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RESEARCH ARTICLE

ENVIRONMENTAL IMPACTS OF AQUACULTURE IN URBAN WASTEWATER

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ABSTRACT

The role of aquaculture in world food production is increasing very fast, contributing with more than 40% for the total production of aquatic organisms. The general approach in modern aquaculture resembles much that of industrial agriculture and husbandry, with large energy subsidies and the usage of many chemicals in, predominantly, monoculture systems, with a large ecological footprint. In spite of the large body of regulation available worldwide, there are important ecologic, economic and social impacts in many countries as a result of aquaculture. In some cases, the anticipation of these impacts by local populations represents a negative feedback for aquaculture development. In the present work, a review of those impacts is presented, followed by a discussion of the carrying capacity concept, then by presenting some approaches and methods that may help planning aquaculture developments including the Drives Pressures States Impacts Responses framework, modeling and Decision Support Systems and, finally, by a synthesis of aquaculture related legislation worldwide. In the 21st century the fresh water scarcity increased very rapidly due to the urbanization and industrialization process. In these conditions the urban wastewater plays an important role in the water usage criteria. In this aspect, in all the major cities, wastewater treatment plants have been constructed to treat the urban wastewater in view of decreasing the water scarcity. The presence of nutrients in the wastewater is considered as beneficial to agricultural and aquaculture practices. The contaminants present in the wastewater pose health risks directly to agricultural and aquaculture system and indirectly to the consumers as the long term application of the wastewater may result in the accumulation of toxic elements in fishes. In this way the heavy metals will circulate among the food chain and food web to cause adverse effects on human health as well as on soil health. In the present study an attempt has been made to study the characteristics of urban wastewater at wastewater treatment plant of Mysuru city, also heavy metal concentration was studied in fishes and wastewater.

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INTRODUCTION

Aquaculture units can generate considerable amounts of wastes/effluents containing a variety of substances such as, particulate material (mainly resulting from uneaten feed and faecal material), dissolved metabolites (from excretion via gills and kidneys), and various forms of chemicals (e.g. the-rapeutants, fertilizers, heavy metals), with undesirable environmental consequences (Wu 1995; Kelly *et al.,* 1996; Deb 1998; Tovar *et al.,* 2000a, 2000b; Pearson and Black 2001; PáezOsuna 2001a, 2001b; Read and Fernandes 2003). The environmental impact resulting from particulate and dissolved organic and inorganic material is particularly important because these compounds are directly discharged into the environment affecting both the water column and the sediment compartment (Dalsgaard and Krause-Jensen 2006; Holmer *et al.,* 2007). The magnitude of these impacts depends mainly on farm location, species, culture type, stocking densities, food digestibility, and on other husbandry factors such as feeding strongly influence the fate of any type of waste released into the water column. For instance, high-energy environments, well swept by bottom currents, are usually less affected by the impacts of waste material than low-energy environments, most likely due to the contribution of hydrodynamics to the dissipation and dispersion of exogenous material (Klaoudatos *et al.,* 2006). Furthermore, re-suspension periodically reexposes superficial sediments and waste products to oxygen, enhancing organic matter de-composition (Burdige 2006). Conversely, in shallow waters or in restricted exchange environments (e.g. semi-enclosed estuaries, bays or fjords) with weak bottom currents, there is a higher risk of particulate organic matter and nutrients to increase locally (Wallin and Hakanson 1991), causing not

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only the degradation of water quality but also severe nega-tive impacts on benthic assemblages. Effluents from intensive production systems, with a large feed input, typically have greater negative impacts than effluents from semi-intensive or extensive systems with little or no feed addition (Kautsky *et al.,* 2000; PáezOsuna 2001a; Banas *et al.,* 2008). Species cultured in intensive systems, usually high trophic level species, have a higher ecological footprint than those producing lowtrophic level species, as omnivorous or herbivorous fish (e.g. catfish, tilapia) by the environment (Karakassis *et al.,* 2000; Choo 2001; Páez-Osuna 2001a; Pearson and Black 2001; King and Pushchak 2008). For instance, a study carried out by Folke *et al.,* (1998) revealed that Atlantic salmon marine cage farming requires an ecosystem area 40000 to 50000 times higher than the farm area. However, as feed technology improves and higher feed conversion rates (FCR) are attained, the footprint of intensive carnivore production is likely to decrease (Black 2001). An additional factor contributing to the high ecological footprint of carnivorous aquaculture is the use of the so-called "trash fish" (i.e. fish unfit to human consumption) for the production of pelleted diets, which consumes a large quantity of natural resources (Black 2001).

