Plastic originated bisphenol A: A potential endocrine disruptor for fish reproduction

Abhilipsa Biswal, PP Srivastava, Shamna N and Munish Kumar

DOI: https://doi.org/10.22271/chemi.2020.v8.i1ae.8573

Abstract
Bisphenol A (BPA) is an organic synthetic compound, abundantly used worldwide for the production of polycarbonate plastic and epoxy resins. It is an endocrine disruptor that can mimic estradiol by binding to and activating the same estrogen receptor as the natural hormone. It is not only hazardous to human population but also found to be acutely toxic to aquatic organisms in the range 1000–10,000μg/L for freshwater and marine species. In 2010, the U.S. Environmental Protection Agency reported that over one million pounds of BPA are released into the environment annually. BPA can enter the environment either directly from chemical, plastics, coat and staining manufacturers, from paper or material recycling companies, or indirectly leaching from plastic, paper and metal waste in landfills or ocean-borne plastic trash. BPA in anaerobic or semi aerobic sediment environments can persist for a prolonged period of time, leading to higher BPA levels in sediments than in surface water. Interestingly BPA can persist longer in seawater than in fresh water without any degradation (about 30 day) and the possibility of BPA contamination is higher marine than freshwater organisms. BPA possess endocrine disruption in different types of fishes by vitellogenin induction, upregulation of brain aromatase isofrom mRNA, reduction of total sperm counts and induction of testis ova and poor somatic growth of male. It was also observed that environmentally relevant low level of BPA increased the expression of genes related to reproduction axis such as kiss1, kiss1r, Gnrh3, LH β, FSHβ, and ERα and dmrt1. BPA is also assumed to involve THR, in increasing the rate of early embryonic development in several fish species. Further, BPA exhibit very high estrogenic activity on the cyp19α1b gene, and increase concentration of vitellogenin in swim-up fry of freshwater fish species. Keeping in view of these, the present study is aimed to elucidate a baseline information about contamination routes of BPA in the aquatic environment and its endocrine-disruptive effects on aquatic organisms.

Keywords: Bisphenol A, endocrine disruption, reproduction, fish

1. Introduction
Bisphenol A (BPA) is an anthropogenic organic compound, tremendously used as a monomer for the production of polycarbonate plastic and epoxy resins (Staples et al., 1998) [37]. It is used for the production of transparent plastic bottles, plastic toys and a constituent of dental sealant (Suzuki et al., 2000) [40]. With the constant demand for plastic products, the worldwide production of BPA has also increased in many folds. Out of all the xenobiotic compound registered for human use purpose by Environmental protection act, BPA (CAS Registry No. 80-05-7) has earned the highest amount of interest as well as controversy during the last decade (Crain et al., 2007) [6]. It is a xenoestrogen compound and mimics the structure of estrogen hence it is considered as a potential endocrine disrupter (Goodman et al., 2006) [13]. BPA has increased human health concern to a large extent, due to its ubiquitous existence in the environment (Huang et al., 2012) [17]. This compound is detected in the urine of 95% of adults in the USA and Asia (Calafat et al., 2005; Zhang et al., 2011) [3, 48]. Discouraging the use of BPA, now-a-days some regulatory bodies such as the European Commission, the US Food and Drug Administration, have banned the use of BPA in baby bottles (Qiu, 2016) [32]. BPA is found to be acutely toxic to aquatic organisms in the range 1000–10,000μg/L for freshwater and marine species (Alexander et al., 1988). In fishes, BPA exposure can lead to detrimental effect particularly during ontogenesis period (Crain et al., 2007) [6]. Its concentration is lower in stream water (max upto 21 mg/L) (Staples et al., 2002) [38], but it can reach concentrations as high as 17,200 mg/L in landfill leachates (Alexander et al., 1998).
2. Mode of contamination in aquatic ecosystem
Generally, the lower concentration of BPA found to be present in domestic sewage effluent than industrial sewage effluent (Fuerhacker et al., 2000) [11]. It has been observed that wastewaters from paper plants contain very high concentration of BPA, therefore, complete removal of BPA from the effluents of the plastic and paper production plant is not feasible (Rigol et al., 2002; Quinn et al., 2003) [34, 32]. Fuerhacker et al. (2000) claimed that during wastewater treatment more than 90% of BPA concentration can be curtailed. However, several other studies suggested that the elimination rate of BPA in treatment plants varies from 37 to 94% (Lee and Peart, 2000; Fuerhacker et al., 2003) [29, 11].

