Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 11 (12): 2092-2099, 2011
ISSN 1812-5654 / DOI: 10.3923/jas.2011.2092.2099

Heavy Metal Risks in Integrated Chicken-fish Farming

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Abstract: The study reviews the likely health risks to human beings and fish from heavy metal contamination arising from the use of chicken manure and spilled chicken feed in rearing fish in an integrated chicken-fish system especially when fish is reared in such a system and consumed for long periods of time. The necessity, history and present status of the practice of integrating chicken and fish farming is explored and the chemical composition and effect of chicken manure on the pond water/sediments is also explained. The pathway for the entry and accumulation of heavy metals in the system together with their fate in ponds and toxicity to fish is elucidated. The review also includes the maximum permissible limits of some metals in fish, water and sediments and makes recommendations on possible ways of reducing the incidence of heavy metals in fish grown in the chicken-fish system prior to human consumption.

Key words: Heavy metals, manure, feed, chicken, aquaculture

INTRODUCTION

Fish is a major source of protein for the increasing world population especially in the developing countries of Africa, Asia and South America (FAO, 2006a; Gabriel *et al.*, 2007) and the major solution to the dietary protein shortage in such countries is increased fish production (Nnaji *et al.*, 2009a). However, fish consumption is an important avenue for pathogen and heavy metal exposure to man (Musaiger and D'Souza, 2008; Christopher *et al.*, 2009). Fish is produced from capture and culture (aquaculture) fisheries operations and according to FAO (2006b, 2008 and 2010), capture fisheries production decreased from year 2000 to 2008 (95.6-89.7 million tonnes) while aquaculture production rose from 35.5 million tonnes in 2000 to 52.5 million tonnes in 2008. However, aquaculture production in some areas is hampered by obsolete fish farming technology, dearth of good quality fish seed, high cost of aquaculture operations etc. The need for a low-cost system of fish production that will meet the food needs of the rural and urban poor and at the same time maximize the utilization of resources becomes pertinent. This need is provided for by integrated fish farming which combines fish farming and other types of human activity (mainly agricultural activities). Such combination ensures that waste products from one activity become an input into the fish farming activity and this leads to reduction of production costs. Integrated chicken-fish farming involves the combination of chicken farming with fish culture where the wastes (manure and spilled feed) from the chicken sub-system become an input into the fish sub-system (Sinha, 1985). Nutrients from the chicken sub-system are recycled in the pond and this allows for intensification of production and income while reducing the impact, the disposal of the wastes would have had on the environment (Costa-Pierce, 2002). Direct use of livestock production wastes is one of the most widespread and conventionally recognized type of integrated fish farming and the practice increases the efficiency of both chicken farming and fish culture through the profitable utilization of animal and feed waste products (Little and Edwards, 2003; Nnaji *et al.*, 2009b). According to FAO (2003), the practice of livestock-fish farming needs to be placed in perspective with the likely health risks. One of the risks involved in livestock-fish farming is the role of cultured fish in the possible transfer of pathogens between livestock and humans. Parasites may also affect the health of fish since they can reduce fish growth rate, resistance to disease and cause fish mortalities. Another important but neglected health risk is the possibility of transfer of toxic heavy metals from fish to man in the livestock-fish system. According to Alinnor and Obiji (2010), the contamination of waterbodies and aquatic animals by heavy metals have been a global problem and constant monitoring of the environment for heavy metal contamination is important. This is concern is largely due to the persistence, toxicity, bio-

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accumulative and non biodegradable nature of such metals (Azmat *et al*., 2008; Bhattacharya *et al*., 2008). Poultry litter and indeed animal wastes in general contain high concentrations of some trace elements (Jackson *et al*., 2003). Heavy metals are contained in both the spilled chicken feed and manure and these are consumed by fish with the possible accumulation of these metals to high levels if fish is cultured in such systems, especially for long periods of time. This study makes a review of the possible health risks from heavy metal deposition and accumulation in chicken-fish farming and makes some recommendations on possible ways of reducing these risks.

THE NEED FOR INTEGRATED CHICKEN-FISH FARMING

Integrated Fish Farming (IFF) systems can be divided into four broad groups, namely: integrated plant-fish farming, integrated animal-fish farming, integrated animal-plant-fish farming and integrated wastewater-fish farming (Nnaji *et al.*, 2003). According to Little and Muir (1987), Asian farmers, in the quest to achieve higher food production due to rapidly increasing population and nutrient limitation, integrated aquaculture into their agricultural farming systems. The cost of formulated fish feed is usually about 70% of production costs (Adebowale and Olubamiwa, 2008) and the use of animal manure considerably reduces operational costs and makes it possible for low income fish farmers to profitably engage in the enterprise. Manure is regarded as a "complete" fertilizer with characteristics of both organic and inorganic fertilizers and can be used without the addition of other chemicals (FAO, 2003). According to Francis *et al.* (2004) integrated chicken-fish farming leads to better utilization of land and water resources, effective recycling of wastes, improved agricultural waste resource utilization efficiency, reduction in operational expenses usually incurred through the use of feeds and fertilizers in fish ponds and more income for small holder farmers which translates to higher living standards. This is due to the fact that about 72-79% of Nitrogen (N), 61-87% of Phosphorus (P) and 82-92% of Potassium (K) in feed given to animals are recovered in their excreta. Table 1 shows annual fish biomass production range from manure derived from confined livestock species according to Muller (1980).