The most environmentally benign production systems are probably those cultivating species from the base of the food web, like seaweeds or filter-feeders (Crawford *et al.,* 2003). However, even these systems may have a relevant ecological footprint, depending on the location, farm di-mension and stocking densities (Folke *et al.,* 1998; Black 2001; World Bank 2006). For instance, large amounts of biodeposits (e.g. bivalves' faeces and pseudofaeces) may induce changes on benthic processes and benthic communi-ties (Buschmann *et al.,* 1996; Kaiser 2001; SECRU 2002; Watson-Capps and Mann 2005), with consequences for the entire ecosystem. Aquaculture systems combining species from different trophic levels (e.g. fish-shellfish or fish-seaweeds polyculture) or integrated with other activities like agriculture or waste treatment may significantly lower the environmental impacts of aquaculture because nutrients and organic matter are recycled within the system (Buschmann *et al.,* 1996; World Bank 2006). Inputs of inorganic compounds (e.g. ammonia, nitrates, nit-rites and phosphates) through organic matter breakdown, animal excretion and pond fertilization may also have potentially hazardous effects on the surrounding environment (Wu 1995; Buschmann *et al.,* 1996; Deb 1998; Tovar *et al.,* 2000a, 2000b; Páez-Osuna 2001a; Pearson and Black 2001; Read and Fernandes 2003; Biao and Kaijin 2007; Pérez *et al.,* 2008; Rodriguez-Gallego *et al.,* 2008). Most of the undesirable ecological consequences related to the excessive nutrient availability from aquaculture discharges are related to eutrophication, and include, for example, hypernutrification and the depletion of dissolved oxygen that cause the deterioration of water quality (Tovar *et al.,* 2000a; Read and Fernandes, 2003). Nutrient loadings also contribute to the pool of plant nutrients in aquatic systems, stimulating the growth of primary producers (Read and Fernandes, 2003; Biao and Kaijin, 2007) and even changing the structure and composition of these key communities (SECRU 2002). The overuse and misuse of chemicals in aquaculture operations is also a reason for apprehension due to the pollution and contamination effects that it may have on the aquatic The main environmental risks associated with the use of chemical compounds relate to: i) deterioration of water quality, ii) interference on biogeochemical processes, iii) direct toxicity to wild fauna and flora, iv) development of resistance by pathogenic organisms, and v) reduction of the prophylactic efficiency of therapeutants (Costello *et al.,* 2001). The improper use of chemical compounds may also affect the safety of the aquaculture products, constituting a threat to human health (Choo 2001, Islam *et al.,* 2004).

Study Area

Mysuru is a unique city and was the capital city of former princely state of Karnataka. It has kept alive the royal traditions and spender. City has adequate water supply resources due to the proximity of Rivers Cauvery and Kapila. The topography of the city is such that the entire Urban wastewater drains into three valleys viz., northern out-fall into Kesare Valley, and other outfalls to the south one into Dalvai tank feeder valley and another to Malalavadi tank valley. Based on the topography of the city, Mysuru city comprises of five drainage districts, namely, A, B, C, D and E districts respectively, covering different areas. The city has been provided with three wastewater treatment plants. Drainage districts of A & D have the wastewater treatment plant of capacity 60.00 MLD, which is located at Rayankere, H.D.Kote Road, Mysuru. The treatment plant for drainage district B is of capacity 67.65 MLD, which is located at sewage Farm, Vidyaranyapuram, Mysuru. The treatment plant for drainage district C is of capacity 30.0MLD, which is located at Kesare Village, Mysuru. City serves as a growth centre with intent to release the stress on the bangaluru metropolitan city. The following sampling stations were selected for the present study located at wastewater run-off and Wastewater irrigated areas of Semi-urban regions of Mysuru city.