Landfill leachates are the major point source of BPA contamination. By the hydrolysis of plastic in landfill leachates, BPA is released. Therefore, a very high concentration of BPA was reported from waste landfill leachates ranging from 1.3 to 17,200 μg/L with an average of 269 μg/L (Yamamoto et al., 2001) [41]. On note, the level of BPA in effluent is considerably lower than the leachates. As an instance, Yamada et al. (1999) [42] commented that the levels of BPA in four landfill leachates ranged from 15 to 5400 μg/L, whereas it ranged from 0.5 to 5.1 μg/L in the treated effluents. Its already proclaimed that marine debris washed ashore contain 60-80% plastic in volume, increasing the risk of further contamination of such anthropogenic chemicals into aquatic environment. Although in microbe-rich aerobic environment BPA degrades easily, it further creates a non-point source of contamination threat to the water body (Dorn et al., 1987) [7]. Crain et al. (2007) [43] stated that the comparatively lesser concentration of BPA found in stream waters (21 μg/L) than that of the BPA concentration of landfill leachates (17 mg/L). However, the river surface water contains very low concentration of BPA than that of the sediments (Kang, 2007) [22].

3. Fate of BPA in the aquatic environment
Photodegradation and biodegradation are two potential phenomena responsible for the degradation of this potential toxicant in the aquatic ecosystem. Photodegradation is the primary non-biological pathway responsible for the degradation of BPA in an aquatic environment. Chin et al. (2004) [35] reported that dry organic matter such as humic acid and fluvic acid found in the surface water helps in absorbing the irradiation thus generating reactive oxidant species (ROS) and some non-ROS intermediates. Since iron can yield ROS by reacting with hydrogen peroxides, complexes of iron with ROS or dry organic matter, for instance, Fe(III)-OH and Fe(III)-humic acid complexes, has found to impel further photodegradation of BPA (Zhou et al., 2004) [49]. However, biodegradation is a more potential phenomenon prevailing in the aquatic ecosystem for degradation of BPA. According to Kang and Kondo. (2002) [20], several bacteria species are responsible for degrading BPA in an aquatic environment and shortening its half-life to less than 5 days. Kang and Kondo, (2002) [20] stated that the efficiency of bacterial degradation can vary from (18-91%) depending on the bacterial species, however, two bacterial species such as (Pseudomonas strain and streptomyces species strain) has been isolated from river water with high BPA biodegradability (more than 90% over 10 days). The extent of biodegradation is mainly dependent upon bacterial population and abiotic factors such as temperature and oxygen. According to Kang and Kondo (2002a) [21], BPA in river samples was found to be readily biodegraded under aerobic conditions (>90%), while in anaerobic conditions even after 10 days period no depression of BPA level was found. Along with the bacteria several planktons are reported for having the capacity for biodegradation and removal of estrogenic activity of BPA such as Chlorellafusescavacuolatae (Hirooka et al., 2005) [15].

| Table 1: Endocrine disruption effect of BPA in different fish |
|---------------------------------------------------------------|
| **Species** | **BPA exposure period** | **Endocrine-disrupting effect** | **Reference** |
| Gold fish (Carassius auratus) | 1 μmol for 8 day | Vitellogenin induction | Suzuki et al. (2003) [40] |
| Swordtail (Xiphophorus helleri) | 2000 μg/ml for 3 day 2000 μg/ml for 60 days | Vitellogenin mRNA expression Induction of apoptosis in Fish testes cell | Kwak et al. (2001) [24] |
| Fathead minnow (pimelophiles pomenas) | 119-205 μg/ml for 71 days | Vitellogenin induction | Sohoni et al. (2001) [16] |
| Zebra fish (Danio rerio) | 1000 μmol for 3 weeks | Vitellogenin induction | Van den Belt et al. (2003) |
| Rainbow trout (Onchorhyncus mykiss) | 274 and 579 μg/l | Reduction of total sperm count | Haubruge et al. (2000) [14] |
| Guppies (Poecilia reticulata) | 2.4 μg/l and 5 μg/l for two weeks | Delayed ovulation at 2.4 μg/l and elimination of ovulation at 5 microgram/l | Lahnsteiner et al. (2005) [25] |
| Medaka (Oryzias latipes) | 1820 μg/l for 60 days | Induction of tests –ova and poor somatic growth of male | Yokota et al. (2000) [47] |
| Catla (Catla catla) | 10, 100 and 1000 μg/ml for 2 weeks | Increase in serum stress biomarker responses such as AST and ALT in all the concentrations. Concentration independent increase in serum creatinine level resulting kidney dysfunction Only 1000 μg/ml induced significant vitellogenin expression | Faheem et al. (2019) [19] |
| Medaka | 10 μg/l for 100 day after hatch | Induction of testes ova | Metcalfe et al. (2001) [10] |
| Swordtail | 2 mg/l and 10 mg/l for short term (3 day) and long term (6 day) | Short term exposure induced vitellogenin mRNA expression And long-term exposure affected the growth | Kwak et al. (2001) [25] |
| Medaka | 837-3120 μg/l for 3 weeks | Induction of testes ova | Kang et al. (2002) [23] |
| Medaka | 1000 μg/l for 5 weeks | Vitellogenin induction | Tabeta et al. (2004) [41] |
| zebrafish | 5 and 50 μg/l for 21 days | Adverse effect on F1 generation GSI and egg production decreased | Ji et al. (2013) [18] |
4. Mechanism of action