However, it is important that an efficient nutrient linkage between the components of an IFF system is developed if the system is to function optimally (Prein, 2002). According to Huet (1975) the mechanism of manure recycling in fresh water is such that under the right conditions, efficient nutrient linkage can be achieved.

Table 1: Fish biomass production range from livestock manure

Manure source	Fish biomass production range (kg year^{-1})
One dairy cow	100-200
One beef cattle	90-160
One sheep	10-17
One laying hen	6-8
One broiler	3-4
One turkey	7-8

Source: Muller (1980)

HISTORY AND PRESENT STATUS OF INTEGRATED CHICKEN-FISH FARMING

IFF has a long history in Asia dating back to more than 2400 years in China and is well established in Asian Countries as a source of plant and animal protein (Willman *et al.*, 1998; Prinsloo *et al.*, 1999). Indeed, Asia is the world's foremost continent in terms of IFF. Vast areas of land in China, India, Japan, Indonesia, Thailand, Vietnam, Philippines and Bangladesh are used for integrated fish farming. However, NACA (2007) noted that while integrated fish farming is still widely practiced in many countries in Asia, factors like availability of pelleted feeds and intensification of production have lead to a slight decrease in the practice. In Africa, integrated fish farming has been reported in countries like Nigeria, Benin, Madagascar, South Africa, Egypt, Zambia, Cameroon and Malawi but the practice is still poorly developed and is mainly at subsistence level. According to Gabriel *et al.* (2007), chicken-fish farming is the most popular form of integrated poultry-fish farming in Nigeria. The National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, Nigeria, carried out a National Aquaculture Diagnostic Survey and concluded that about 48% of all the fish farms studied carried out one form of integrated fish farming or the other. 50% of these practiced chicken-fish farming, 38% practiced ruminant/cattle-fish farming, 14% pig-fish farming and 1.6% practiced rice-fish farming (NIFFR, 1995). The first experiments on integrated fish-cum-duck farming in Europe was conducted in 1934, by the German scientist, Probst but the outbreak of World War II halted the research (NACA, 1989). However, the shortage of animal protein after the war prompted the reactivation of integrated fish farming experiments and integrated livestock-fish farming is presently done in Hungary, Germany, Poland and Russia (NACA, 1989; FAO, 2003). Rice-fish farming is also being given attention in Spain and Italy. In the American continent, rice-fish farming is carried out at a low level in United States, Argentina, Brazil, Haiti, Panama and Peru (Willman *et al.*, 1998).

CHEMICAL COMPOSITION OF CHICKEN MANURE

The chemical composition of poultry manure varies because of factors like source of manure, feed given to the animals, age of animals, condition of animals, manner of storage/handling and litter used (Mariakulandai and Manickam, 1975). Fresh poultry manure contains about 77-80% water but as a measure of the overall dry matter, 5% is N, 3.9% is P and 2.4% is K (Kroodsma, 1986). Approximately 60-70% of the total nitrogen excreted in poultry manure occurs as uric acid and urea (Nahm, 2003). Table 2 shows the chemical composition of chicken manure from different authors. It shows that the crude protein content of chicken manure can be more than 20% and this makes it appropriate for use in farming fish. In addition the energy content of chicken manure is in the range of 110-1400 kcal kg^{-1} manure and it contains a high concentration of synthesized soluble vitamins (Tuleum, 1992). Fresh manure seem to lead to faster fish growth than fermented or stored manure since fish feed directly on manure detritus and also products of nutrient release into the system (Yejin *et al*., 1987). Nutrient value (physical, chemical and biological quality) of animal manure usually deteriorates during storage. For instance, nitrogen loss (in form of volatilization as ammonia and as nitrate and nitrite) can be up to 90% under some climatic conditions (FAO, 2003).

Chicken manure, when added into a pond, undergoes microbial decomposition releasing nutrients for the growth of microscopic green plants (algae or phytoplankton) which is the base of the trophic level (food chain) in aquatic systems (Aquaculture South Africa, 1999). Phytoplankton are eaten by zooplankton (microscopic animals) while zooplankton serve as food for small fish and aquatic insects. These are in turn consumed by bigger fish and thus, addition of manure and other fertilizers stimulates the production of phytoplankton and zooplankton which is referred to as primary productivity of the pond. The primary nutrients released by microbial decomposition of manure are N, P and K (Boyd, 1982). Secondary nutrients are Calcium (Ca), Magnesium (Mg) and Sulphur (S) while minor nutrients include heavy metals like Copper (Cu), Zinc (Zn), Iron (Fe) etc. Nitrogen and phosphorus are the nutrients most likely to be limiting for plankton growth in the pond but fish yield is probably more directly correlated to manure nitrogen content since nitrogen is more volatile than phosphorus.