Table 1. Sampling location

S.No	Sampling Site	Sampling Location
1	Gudumadanahalli	N 12^0 14' 15.4528'' E 76^0 39' 29.9412''
2	Hebbal	N 12^0 21' 36.5076'' E 76^0 36' 42.0804''
3	Kesare	N 12^0 21' 7.2936'' E 76^0 39' 53.6868''
4	Gurur	N 12^0 14' 15.738'' E 76^0 37' 10.3476''
5	Sidhalingapura	N 12^0 21' 38.394'' E 76^0 39' 57.6612''
6	Vidyaranyapuram	N 12^0 16' 34.4208'' E 76^0 39' 16.1028''

Sample Collection and Analysis

Samples may change very rapidly. However, no single preservation method will serve for all samples and constituents, so the purpose of sample preservation is to minimize any physical, chemical, and biological changes that may take place in a sample from the time of sample collection to the time of sample analysis. Variation in water quality is the most important factor to assess in water resources research and risk management. Semi-urban water samples from six locations of the sampling stations were collected in polyethylene cans and bags. All the samples were brought to laboratory and stored at 4°C. The separate samples of untreated Semi-urban samples of one litre capacity in polyethylene cans were collected for heavy metal analysis and preserved by adding 2 ml of concentrated nitric acid to prevent precipitation of metals and growth of algae. Inductively Coupled Plasma Atomic Emission Spectroscopy techniques, (ICPAES) using the Perkin-Elmer

Optima 8000, ICP-OES. Also, referred to as Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) is an analytical technique used for the detection of Heavy Metals. Samples were analyzed on the same day of collection and samples were analyzed according to methods in APHA, 2008.

RESULTS AND DISCUSSION

Indicators of Water Quality for Agricultural Use

The indicators mainly consist of certain physical and chemical characteristics to interpret the secondary parameter indexes. It helps evaluation of agricultural water quality

a) **Percent sodium**: Percent sodium in water is a parameter computed to evaluate the suitability for irrigation (Wilcox, 1948, and Tiwari, and Manzoor, 1988). Excess sodium in waters produces the undesirable effects of changing soil properties and reducing soil permeability. Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation. The quantities of all cations are expressed in milli equivalents per liter.

- $Na\% = [(Na^{+} + K^{+}) / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})] 100$

Table 2. Classification based on values of Secondary indexes

Percent sodium	Sodium Absorption Ratio	Residual sodium carbonate	Permeability index	Kelly's ratio
<20 (Excellent)	<10 (Excellent)	<1.25 (Safe)	Class I (<75%)	<1 (Safe)
20-40 (Good)	10-18 (Good)	1.25-2.5 (Marginal)	Class II (> 75%)	>1 (Unsafe)
40-60 (Permissible)	18-26 (Fair)	>2.5 (Unsuitable)		
60-80 (Doubtful)	>26 (Poor)		Class III (Unsuitable > 25%)	
>80 (Unsuitable)				

Table 3. Calculated secondary parameters indexes of untreated semi-urban wastewater used for aquaculture in Monsoon season

Parameters / Sampling Stations	Sodium Percentage (%)	Sodium Absorption Ratio	Permeability Index (%)	Kellys Ratio (meq/L)	Residual Sodium Carbonate (meq/L)
Gudumadanahalli	20.2	6.07	65	0.22	-13.5
Hebbal	19.5	7.04	64	0.32	-20.5
Kesare	37.9	12.46	11	0.48	7.0
Gurur	19.9	6.41	70	0.19	-13.6
Sidhalingapura	10.7	2.94	61	0.22	-14.3
Vidyaranyapuram	26.4	8.35	92	0.22	-30.5

Table 4. Calculated secondary parameters indexes of untreated semi-urban wastewater used for aquaculture in Post Monsoon season

Parameters / Sampling Stations	Sodium Percentage (%)	Sodium Absorption Ratio	Permeability Index (%)	Kellys Ratio (meq/L)	Residual Sodium Carbonate (meq/L)
Gudumadanahalli	10.6	2.71	60	0.13	-12.3
Hebbal	13.9	4.69	64	0.15	-18.3
Kesare	41.1	11.63	15	0.36	16.0
Gurur	8.8	2.87	60	0.10	-20.1
Sidhalingapura	28.5	7.55	12	0.40	7.4
Vidyaranyapuram	43.3	1.31	50	0.04	-23.5