It was observed that environmentally relevant low level of BPA, affects the HPG axis and upregulates the expression of genes associated with reproduction axis such as kiss1, kiss1r, GnRH3, LHα, FSHβ and ERα (Qui et al., 2015) and reduces expression of gene dnr1 in male fish, which gene is responsible for male sex determination (Laing et al., 2016).[28] kiss1 is considered as the upstream regulator of GnRH neurons and it is observed that by exposure of BPA the kiss1 gene expression is upregulated along with the GnRH levels (Elizur, 2019).[8] These cyp19a and cyp19b genes encode the cyt p-450 aromatase enzyme, which enzyme is responsible for the conversion of testosterone to estradiol and In various studies it has been reported that in BPA exposed fish, the upregulation of cyp19a (ovarian type) and cyp19b (brain type) genes has been seen (Sohoni et al., 2001; Lee et al., 2006).[26] This synthetic xenoestrogen is further reported to interfere with the normal oestrogen signalling pathway by upregulating the expression of both ERα and ERβ in fishes (Qui et al., 2016). Along with that, it has been reported that BPA exposure also escalates FSH and LH hormone concentration in fish (Qui et al., 2016). FSH and LH possess critical roles in Gonadal development of different teleost fishes (Prat et al., 1996).[31] Not only BPA interferes with the hormones of the Hypothalamic-Pituitary-Gonadal axis, but also it alters the thyroid hormone function during the period of ontogenesis. It is observed that BPA hasten up the embryonic development of fishes by acting as a thyroid hormone antagonist (Castro et al., 2013).[41] It is also reported that even at environmentally relevant concentration BPA down-regulates the expression of the dmnt1 which is involved in DNA methylation during ontogenesis, indicating the epigenetic action of this chemical (Laing et al., 2016).[28] So, there by upregulating and downregulating so many different genes, BPA causes the endocrine disruption of fishes.

5. Metabolism and Bioaccumulation potential of BPA in fish

Detoxification of xenobiotic compounds in the fish body is dependent on UGT which a critical enzyme essential for this process (Tephly and Burchell, 1990).[42] Basically in BPA exposed fishes, two types of BPA metabolites such as BPA sulfate and BPA glucuronide were identified, but the later one is considered as a major metabolite as it the concentration of the later one in plasma is reported to be 100- 22600 times higher than the former one (Lindholst et al., 2003).[30] Detoxification process is also linked with the bioaccumulation process. It is reported that when the detoxification pathway is saturated, excessive BPA leads to bioaccumulation (Upmeier et al., 2000).[43] Kang (2007)[21] stated that the bioaccumulation factor in freshwater fish can range from 5 to 68. However, during the initial phases of the life cycle, the fishes are more prone to higher bioaccumulation threat (Honkanen et al., 2004).[16] Although is reported that sea food

| Fish          | BPA Concentration   | Effect                                        | Reference          |
|---------------|---------------------|-----------------------------------------------|--------------------|
| Medaka        | 10 µg/l             | Delayed hatching and decrease in hatching rate | Shioda et al. (2000) [35] |
| Turbot (Scophthalmus maximus) | 59 µg/l for 3 weeks | Reduction in number of eggs and hatching | Labadie and Budzinski, 2006 [26] |
| Zebra fish    | 10 µg/l for 72 hrs after fertilization | Reduction of testosterone and 11-keto testosterone | Kishida et al. (2001) [23] |

![Fig 1: Model for the pathway of vitellogenesis regulation in teleost fish via the brain-pituitary-gonad (BPG) axis (Sullivan and Yilmaz, 2018).](image)
of supermarket is reported to be containing a potentially threatening amount of BPA with a range of (13-213 µg/ kg wet weight), indicating the higher bioaccumulation potential of BPA in the marine organisms (Basheer et al., 2004) [3]. This might be probably due to the reason that the persistence period of undegraded BPA in marine water can be as high as 30 days unlike the freshwater (Kang, 2007) [31].

