Aquatic pollution and fish reproduction: a bibliographical review

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ABSTRACT
The present review reveals that most of the extant work on the effect of aquatic pollution on fish reproduction pertain to the changes in percentage gonadal weight and structural changes in the reproductive system in majority of the fishes studied. Effect on hormonal titres and synthesis has been worked out in only few species. From these studies, it is apparent that aquatic pollution retards the reproductive processes in both sexes by impairing the gonadal development, inhibiting the maturation of spermatocytes and oocytes, delaying ovulation, breaking and clumping of yolk material in oocytes and suppressing the synthesis of gonadal steroids via hypothalamo-hypophysial-gonadal axis. Ultrastructural studies are lacking. No fish group, other than teleosts, majority being freshwater, has been attempted so far. Most of the extant work are confined to Channa (Ophiocephalus) punctatus, Heteropneustes fossilis, (Saccobranchus), Sarotherodon (Tilapia) mossambicus, Clarias batrachus and Colisa (Trichogaster) fasciatus.

Introduction
Modern agricultural practices, even though contributed to enhance the crop production, also widely polluted the aquatic environment (Pandey et al., 2000). The industrial effluents and urban sewage released into rivers directly after little or no treatment have added to the problem. Increasing pollution of rivers and other water bodies has become a matter of great concern in recent years (Dikshith et al., 1990). Further, fishes, though non-target organisms, are also affected and the accumulated toxicants may reach human being as they form a staple food for them.

There have been few attempts to study the influence of aquatic toxicants on the fish reproduction. Fish reproduction is affected by the direct or indirect exposure to aquatic pollution (Kime, 1995). It is understood that the reproduction is basic to the survival of the maximum number of young and, hence the success of the fish species. Therefore, in this review, influence of aquatic pollutants on the reproductive systems is considered.

Impact on male reproductive system
Gonads of teleosts, unlike those of other vertebrates, lack medullary tissue. Therefore, the gonads of teleosts correspond only to the cortex of other vertebrates. In most teleosts, the testes are paired and elongated organs attached to the dorsal body wall and in some they are combined into a single
The teleost testis, as in mammals, is composed of steroid hormone-secreting endocrine interstitial cells and sperm-producing lobular or tubular compartments (Nagahama, 1983).

Available information show that few studies have been conducted on the effect of aquatic pollution on the reproduction in males. Pandey and Shukla (1980) have shown that BHC exposure produced vacuolated cells and necrosis in the seminiferous tubules (ST), atrophy of interstitial Leydig cells (LC), thickening of sperm duct wall and decreased secretory activities and gonadosomatic indices in tilapia. Acidophilic granular cells of chromatophore degeneration and focal leucocyte aggregation have been reported in the testes of eleven species of fishes collected from petroleum production sites in the Gulf of Mexico. Status of the spermatogenic cycle at the time of collection correlated well with the known spawning times for the respective species with one exception. No evidence of adverse effect on testes morphology was found (Stott et al., 1980).

Abnormal structural changes viz. greatly vacuolated cells in ST and disintegration of lobules, arrested spermatogenesis at spermatid stage, necrotic LC, fibrosis and thickening of sperm duct wall, and reduced GSI have been observed in tilapia following treatment with malathion (Pandey and Shukla, 1982). Long term exposure to carbamid caused development of abnormal lobular architecture, dissolution of germinal epithelium, scattered LC with homogeneous liquified cytoplasm, prominent vacuolization and necrosis during preparatory and maturing phase. However, no such significant changes were observed during spawning and postspawning phases (Shukla and Pandey, 1984). Exposure to dimecron elicited atrophy of ST, sperm mother cells and spermatocytes, reduction in GSI, thickening of sperm duct and enlargement of LC (Lakhani and Pandey, 1985).

Thiourea-induced reduction in the GSI and increased level of cholesterol in Gara mulya have been reported by Wani and Latey (1984). Treatment with dimecron and carbofuran has been shown to lower GSI, cause necrosis of spermatogonia and spermatocytes, enhance involution of LC and formation of collagenous capsules around necrotic germ cells in Channa punctatus (Saxena and Mani, 1985). Dimecron and carbofuran treatment also induced decrease in testicular proteins, RNA, lipids and ascorbic acid and elicited elevation of cholesterol and phospholipids in C. punctatus (Saxena et al., 1986). Treatment of C. punctatus with cythion resulted in the arrest of spermatogenesis at spermatid stage; the ST looked like solid cords packed with spermatogonia and spermatocytes but without sperms. Some necrotic spermatocytes were also observed and involuted LC were inactive with darkly stained nuclei (Ram and Sathyanesan, 1987).

