et al*., 2001
Tilapia (*Oreochromis mossambicus*)	10-100	↓thymidine uptake in cartilage	Ng *et al*., 2001
Fathead minnow *(Pimephales promelas)*	10	Vitellogenin induction	Pickford *et al*., 2003
Zebrafish *(Danio rerio)*	10-100	↑ Female/male ratio, ↓ swim-up	Lin and Janz, 2006
	17.7	↓ population growth	Lin *et al*., 2005
	39-100	Ovatestes @ 60 days, not after100-day recovery	Hill and Janz, 2003
	100	↓ / ratio ↓ % viable eggs, hatchability, and swim-up	
	500	↓ Gonadosomatic index	Yang *et al*., 2006
Atlantic salmon *(Salmo salar)*	5-50	↓ brain p450 aromatase B mRNA ↑ zonaradiata protein mRNA ↑liver & brain ER á, ↓VTG	Meucci and Arukwe, 2006
	15-50	↑ VTG in plasma & mucus	
Platyfish *(Xiphophorus maculates*)	80	Hypertrophied Sertoli cells & efferent duct cells. ↓cysts of spermatogenetic cells	Kinnberg *et al*., 2000
	14	↓ gonad development, ↑ spermiogenesis,	Magliulo *et al*., 2002
Swordtail *(Xiphophorus helleri)*	100	Testicular necrosis	Kwak *et al*., 2001
	0.02	↓ sword length	
Sea bream	200 ìg/kg bw	↓ kidney Na+,K+-ATPase, ↓ plasma osmolality	Carrera *et al*., 2007
Fathead minnow *(Pimphales promelas)*	14 (NOE = 7.4)	↑ fry survival	USEPA, 2005
Atlantic salmon (*Salmo salar*) smolts	10 100	↓ plasma cortisol Loss of osmoregulatory control	Lerner *et al*., 2007
	10	↓ gill (Na+, K+-ATPase) ↑ preference for & tolerance of seawater	Lerner *et al*., 2007a

OEHHA (2009)

Histopathological indices

According to Schwaiger *et al* (2000) severe morphological alterations occurred in the kidney, liver, gill and spleen during experiment. They also found that the kidney lesions consisted in extensive haemorrhages within the kidney tubules, Bowman's space and in renal