6. Conclusion and future research prospects
The anthropogenic endocrine disruptive chemical BPA is used abundantly in the plastic production industry. Although a lot of different alternatives were tried and tested, nothing can be considered as the safe alternative of BPA as all the alternatives are having endocrine disruptive effect to various extents. Further, the bioaccumulation potential of BPA varies from species to species and this bioaccumulation elicits higher endocrine disruptive effect in fishes and organisms. Interestingly, very few existing literatures explained the effect of bioaccumulation in the endocrine system. Also, most of the studies have been conducted using BPA concentration not in relevance to the range of environmentally available concentration. Further, a research gap exists in regards to the effect of BPA in organisms of the marine environment, as most of the study models are based on freshwater organisms. Future studies can be directed keeping in view for the production of a safer alternative of BPA and more detailed study should take place for marine fishes keeping in view, the environmentally relevant concentration and the bioaccumulation effects.

7. References
1. Alexander HC, Dill DC, Smith LW, Guiney PD, Dorn P, Bisphenol A: acute aquatic toxicity. Environmental Toxicology and Chemistry: An International Journal. 1988; 7(1):19-26.
2. Basheer C, Lee HK, Tan KS, Endocrine disrupting alkylphenols and bisphenol-A in coastal waters and supermarket seafood from Singapore. Marine pollution bulletin. 2004; 48(11-12):1161-1167.
3. Calafat AM, Kuklenyik Z, Reidy JA, Caudill SP, Ekong J, Needham LL, Urinary concentrations of bisphenol A and 4-nonylphenol in a human reference population. Environmental health perspectives. 2005; 113(4):391-395.
4. Castro B, Sanchez P, Torres JM, Preda O, Del Moral RG, Ortega E, Bisphenol A exposure during adulthood alters expression of aromatase and 5α-reductase isozymes in rat prostate. PloS one. 2013; 8(2).
5. Chin YP, Miller PL, Zeng L, Cawley K, Weavers LK, Photosensitized degradation of bisphenol A by dissolved organic matter. Environmental science & technology. 2004; 38(22):5888-5894.
6. Crain DA, Eriksen M, Iguichi T, Jobling S, Lauber H, LeBlanc GA et al. An ecological assessment of bisphenol-A: evidence from comparative biology. Reproductive toxicology. 2007; 24(2):225-239.
7. Dorn PB, Chou CS, Gentempo JJ, Degradation of bisphenol A in natural waters. Chemosphere. 1987; 16(7):1501-1507.
8. Elizur A, The KiSS1/GPR54 system in fish. Peptides. 2019; 30(1):164-170.
9. Faheem M, Khalid S, Lone KP, Effect of bisphenol-A on serum biochemistry and liver function in the freshwater fish, Catla catla. Pakistan veterinary journal. 2019; 39:71-75.
10. Metcalfe CD, Metcalfe TL, Kiparissis Y, Koenig BG, Khan C, Hughes RJ et al. Estrogenic potency of chemicals detected in sewage treatment plant effluents as determined by in vivo assays with Japanese medaka (Oryzias latipes). Environmental Toxicology and Chemistry: An International Journal. 2001; 20(2):297-308.
11. Fuerhacker M, Bisphenol A emission factors from industrial sources and elimination rates in a sewage treatment plant. Water science and technology. 2003; 47(10):117-122.
12. Führacker M, Scharf S, Weber H, Bisphenol A: emissions from point sources. Chemosphere. 2000; 41(5):751-756.
13. Goodman Julie E, Ernest E McConnell, Glenn Sipes I, Raphael J Witorsch, Tracey M Slayton, Carrie J Yu et al. An updated weight of the evidence evaluation of reproductive and developmental effects of low doses of bisphenol A. Critical Reviews in Toxicology. 2006; 36(5):387-457.
14. Haubruege E, Petit F, Gage MJ, Reduced sperm counts in guppies (Poecilia reticulata) following exposure to low levels of tributyltin and bisphenol A. Proceedings of the Royal Society of London. Series B: Biological Sciences. 2000; 267(1459):2333-2337.
15. Hirooka T, Nagase H, Uchida K, Hiroshige Y, Ehar Y, Nishikawa JI et al. Biodegradation of bisphenol A and disappearance of its estrogenic activity by the green alga Chlorella fusca var. vacuolata. Environmental Toxicology and Chemistry: An International Journal. 2005; 24(8):1896-1901.
16. Honkanen JO, Holopainen IJ, Kukkonen JV, Bisphenol A induces yolk-sac oedema and other adverse effects in landlocked salmon (Salmo salar m. sebagu) yolk-sac fry. Chemosphere. 2004; 55(2):187-196.
17. Huang YQ, Wong CKC, Zheng JS, Bouwman H, Barra R, Wahlström B et al. Bisphenol A (BPA) in China: a review of sources, environmental levels, and potential human health impacts. Environment international. 2012; 42:91-99.
18. Ji K, Hong S, Kho Y, Choi K, Effects of bisphenol S exposure on endocrine functions and reproduction of zebrafish. Environmental science & technology. 2013; 47(15):8793-8800.
19. Kang IU, Yokota H, Oshima Y, Tsuruda Y, Oe T, Imada N et al. Effects of bisphenol A on the reproduction of Japanese medaka (Oryzias latipes). Environmental Toxicology and Chemistry: An International Journal. 2002; 21(11):2394-2400.
20. Kang JH, Kondo F, Bisphenol A degradation by bacteria isolated from river water. Archives of environmental contamination and toxicology, 2002; 43(3):0265-0269.
21. Kang JH, Kondo F, Effects of bacterial counts and temperature on the biodegradation of bisphenol A in river water. Chemosphere. 2002; 49(5):493-498.
22. Kang JH, Aasi D, Katayama Y, Bisphenol A in the aquatic environment and its endocrine-disruptive effects on aquatic organisms. Critical reviews in toxicology. 2007; 37(7):607-625.
23. Kishida M, McLeIman M, Miranda JA, Callard GV, Estrogen and xenoestrogens upregulate the brain aromatase isoform (P450aromB) and perturb markers of early development in zebrafish (Danio rerio). Comparative Biochemistry and Physiology Part B:
Biochemistry and Molecular Biology. 2001; 129(2-3):261-268.