MODE OF ENTRY OF HEAVY METALS INTO THE AQUATIC FOOD CHAIN IN THE CHICKEN-FISH SYSTEM

Islam *et al.* (2007) defined heavy metals as metals having a density greater than 5 gcm^{-3}. According to Jennett *et al.* (1980), heavy metals include those elements on the periodic table with atomic numbers 22 to 34 (Titanium-Selenium), 40-52 (Zirconium-Tellurium) and 72-83 (Hafnium-Bismuth). Heavy metals, according to Zaidi *et al.* (2005) are among the major contaminants of food supply and may be considered the most important problem to the environment. Heavy metals get into the body of man and animals through ingestion, inhalation and dermal contact. Animals contaminated by heavy metals transfer same to man when they are eaten. Ingested heavy metals are first digested (i.e., metabolised) in the alimentary canal before transport to other tissues. However, human and animal bodies provide defences against metals, natural and organic toxicants through detoxication, excretion and homeostatis (Luckey and Venugopal, 1977).

Heavy metals are introduced into aquatic systems through the weathering of rocks and soils; volcanic eruptions and various forms of human activities involving mining, processing or use of metals and or substances containing metal contaminants (Laws, 1981). Sewage and animal manure also serve as sources of heavy metals in water bodies either when applied directly or via surface runoff when used as soil manure. Taiganides (1978) reported that animal manures contain the major inorganic nutrient components (N, P, K), in addition to such trace elements as Ca, Cu, Zn, Fe and Mg. Cang *et al.* (2004), in a study of poultry and livestock feeds and manure in Jiangsu province, China, reported that Cu, Zn, Pb, Cd and Cr concentrations in animal manures were high with Cu concentration in a manure sample as high as 1726.3 mg kg^{-1}. Table 3 shows heavy metal concentrations in representative manure samples from several sources.

Heavy metals are ubiquitous and easily get into human and animal feedstuff and are consequently passed out during excretion and defecation. Heavy metal contamination of feedstuffs used in making animal feed may occur as a result of the use of metal-based herbicides and pesticides, metal contaminated fertilizers, atmospheric deposition, irrigation with metal-laden water etc. Heavy metals like As, Zn and Cu are also added as feed supplements to boost poultry production and when added above the required levels, they may be accumulated to high levels in the animals which is also transferred to aquatic systems when poultry is integrated

Table 2: Chemical composition (%) of chicken manure from different sources

Manure	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Organic matter (%)	Moisture (%)
Fresh[1]	0.9	0.5	0.8	0.4	2.0	30.7	64.8
Fresh[2]	1-1.5	1-2	0.7	2.2			
Fresh[3]	1	0.9	0.5				
Litter [2]	1-2	2	1.0	3.0			
Litter[4]	22	1.10	10.0				73.0
Dried[1]	4.5	2.7	1.4	2.9	0.6	58.6	9.2
Dried[4]	41	2.05	23.0				13.0
Proximate composition	**Moisture (%)**	**Crude protein (%)**	**Crude fat (%)**	**Nitrogen free extracts (%)**	**Crude cellulose (%)**	**Ash/minerals (Ca, P etc.,) (%)**	**Dry matter (%)**
Fresh[5]	11.4	26.7	1.7	30.6	13.0	16.5	
Litter[6]		15.4		36.2	17.1	20.5	94.3
Litter[7]		26.8	2.4	27.5	21.2	18.6	80.6

[1]The Ecochem company (2010), [2]Wachira (2000), [3]Kroodsma (1986), [4]Christensen and Peacock (1998), [5]FAO (2003), [6]Lanyasunya *et al.* (2006), [7]Martin *et al.* (1983)

Table 3: Heavy metal contents in manures from different sources (mg kg^{-1})

Metal	As	Cd	Cr	Cu	Fe	Mg	Mn	Pb	Zn
Litter[1]	4.1	0.86	6	50	0.07	0.06	211	2.3	187
Litter[2]		0.09-0.42		17-486				1.5-4.9	237-789
Litter[3]								110.5	284.2
Manure[4]		1.5		65				15	220