Treatment of Clarias batrachus with emisan has been shown to reduce the activity of 5-3 p-hydroxysteroid dehydrogenase (HSD) enzyme (Kirubagran and Joy, 1988a); smaller ST filled with spermatids, pyknotic LC, lower GSI, total lipid, phospholipid, free cholesterol and 3 IP uptake were also observed (Kirubagran and Joy, 1992). Chlordecone-led extensive damage of singhi testes has been reported
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(Srivastava and Srivastava, 1994). The ST were flattened, germinal epithelium appeared degenerated and squamated and the LC were atrophied and vacuolated. However, no apparent change in the production of milt could be observed in phosphamidon treated scale carps (Pandey et al., 1999).

Effects on female reproductive system

The female reproductive system of teleost, unlike that of mammals, is highly variable, representing a wide range of reproductive patterns, including viviparity. In most teleosts, the ovary is a hollow paired organ, however, in some species paired structures become fused into one solid, single organ during their early development. The ovary consists of oogonia, oocytes and their surrounding follicle cells, supporting tissue or stroma, and vascular and nervous tissue (Nagahama, 1983).

Stott et al. (1981) have observed atresia, acidophilic cells, chromatophores and leucocytic foci or infiltration in the ovaries of eleven species of fishes collected from petroleum-induced lesions. The status of ovarian cycle correlated well in the majority of cases with known spawning times.

Cythion-led delayed secondary yolk deposition during summer ovarian growth (Lesniak and Ruby, 1982) and pronounced decrease in GSI and cholesterol (Wani and Latey, 1984) have been observed. Fenitrothion and carbofuran caused decrease in total ovarian protein, RNA, lipids and ascorbic acid but enhanced cholesterol and lipids during different phases of ovarian cycle (Saxena et al., 1986). Mercuric chloride treatment reduced the ovarian total protein and alkaline phosphate but increased the glycogen, acid phosphatase and cholesterol (C. batrachus - Saksena and Agrawal, 1991). Reduced GSI and oocyte diameters, and lowered levels of E2, T3 and vitellogenin have been observed in rainbow trout after cyanide treatment (Ruby et al., 1993). Ammonium sulphate inhibited ovarian growth and enhanced degeneration of vitellogenic oocytes (Barbus stigma - Khillare, 1992).

Retardation of ovarian growth as evidenced by decreased GSI, presence of fewer maturing stage II and III oocytes following treatment with various pollutants have also been noticed by different workers (Saxena and Garg, 1978; Mani and Saxena, 1985; Haider and Upadhyay, 1985; Shukla and Pandey, 1986; Shukla et al., 1984; Ram and Sathyanesan, 1987; Kirubagaran and Joy, 1988b; Ram and Joy, 1988; Pandey, 1988, 1998; Dey and Bhattacharya, 1989; Rastogi and Kulshrestha, 1990; Sukumar and Karpaganapathy, 1992; Singh et al., 1993; Srivastava and Srivastava, 1994). Since degenerative changes were also noticed in hypothalamus and gonadotrops of the treated fish, it was assumed that pollutant-induced impairment of ovarian function was mediated through hypothalamo-hypophysial ovarian axis (Shukla and Pandey, 1986; Ram and Joy, 1988, Pandey, 1988, 1998).

However, Dey and Bhattacharya (1989) could not observe atresia in the treated C. punctatus; size of stage I oocytes was also not affected but that of stage II and III oocytes was diminished.

Absence of 5-3 P-HSD and glucose-6-phosphodehydrogenase enzymes (Inbaraj and Haider, 1988), inhibition of steroidogenesis (Haider and Upadhyay,
1985) and clumping and damage of yolk in stage II and III oocytes (Pandey, 1988, 1998) have also been reported in fishes exposed to several pesticides.

Decreasing GSI, water and lipid contents of ovary with increasing dose of pesticide have been observed by Choudhury et al. (1982).

Impairment of hydrolysis of esterified cholesterol but not the synthesis of cholesterol, restriction on translocation of various lipids from liver to ovary (Singh and Singh, 1992b), suppression of testosterone, estradiol and 17 a-OH-progesterone in ovarian tissue and plasma (Singh and Singh, 1991), greater reduction in ovarian hormones at higher doses of pesticides and impaired steroidogenesis by inhibiting gonadotropin secretion (Singh and Singh, 1992a), decreased ovarian phospholipids, checking of hydrolysis of esterified cholesterol to free cholesterol, impairment of translocation of lipid to ovary by inhibiting hypothalamo-hypophysial-ovarian axis (Singh and Singh, 1992b), inhibition of de-esterification of esterified cholesterol to free cholesterol and steroidogenesis and hormone secretion into plasma (Singh et al., 1993) have been reported in singhi catfish treated with varying doses of malathion and y-BHC over different periods.

Phosphamidon-led delayed ovulation has also been observed in scale carp (Pandey et al., 1999).

Histological studies have used the light microscopical techniques only and hence ultrastructural studies are wanting. No fish group, other than teleosts, majority being freshwater, has yet been attempted. Most of the available literature is restricted to 4-5 freshwater teleost species namely, *C. punctatus*, *Heteropeustes fossilis*, *Sarotherodon mossambicus*, *C. batrachus* and *Colisa fasciatus*.

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**References**