24. Kwak HI, Bae MO, Lee MH, Lee YS, Lee BJ, Kang KS et al. Effects of nonylphenol, bisphenol A, and their mixture on the viviparous swordtail fish (Xiphophorus helleri). Environmental Toxicology and Chemistry: An International Journal. 2001; 20(4):787-795.

25. Kwak HI, Bae MO, Lee MH, Lee YS, Lee BJ, Kang KS et al. Effects of nonylphenol, bisphenol A, and their mixture on the viviparous swordtail fish (Xiphophorus helleri). Environmental Toxicology and Chemistry: An International Journal. 2001; 20(4):787-795.

26. Labadie P, Budzinski H. Alteration of steroid hormone balance in juvenile turbot (Psetta maxima) exposed to nonylphenol, bisphenol A, tetrabromodiphenyl ether 47, diallylphthalate, oil, and oil spiked with alkylphenols. Archives of environmental contamination and toxicology. 2006; 50(4):552-561.

27. Lahmestein F, Berger B, Kletzli M, Weismann T. Effect of bisphenol A on maturation and quality of semen and eggs in the brown trout, Salmo trutta f. fario. Aquatic Toxicology. 2005; 75(3):213-224.

28. Laing LV, Viana J, Dempster EL, Trznadel M, Trunkfield LA, Uren Webster TM et al. Bisphenol A causes reproductive toxicity, decreases dnm1 transcription, and reduces global DNA methylation in breeding zebrafish (Danio rerio). Epigenetics. 2016; 11(7):526-38.

29. Lee HB, Peart TE. Bisphenol A contamination in Canadian municipal and industrial wastewater and sludge samples. Water Quality Research Journal. 2000; 35(2):283-298.

30. Lindholm C, Wynne PM, Marriott P, Pedersen SN, Bjerregaard P. Metabolism of bisphenol A in zebrafish (Danio rerio) and rainbow trout (Onchorhynchus mykiss) in relation to estrogenic response. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology. 2003; 135(2):169-177.