[1]Martin *et al.* (1983), [2]Menzi and Kessler (1998), [3]Ramadan and Adam (2007), [4]Ha and Tuyen (2010)

with fish. Fakayode *et al.* (2003) analysed 151 chicken eggs and 4 local chicken feeds in Ibadan, Nigeria for Pb, Cu, Zn, Co, Fe, Ni and Cd concentrations with carbon graphite atomic absorption spectrophotometry and found positive correlation between metal concentrations in feeds and in eggs. The overall average concentrations (mg kg^{-1}) of each metal in eggs were as follows: Pb, 0.59; Cd, 0.07; Cu, 0.78; Fe, 23.20; Ni, 0.03; Zn, 13.75 and Co, 0.01. Islam *et al.* (2007), in a study of three layer and broiler feeds in Bangladesh, found substantial levels of heavy metals in these feeds (detected maximum and minimum levels for Cd was 0.1852 and 0.0232; Pb, 20.6498 and 0.6019; As, 0.7640 and 0.0069; Hg, 0.0579 and 0.0116; Cr, 5.7875 and 0.0926; Manganese (Mn), 302.2001 and 0.0695; Ni, 5.1625 and 0.0125, Cu, 37.5725 and 0.0463; Zn, 422.3023 and 0.0232 ppm etc.,). Alkhalaf *et al.* (2010) analysed some poultry feed samples for aflatoxins and heavy metals and found high levels of Zn, Cu, Mn and Fe in the samples. They also concluded that levels of Pb in most of the samples exceeded the permissible limit of <1 mg kg^{-1} in the United Kingdom. Alexieva *et al.* (2007) studied 152 samples of feed ingredients and compounded feed for pigs and poultry in Bulgaria and found that Pb and Cd levels the feeds were higher than current European official regulations.

TOXICITY OF HEAVY METALS TO MAN AND AQUATIC ORGANISMS

Heavy metals are contained in different types of food and virtually all, including the essential heavy metals (Fe, Cu, etc.,) are toxic if safe limits are exceeded (Wakawa *et al.*, 2008). Cd for instance, is toxic to all man and animal tissues and has no known beneficial effect. Cd poisoning leads to growth retardation, impaired reproduction and mortality of fish. Cu is an essential metal to both fish and man but Cu poisoning induces gill, liver and kidney damage in fish leading to fish mortalities. Cr is regarded, as an essential metal in the human body especially in enhancing insulin activity which is of crucial importance to diabetics and is also important in the membrane transport of human cell metabolites. However, Cr and its compounds are also well known toxins especially Cr (VI) which due to its oxidizing potential, easily permeates biological membranes and causes renal damage, diseases of the central nervous system, cancer etc., in man (Bae *et al.*, 2000). Pb is ingested by humans when Pb-containing foods and drinks are consumed. Water bodies are easily contaminated with Pb-laden effluents and this gets into aquatic organisms and then to man. Pb has no known essential function in animals and is a well known toxic metal that damages the liver, kidneys, brain, central nervous and reproductive systems (Lovei and Levy, 2000) of man and aquatic organisms causing all kinds of diseases. Zn is a ubiquitous essential trace element necessary for normal growth of animals and is present in a host of enzymes in the human body and foods vary in their Zn content. Wheat germ and bran (used in compounding chicken feed) contain 40-120 ppm of Zn. Unsafe levels of Zn in fish can lead to respiratory system damage, stress and inhibition of normal growth and maturation (Weatherley *et al.*, 1988). Other dangerous heavy metals of interest include Hg, Ni, As which are carcinogenic.

The toxic effects of heavy metals on man and animals can be additive, antagonistic or synergistic (Ellis *et al.*,

Table 4: Limits for heavy metals in river water, fish muscle and sediments

Metal	Cd	Cr	Cu	Pb	Zn	Fe	Ni
UNEP(1999) limits in freshwater (mg L^{-1})		<0.05 Total Cr <0.05 Cr (VI)	<1.0	<0.1	<0.5		
MAFF limits in fish muscle (mg kg^{-1})[a]	0.2		20	2.0	50		
FAO (1983) Limits in fish muscle (mg kg^{-1})	0.5		30	0.5	30		
USEPA (1997) limits in sediments (mg kg^{-1}) TEL	0.676		18.7	30.2	124		
EOS (1993) MPL in fish (mg kg^{-1})	0.5		20	2	40	30	10
EOS (1993) MPL in water MPL	0.01		1	0.1	5	0.3	0.01

MDL: Maximum desirable limits, MPL: Maximum permissible limits, TEL: Threshold effects levels, EOS: Egyptian organization for standardization, a: Source-Kebede and Wondimu (2004)

1989). For instance Zn and Cu are Cd antagonists and so adverse effects of high Cd intake can be reduced by above normal amounts of Zn and Cu in the body. Toxicity of metals is also dependent on dosage: Acute toxicity occurs as a result of large doses of a metal toxicant and symptoms appear rapidly and may result in death. Chronic toxicity is as a result of prolonged exposure to small doses of toxicants and symptoms appear gradually and may also lead to death. Factors that determine the toxicity of heavy metals in water include concentration, speciation, dissolved oxygen content (DO), hardness, temperature, physiochemical form (ionic or complexed), pH and presence of other metals or substances. Toxicity tends to increase as DO and hardness decrease and as temperature increases. According to Nnaji *et al*. (2007b), the net effect of heavy metal toxicity on aquatic systems is the reduction of production and income from fish and other aquatic resources.