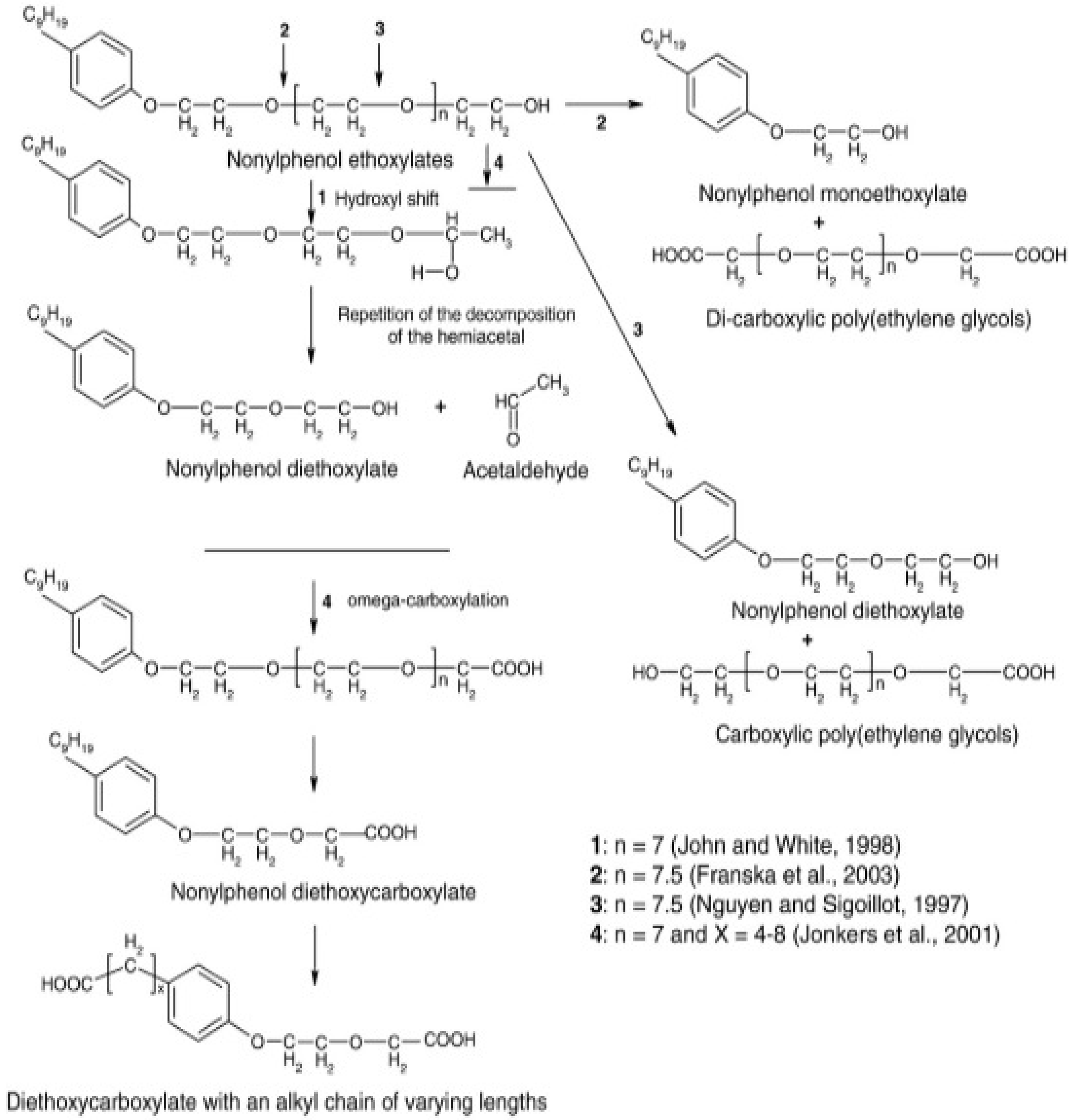

Fig. 2 : Proposed pathways of aerobic degradation of Nonylphenolethoxylate (Soares *et al*, 2008).

interstitium. Hypertrophy, degenerative and necrotic changes were found in the tubular epithelia. Eosinophilic material was found to be accumulated in the renal tubules and in the sinusoids of the head kidney. Hypertrophy of the hepatocytes was found in liver. Schwaiger *et al* (2000) also observed the enlargement of the cell nuclei and reduction of glycogen deposits in the liver.Haemorrhages, a massive proliferation and hypertrophy of reticuloendothelial cells were also found in the spleen.

According to Amaninejad *et al* (2018) no histological changes were found in the ovaries of control fish when the fish sample (koi carp) were exposed to 10-50ìg/l then loaded of oocytes in different vitellogenic stages and late vitellogenesis were decreased. A reduction in size of the growing vitellogenic oocytes, ova damage and irregular shape of ovum with rupture of follicular layer were also found when the fish sample (koi carp) was exposed in 100 µg/l NP concentration. A large extended sperm duct loaded with spermatozoa and seminiferous lobules with different amounts of spermatozoa were detected when the fishes (koi carp) were treated with 50 µg/l NP. In that experiment it was also found that a decrease in spermatid and spermatozoa, degeneration of leydig cells and atrophy of testis cells occurred in the fish (koi carp) treated with 100 µg/l NP. Necrosis, degeneration, psychosis, sedimentation of cytoplasmic materials and cytoplasmic vacuolization of hepatic parenchyma were observed in the liver of all treated fish. Mucus cell hyperplasia and epithelial lifting were also observed in the gill of all treated fish in that experiment.

Sayeda and Hamdy (2018) observed some histopathological alteration in the liver of treated fish sample (*Clarias gariepinus*) such as vacuolization of

Table 4 : Effects of on different invertebrates species.

Species	**Exposure (ìg/l)**	**Effect**	**Reference**
Killifish *(Fundulus heteroclitus)*	65	↑ liver vitellogenin mRNA	Garcia-Reyero *et al*., 2004
Worm (*Tubifex tubifex*)	610 ìg/g sediment	Surviving adults had empty spermatheca if present, ovocytes do not developed	Bettinetti and Provini, 2002
Pond snail (*Lymnaea stagnalis*)	105-124	↓ egg masses, ‘! embryo mortality, delayed development	Lalah *et al*., 2007
Freshwater mud snail (*Potamopyrgus antipodarum*)	100	↓ fecundity	Czech *et al*., 2001
Zebra mussel *(Dreissenapoly morpha)*	500	↑ vitellogenin	Quinn *et al*., 2006
Sea urchin *(Para-centrotus lividus)*	0.27	↓ fertilization (sperm toxicity EC50)	Ghirardini *et al*., 2001
Daphnia magna	40 25,50	↓fecundity Altered sex ratio	Brennan *et al*., 2006 Zhang *et al*., 2003
Rotifer *(Brachionus calyciflorus)*	>0.59 ì M (130 ìg/L)	↓ population growth	Radix *et al*., 2002
Mussel *(Mytilus sp)*	228	Hemocytelysomal membrane de-stabilization	Canesi *et al*., 2007
Algae *(Isochrysis galbana)*	1000	Absence of photosynthesis	Correa-Reyes *et al*., 2007
Oyster *(Crassostrea gigas)*	1-100	↓ sperm motility	Nice, 2005
Copepod *(Eurytemora affinis)*	3	Delayed development	Forget-Leray *et al*., 2005

OEHHA (2009).

hepatocytes, congestion in vein and necrosis. They also found the depletion of glycogen content in the cytoplasm of the hepatocytes.