31. Prat F, Sumpter JP, Tyler CR. Validation of radioimmunoassays for two salmon gonadotropins (GTH I and GTH II) and their plasma concentrations throughout the reproductive cycle in male and female rainbow trout (Onchorhynchus mykiss). Biology of reproduction. 1996; 54(6):1375-1382.

32. Qiu W, Zhao Y, Yang M, Farajzadeh M, Pan C, Wayne NL. Actions of bisphenol A and bisphenol S on the reproductive neuroendocrine system during early development in zebrafish. Endocrinology. 2016; 157(2):636-647.

33. Quinn BP, Booth MM, Delfino JJ, Holm SE, Gross TS. Selected resin acids in effluent and receiving waters derived from a bleached and unbleached kraft pulp and paper mill. Environmental Toxicology and Chemistry: An International Journal. 2003; 22(1):214-218.

34. Rigol A, Latorre A, Lacorte S, Barceló D. Determination of toxic compounds in paper-recycling process waters by gas chromatography-mass spectrometry and liquid chromatography-mass spectrometry. Journal of Chromatography A. 2002; 963(1-2):265-275.

35. Shiota T, Wakabayashi M. Effect of certain chemicals on the reproduction of medaka (Orzysis latipes). Chemosphere. 2000; 40(3):239-243.

36. Sohoni PCRT, Tyler CR, Hurd K, Caunter J, Hetheridge M, Williams T et al. Reproductive effects of long-term exposure to bisphenol A in the fathead minnow (Pimephales promelas). Environmental science & technology. 2001; 35(14):2917-2925.

37. Staples CA, Dome PB, Klecka GM, Oblock ST, Harris LR. A review of the environmental fate, effects, and exposures of bisphenol A. Chemosphere. 1998; 36(10):2149-2173.

38. Staples CA, Woodburn K, Caspers N, Hall AT, Klec Ka GM. A weight of evidence approach to the aquatic hazard assessment of bisphenol A. Hum Ecol Risk Assess. 2002; 8:1083-1105.

39. Sullivan CV, Ylirmaz O. Vitellogenesis and yolk proteins, fish. Encyclopedia of reproduction, 2nd edn. Elsevier. 2018.

40. Suzuki N, Kambaegawa A, Hattori A. Bisphenol A influences the plasma calcium level and inhibits calcitonin secretion in goldfish. Zoological science. 2003; 20(6):745-748.

41. Tabata A, Watanabe N, Yamamoto I, Ohnishi I, Itoh M, Kamei T et al. The effect of bisphenol A and chlorinated derivatives of bisphenol A on the level of serum vitellogenin in Japanese medaka (Orzysis latipes). Water Science and Technology. 2004; 50(5):125-132.

42. Tephly TR, Burchell B. UDP-glucuronosyltransferases: a family of detoxifying enzymes. Trends in Pharmacological Sciences. 1990; 11(7):276-279.

43. Upmeier A, Degen GH, Diel P, Michna H, Bolt HM. Toxicokinetics of bisphenol A in female DA/Han rats after a single iv and oral administration. Archives of toxicology. 2000; 74(8):431-436.

44. Vanden Belt K, Verheyen R, Witters H. Comparison of vitellogenin responses zebra fish and rainbow trout following exposure to environmental estrogens. Ecotoxicol. Environ. Safety. 2003; 56:271-281.

45. Yamada K. Constituents of organic pollutants in leachates from different types of landfill sites and their fate in the treatment processes (in Japanese). J Jpn Soc Water Environ. 1999; 22:40-45.

46. Yamamoto T, Yasuhara A, Shiraishi H, Nakasuji O. Bisphenol A in hazardous waste landfill leachates. Chemosphere. 2001; 42(4):415-418.

47. Yokota H, Tsuruda Y, Maeda M, Oshima Y, Tadokoro H, Nakazono A et al. Effect of bisphenol A on the early life stage in Japanese medaka (Orzysis latipes). Environmental Toxicology and Chemistry: An International Journal. 2000; 19(7):1925-1930.

48. Zhang Z, Alomirah H, Cho HS, Li YF, Liao C, Minh TB et al. Urinary bisphenol A concentrations and their implications for human exposure in several Asian countries. Environmental science & technology. 2011; 45(16):7044-7050.

49. Zhou D, Wu F, Deng N, Xiang W. Photooxidation of bisphenol A (BPA) in water in the presence of ferric and carboxylate salts. Water Research. 2004; 38(19):4107-4116.