METALS IN AQUATIC SYSTEMS

Metals in water are divided into dissolved and particulate fractions. The dissolved metal fraction is a better representation of the biologically active metals and so, they are largely responsible for the toxicity of heavy metals. The dissolved fraction of metals in water is the fraction that passes through a 0.45 μm filter while the particulate fraction of metals in water is total metals less dissolved fraction. Particulate metals are much less toxic than the dissolved metals (Zhen, 2008). Biney *et al.* (1994) stated that heavy metals, on entry into waterbodies, are partitioned between water, sediments, suspended solids and aquatic biota and they tend to accumulate more in sediments than in water and aquatic organisms (Lee *et al*., 2003; Mansour and Sidkey, 2003). However, heavy metals tend to accumulate more in the visceral tissues of fish than in the muscles (Nnaji *et al*., 2007a). Benson *et al.* (2006) stated that fishes are important bio-indicators of heavy metal loads in aquatic systems. According to Uzairu *et al*. (2008), sediments are important sinks for heavy metals from water in aquatic systems and are also crucial in the remobilization of trace metals to the water column under suitable conditions. The accumulation of metals in an aquatic environment has direct consequences on man and the ecosystem. Fish tend to bioaccumulate heavy metals which enter through their body surface, the highly permeable gill epithelial membranes and through ingestion/gastrointestinal absorption. Heavy metals accumulate more in the visceral tissues (liver, kidney, intestines etc) of fish than in other organs and least in the muscles (Cheung *et al*., 2006; Gbem *et al*., 2001). Heavy metals adsorb on sediments and there exists interchange of these metals and other chemical species between sediments and the water column. Adsorption which occurs when dissolved metals are attached to surfaces of particulate matter (notably iron, manganese and aluminum oxide minerals, clay and organic matter) is also strongly dependent on pH and of course, the availability of particulate surfaces and total dissolved metal content. The environment created by integrated fish farming systems is conducive for the accumulation of metals in water, fish and sediments. This is due to the fact that these metals are contained in chicken feed and manure which ensures that these metals get into the system and may reach dangerous levels after prolonged deposition of feed and manure into the system.

GLOBAL LIMITS FOR HEAVY SOME METALS IN AQUATIC SYSTEMS

There are some existing maximum limits for heavy metal contents in aquatic organisms, sediments and water and these are shown in Table 4. Regular analysis for metal contaminants in ponds used for integrated fish farming is necessary in order to ensure that these metals are not above recommended levels.

RECOMMENDATIONS FOR THE REDUCTION OF HEAVY METAL LOADS IN CHICKEN-FISH SYSTEMS

- Regular testing of water, sediments and fish for metals to ensure that they are not above desirable levels
- Depuration of fish to reduce heavy metal loads prior to selling them. However, depuration may not be effective if fish is raised in heavily polluted water
- Heavy metals accumulate more in the visceral tissues of fish (liver, kidney, gut etc.) and the removal of these tissues before fish is sold or consumed is recommended

- The use of heavy metal additives like arsenic and zinc in chicken feed should be discontinued or reduced drastically

CONCLUSION

The persistence and toxicity of heavy metals in man and aquatic organisms calls for the constant monitoring of the incidence of these metals in the environment. Chicken-fish farming is a means for the possible transfer of heavy metals into aquatic systems because the metals are contained in chicken feed and manure. Culturing fish in integrated chicken-fish farming systems may lead to the accumulation of these metals to unsafe levels and there's a need for adequate measures that will prevent the harmful effects of these metals.

REFERENCES

Adebowale, B.A. and O. Olubamiwa, 2008. Growth response of *Clarias gariepinus* juvenile to cocoa husk endocarp based diets. Agric. J., 3: 425-428.

Alexieva, D., S. Chobanova and A. Ilchev, 2007. Study on the level of heavy metal contamination in feed materials and compound feed for pigs and poultry in Bulgaria. Trakia J. Sci., 5: 61-66.

Alinnor, I.J. and I.A. Obiji, 2010. Assessment of trace metal composition in fish samples from Nworie River. Pak. J. Nutr., 9: 81-85.

Alkhalaf, N.A., A.K. Osman and K.A. Salama, 2010. Monitoring of aflatoxins and heavy metals in some poultry feeds. Afr. J. Food Sci., 4: 192-199.

Aquaculture South Africa, 1999. Water quality in Freshwater Aquaculture ponds. Primary industries and resources Fact sheet. www.pir.sa.gov.au.