Chitra and Sajitha (2014) assessed the effect of Bishphenol-A in the fish species *Oreochromis mossambica* for 20 days and they found upliftment of gill epithelium, gill lamellar fusion and hypertrophy and vasodialation in secondary lamellae.

Enzyme essay

Oxidative stress is a normal phenomenon in the body, and various enzyme systems are involved in maintaining redox homeostasis. On the other hand, endogenous and exogenous substance can alter biochemical homeostasis, thus continuously rising reactive oxygen species (ROS) levels much higher than the detoxifying (antioxidant enzyme or non-enzymatic scavengers) capability of tissues. Oxidative stress is often defined as an imbalance of pro-oxidants and antioxidants (Satyanarayanan *et al*, 2011).

Ecological toxicity of NP was examined on the *Clarias gariepinus* to study the biochemical responses including changes in the activity of Aspartase Transaminase (AST) and Aka alanine Amino transferase (ALT). The results showed that the activity of AST and ALT found to be increased in 250 to 500 µg/l NP concentration. On the other hand the activity of AST and ALT were found to be decreased in 750 to 1000 µg/l NP concentration (Satyanarayanan *et al*, 2011).

Chitra and Sajitha (2014) assessed the effect of Bishphenol A in the *Oreochromis mossambica* and they found a significant decrease in the activities of Super oxidase dismutase (SOD), Catalase (CAT) and Glutathione-S-transferase (GST).

Sayeda and Hamdy (2018) observed the antioxidant activity response in *Clarias gariepinus* to NP exposure. Fish samples (*Clarias gariepinus)* were exposed to different concentrations of NP for 15 days. Results showed thatactivity of GST, CAT, SOD and Ache (Acetyl cholinesterase) was significantly decreased.

Xiao *et al* (2007) exposed the fish sample (*Paralichthys olivaceus*) to 40 µM concentration of NP. They found that the activity of SOD and CAT got increased within 2 hours but after 4 hours the activity of both enzymesgot significantly decreased.

According to Carrera *et al* (2006), the activity of CAT and GST was inhibited very badly in the body of sea bream (*Sparus auratus*) during their 10 days exposure.

Li *et al* (2008) assessed the effects of Bisphenole-A in the freshwater snail (*Bellamya purificata*) in 15 days exposure. They found that the activity level of GST was significantly lower in the body of treated snails.

Physico-chemical parameters of water are critical for the optimum physiological response and wellbeing of aquatic organisms, especially fish. Poor water quality due to contamination can affect the growth, reproduction and survival of fish species. It may even lead to diseases. In general when there is depletion or deficiency in some of the water quality parameters like the dissolved oxygen, pH, temperature and alkalinity, the fish may face survival challenges (Datta *et al*, 2017). In West Bengal sewage feed aquaculture has increased day by day. Sometimes sewage water is contaminated by different alkylphenolic compounds like, Nonylphenol, Octylphenol, Bishphenol-A etc. These compounds are very toxic to the aquatic environment and also terrestrial. These compounds have diverse effects on aquatic organism up to consumer level. So as a consequence most emerging alkylphenolic compound i.e, Noylphenol is selected to evaluate its toxicity level Nonylphenol. (2019, March 09). Retrieved March 09; 2019, fromhttps://en.wikipedia.org/wiki/Nonylphenol].

Labeo rohita is an important species of carp family. It is a column feeder omnivore species. In West Bengal most culturable species is *L. rohita* among the carps. The commercial value of this species is very high. It is also the most favourable species to the consumer. Due to being column feeder the *L. rohita* is affected by Noylphenol. In the surface of the water NP is degraded by the sunlight but in mid-level of the water body, NP is not easily degradable by the sunlight. If this species is affected by the NP, the freshwater aquaculture production of West Bengal may totally damage [Nonylphenol. (2019, March 09). Retrieved March 09; 2019, fromhttps://en.wikipedia.org/wiki/Nonylphenol].

CONCLUSION

The present study shows that the main source of NP is sewage treatment plant. Positive findings of NP have been reported in sediments, atmosphere, ground water and drinking water. The ground water and drinking water mainly contaminated by landfill leachates. The present study also shows that different types of adverse biological effects were observed in various aquatic organisms. The alteration occurred in histopathological, biochemical and haematological parameters. NP is a very common and virtually ubiquitous contaminant in the environment. The fate and occurrence of NP has been reported around in waters, sediment, airs and soils. The amount of NP in environment and sewage treatment can be decreased through the action of aerobic and anaerobic biodegradation. Although, NP is present at low concentrations, the risks of long-term exposure to low concentrations remain largely unknown. Purification or removal techniques such as ozonation or membrane filtration are able to remove contaminations of NP efficiently from drinking water, surface water or even from municipal sewage effluents. But more research needs to be done to determine the potential human and environmental health risks posed by exposure to NP in the environment.

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