Azmat, R., F. Aziz and M. Yousfi, 2008. Monitoring the effect of water pollution on four bioindicators of aquatic resources of Sindh Pakistan. Res. J. Environ. Sci., 2: 465-473.

Bae, D.S., C. Gennings, W.H. Carter Jr., R.S.H. Yang and J.A. Campain, 2000. Toxicological Interactions among arsenic, cadmium, chromium and lead in human keratinocytes. Toxicol. Sci., 63: 132-142.

Benson, N.U., M.U. Etesin, J.P. Essien, I.U. Umoren and M.A. Umoh, 2006. Tissue elemental levels in fin-fishes from Imo river system, Nigeria: Assessment of liver/muscle concentrations ratio. J. Fish. Aquatic Sci., 1: 277-283.

Bhattacharya, A.K., S.N. Mandal and S.K. Das, 2008. Heavy metals accumulation in water, sediment and tissues of different edible fishes in upper stretch of Gangetic West Bengal. Trends Applied Sci. Res., 3: 61-68.

Biney, C., T. Amuzu, D. Calamari, N. Kaba and I.L. Mbome *et al*., 1994. Review of Heavy Metals. In: Review of Pollution in the African Environment. Calamari D. (Ed.). CFA/FAO, Rome, pp: 293-300.

Boyd, C.E., 1982. Water Quality Management for Pond Fish. Elsevier Scientific Publishing Company, Amsterdam, New York.

Cang, L., Y.J. Wang, D.M. Zhou and H.Y. Dong, 2004. Heavy metals pollution in poultry and livestock feeds and manures under intensive farming in Jiangsu Province. China J. Environ. Sci., 16: 371-374.

Cheung, K.C. and M.H. Wong, 2006. Risk assessment of heavy metal contamination in shrimp farming in Mai Po Nature Reserve, Hong Kong. Environ. Geochem. Health, 28: 27-36.

Christensen, P. and B. Peacock, 1998. Manure as fertilizer. http://ucce.ucdavis.edu/counties/cetulare/pubgrape/ng797.htm.

Christopher, A.E., O. Vincent, I. Grace, E. Rebecca and E. Joseph, 2009. Distribution of heavy metals in bones, gills, livers and muscles of (Tilapia) *Oreochromis niloticus* from Henshaw Town Beach market in Calabar Nigeria. Pak. J. Nutr., 8: 1209-1211.

Costa-Pierce, B.A., 2002. Ecology as the paradigm for the future of aquaculture. In: Ecological aquaculture: The Evolution of the Blue Revolution. Costa-Pierce B.A. (Ed.). Blackwell Science, Oxford, USA., pp: 339-372.

EOS, 1993. Egyptian standard, maximum levels for heavy metal concentrations in food. ES 2360-1993, UDC: 546.19:815. EOS, Egypt.

Ellis, K.V., G. White and A.E. Warn, 1989. Surface Water Pollution and its Control. The Macmillan Press Ltd., London.

FAO, 1983. Compilation of Legal Limits for hazardous substances in fish and fishery products. FAO Fishery Circ., 464: 5-100.

FAO, 2003. Recycling of animal wastes as a source of nutrients for freshwater fish culture within an integrated livestock system. http://www.fao.org/docrep/field/003/AC526E/AC526E01.htm

FAO, 2006a. Regional review on aquaculture development 2. Near East and North Africa-2005. FAO Fisheries Circular 1017/2: 90. ftp://ftp.fao.org/docrep/fao/009/a0635e/a0635e00.pdf.

FAO, 2006b. State of the World Fisheries and Aquaculture. http://www.fao.org/docrep/009/a0699e/A0699E00.HTM

FAO, 2008. State of the world fisheries and aquaculture. Part 1: World review of fisheries and aquaculture-Overview. FAO, Rome. http://www.fao.org/docrep/w9900e/w9900e02.htm

FAO, 2010. State of the world fisheries and aquaculture. Part 1: World review of fisheries and aquaculture-Overview. FAO, Rome.

Fakayode, S.O. and I.B. Olu-Owolabi, 2003. Trace metal content and estimated daily human intake from chicken eggs in ibadan, Nigeria. Arch. Environ. Health, 58: 245-251.

Francis, T.F., A. Vathy, P.P. and N.R.A. Than, 2004. Integrated fish farming: A review. World Aqua., 35: 24-29.

Gabriel, U.U., O.A. Akinrotimi, D.O. Bekibele, P.E. Anyanwu and D.N. Onunkwo, 2007. Economic benefit and ecological efficiency of integrated fish farming in Nigeria. Sci. Res. Essay, 2: 302-308.

Gbem, T.T., J.K. Balogun, F.A. Lawal and P.A. Annune, 2001. Trace metal accumulation in *Clarias gariepinus* (Teugels) exposed to sublethal levels of tannery effluent. Sci. Total Environ., 271: 1-9.

Ha, P.Q. and B.C. Tuyen, 2010. Managing metals in vietnamese agriculture. http://www.avrdc.org/pdf/PROD8-managing_metals.pdf.

Huet, M., 1975. Textbook of Fish Culture: Breeding and Cultivation of Fish. Fishing News Books Ltd., West Byfleet, Surrey.

Islam, M.S., M.A.I. Kazi, M.M. Hossain, M.A. Ahsan and A.M.M.M. Hossain, 2007. Propagation of Heavy metals in poultry feed production in Bangladesh. Bangladesh J. Sci. Ind. Res., 42: 465-474.

Jackson, B.P., P.M. Bertsch, M.L. Cabrera, J.J. Camberato, J.C. Seaman and C.W. Wood, 2003. Trace element speciation in poultry litter. J. Environ. Qual., 32: 535-540.

Jennett, J.C., S.W. Effler and B.G. Wixson, 1980. Mobilization and Toxicological Aspects of Sedimentary Contaminants. In: Contaminants and Sediments 1. Baker R.A. (Ed.). Ann Arbor Science Publishers, USA., pp: 429-444.

Kebede, A. and T. Wondimu, 2004. Distribution of trace elements in muscle and organs of tilapia, *Oreochromis Niloticus*, from lakes Awassa and Ziway, Ethiopian. Bull. Chem. Soc. Ethiopia, 18: 119-130.

Kroodsma, I.W., 1986. Treatment of Livestock Manure: Air Drying and Composting Poultry Manure. In: Odour Prevention and Control of Organic Sludge and Livestock Farming. Nielson V.V., J.H. Voorburg, P. L'Hermite, (Eds.). Elsevier Applied Science Publishers, London, pp: 166-174.

Lanyasunya, T.P., W.H. Rong, S.A. Abdulrazak, P.K. Kaburu, J.O. Makori, T.A. Onyango and D.M. Mwangi, 2006. Factors limiting use of poultry manure as protein supplement for dairy cattle on smallholder farms in Kenya. Int. J. Poult. Sci., 5: 75-80.

Laws, E.A., 1981. Aquatic Pollution. John Wiley and Sons, New York.

Lee, S., J.W. Moon and H.S. Moon, 2003. Heavy metals in the bed and suspended sediments of anyang river, Korea: Implications for water quality. Environ. Geochem. Health, 25: 433-452.

Little, D. and J. Muir, 1987. A Guide to Integrated Warm Water Aquaculture. Institute of Aquaculture Publications, University of Stirling, UK.

Little, D.C. and P. Edwards, 2003. Integrated livestock-fish farming systems. Inland Water Resources and Aquaculture Service Animal Production Service. FAO, Rome. ftp://ftp.fao.org/docrep/fao/006/y5098e/y5098e00.pdf.

Lovei, M. and B.S. Levy, 2000. Lead exposure and health in central Eastern Europe. Evidence from Hungary, Poland and Bulgaria. World Bank, Washington D.C.

Luckey, T.D. and B. Venugopal, 1977. Metal Toxicity in Mammals. Plenum Press, New York.

Mansour, S.A. and M.M. Sidkey, 2003. The first comparative study between Lake Ouarum and Wadi El-Rayan. Food Chem., 82: 181-189.

Mariakulandai, A. and T.S. Manickam, 1975. Chemistry of Fertilizers and Manures. Asia Publshing House, New York.

Martin, J.H. Jr., R.C. Loehr and T.E. Pilbeam, 1983. Animal manures as feedstuffs: Nutrient characteristics. Agric. Wastes, 6: 131-166.

Menzi, H. and J. Kessler, 1998. Heavy metal content of manures in Switzerland. Proceedings of the FAO-Network on Recycling Agricultural, Municipal and Industrial Residues in Agriculture (RAMIRAN) Conference, Rennes, France. May 28-29, FAO, Rome, pp: 495-506.

Muller, Z.O., 1980. Feed from animal wastes: State of knowledge. FAO Animal Production and Health Paper 18. pp: 190. http://www.fao.org/DOCREP/004/X6518E/X6518E00.htm.

Musaiger, A.O. and R.D` Souza, 2008. Chemical composition of raw fish consumed in Bahrain. Pak. J. Biol. Sci., 11: 55-61.

NACA, 1989. Integrated fish farming in China. NACA Technical Manual 7. A World Food Day Publication of the Network of Agriculture Centre in Asia and the Pacific, Bangkok, Thailand, pp: 1-278.

NACA, 2007. Report on the workshop on research needs in sustaining the aquaculture sector in Asia-pacific to Year 2025 and Beyond, 4-7th June 2007, Rayong, Thailand. Network of Aquaculture Centres in Asia and the Pacific, Bangkok. pp: 10.

Nahm, K.H., 2003. Evaluation of the nitrogen content in poultry manure. World Poult. Sci. J., 59: 77-88.

National Institute for Freshwater Fisheries Research, 1995. Report of the national aquaculture diagnostic survey, NIFFR, New Bussa-Nigeria. pp: 102-113

Nnaji, C.J., F.C. Okoye and J.O. Ogunseye, 2003. Integrated fish farming practices with special reference to combination rates production figures and economic evaluation. Proceedings of the 18th Conference of Fisheries Society of Nigerian (FISON). Dec. 8-12, Owerri, pp: 173-178.

Nnaji, J.C., A. Uzairu, G.F.S. Harrison and M.L. Balarabe, 2007a. Heavy metals in the muscles of *Oreochromis niloticus* and *Synodontis schall* of River Galma, Zaria, Nigeria. Biol. Environ. Sci. J. Trop., 4: 181-185.

Nnaji, J.C., A. Uzairu, Harrison, G.F.S. and M.L. Balarabe, 2007b. Evaluation of cadmium, chromium, copper, lead and zinc concentrations in the fish head/viscera of oreochromis niloticus and synodontis schall of river galma, zaria, Nigeria. EJEAFChe, 6: 2420-2426.

Nnaji, J.C., F.C. Okoye, C.T. Madu, V.O. Omeje, C. Wonah, Nuhu, M. and J. Isah, 2009a. Optimum temperature and transportation density for tilapia (*Oreochromis niloticus*) broodstock in the semi-arid zone of Nigeria. J. Aquat. Sci., 24: 21-24.

Nnaji, J.C., C.T. Madu, V.O. Omeje, J.O. Ogunseye and J. Isah, 2009b. An integrated chicken-fish system in concrete ponds. Proceedings of the 24th Conference of Fisheries society of Nigerian (FISON). Oct. 25-28, Akure, pp: 51-54.

Prein, M., 2002. Integration of aquaculture into crop-animal systems in Asia. Agric. Syst., 71: 127-146.

Prinsloo, J.F., H.J. Schoonbee and J. Theron, 1999. The production of poultry in integrated aquaculture-agriculture systems. Water SA., 25: 221-230.

Ramadan, M.A.E. and S.M. Adam, 2007. The effect of chicken manure and mineral fertilizers on distribution of heavy metals in soil and tomato organs. Aust. J. Basic Applied Sci., 1: 226-231.

Sinha, V.R.P., 1985. Integrated Carp Farming in Asian Country. Network of Aquacuture Centres in Asia, Bangkok. http://www.fao.org/docrep/field/003/ac236e/ac236e00.htm.

Taiganides, E.P., 1978. Principles and techniques of animal waste management and utilization. FAO Soils Bull., 36: 341-362.

The Ecochem Company, 2010. Manure is an excellent fertilizer. http://www.ecochem.com/t_manure_fert.html.

Tuleum, C.D., 1992. The utilization of heat treated poultry manure in chick's diets. Proceedings of the 17th Annual Conference of the Nigerian Society of Animal Production, Abuja. March 23-27, N.S.A.P, pp: 8-12.

UNEP, 1999. Report on the Development and Harmonization of Environmental Standards in East Africa. Volume 2. pp: 1-4.

USEPA, 1997. The incidence and severity of sediment contamination in surface waters of the United States. EPA 823-R-97-006.

Uzairu, A., G.F.S. Harrison, M.L. Balarabe and J.C. Nnaji, 2008. Trace metal assessment of River Kubanni, Northern Nigeria. Braz. J. Aquat. Sci. Technol., 12: 39-47.

Willman, R., M. Halwatt and U. Barg, 1998. Integrating fisheries and agriculture to enhance fish production and food security. FAO Aquacult. Newslett., 20: 3-9.

Wachira, A., 2000. Average composition of chicken manure. http://www.infonet-biovision.org/default/ct/602/products.

Wakawa, R.J., A. Uzairu, J.A. Kagbu and M.L. Balarabe, 2008. Impact assessment of effluent discharge on physico-chemical parameters and some heavy metal concentrations in surface water of River Challawa Kano, Nigeria. Afr. J. Pure Appl. Chem., 2: 100-106.

Weatherley, A.H., P.S. Lake and P.L. Stahal, 1988. Zinc Pollution and Ecology of the Environment: In Zinc in the Environment and Ecological Cycling. John Wiley, New Yark, pp: 337-417.

Yejin, Y., Z. Yun, H. Dan and W. Junhua, 1987. Preliminary studies on the effects of fresh and fermented pig manures on fish production. Proceedings of integrated fish farming systems. Freshwater Fisheries Research Centre of Chinese Academy Fishery of sciences.

Zaidi, M.I., A. Asrar, A. Mansoor and M.A. Farooqui, 2005. The heavy metal concentration along roadside trees of quetta and its effects on public health. J. Applied Sci., 5: 708-711.

Zhen, G., 2008. Hydrodynamics and Water Quality. Wiley Interscience, New York.