Table 5. Calculated secondary parameters indexes of untreated semi-urban wastewater used for aquaculture in Winter season

Parameters / Sampling Stations	Sodium Percentage (%)	Sodium Absorption Ratio	Permeability Index (%)	Kellys Ratio (meq/L)	Residual Sodium Carbonate (meq/L)
Gudumadanahalli	12.0	3.17	11	0.08	-12.3
Hebbal	12.5	3.92	54	0.11	-18.3
Kesare	39.1	12.00	15	0.28	16.0
Gurur	16.0	4.96	76	0.12	-20.1
Sidhalingapura	15.4	5.17	79	0.39	7.4
Vidyaranyapuram	18.2	6.43	48	0.30	-23.5

Table 6. Calculated secondary parameters indexes of untreated semi-urban wastewater used for aquaculture in Summer season

Parameters / Sampling Stations	Sodium Percentage (%)	Sodium Absorption Ratio	Permeability Index (%)	Kellys Ratio (meq/L)	Residual Sodium Carbonate (meq/L)
Gudumadanahalli	11.7	3.79	73	0.22	-12.6
Hebbal	14.9	5.67	46	0.32	-35.8
Kesare	40.3	12.28	10	0.48	21.0
Gurur	30.5	8.21	88	0.19	-4.7
Sidhalingapura	10.1	3.27	66	0.11	-16.0
Vidyaranyapuram	31.2	12.08	58	0.43	-22.7

Table 7. Statistics of Secondary indexes in Monsoon and Post Monsoon seasons

Secondary Parameters	Monsoon Season				Post Monsoon Season			
	Maximum	Minimum	Mean	SD	Maximum	Minimum	Mean	SD
Sodium Percentage (%)	37.9	10.7	21.64	9.92	43.3	8.8	24.36	15.47
Sodium Absorption Ratio	12.46	2.94	6.98	3.44	11.63	2.71	5.61	4.08
Permeability Index (%)	92	11	54.2	24.36	64	12	43.5	23.71
Kellys Ratio (meq/L)	0.48	0.19	0.286	0.11	0.40	0.04	0.19	0.14
Residual Sodium Carbonate(meq/L)	7.0	-30.5	-10.98	1.46	16.0	-23.5	-8.46	16.26

Table 8. Statistics Secondary indexes in Winter and Summer seasons

Secondary Parameters	Winter Season				Summer Season			
	Maximum	Minimum	Mean	SD	Maximum	Minimum	Mean	SD
Sodium Percentage (%)	39.1	12.0	32.34	4.38	40.3	10.1	23.11	12.50
Sodium Absorption Ratio	12.00	3.17	10.18	2.30	12.28	3.27	7.55	3.98
Permeability Index (%)	79	11	80.85	26.16	88	10	56.83	26.94
Kellys Ratio (meq/L)	0.39	0.08	0.36	0.15	0.48	0.11	0.29	0.14
Residual Sodium Carbonate(meq/L)	16.0	-23.5	-14.51	7.91	21.0	-35.8	-11.8	19.17

In the study of UWW character, percent sodium is one of the important tools to be analyzed since the UWW is being used in the agricultural field. The UWW was said to be as good to excellent in the five sampling stations, whereas it ranges near 40 % in Kesare sampling site during all the collected season indicates the entry of organic matter to the treatment plant.

Sodium Absorption Ratio (SAR): Sodium Absorption Ratio may be determined by the formula (epm). There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. High concentrations of sodium in soils affect its physical condition and soil structure resulting in formation of crusts, water infiltration rate, and reduced soil permeability. Excessive concentrations of sodium in soils may also be toxic to certain types of crops. SAR gives a very reliable assessment of water quality of irrigation water with respect to sodium hazard, since it is more closely related to exchangeable sodium percentages in the soil than the simpler sodium percentage (Tiwari, and Manzoor, 1988). Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure. It becomes compact and impervious. SAR is an important parameter for the determination of the suitability of water for irrigation, because it is responsible for the sodium hazard (Todd, 1995). The water was classified in relation to irrigation based on the ranges of SAR values (Richards, 1954). Concentrations are expressed in milli equivalents per liter.

- $SAR= Na + /\sqrt{[(Ca^{2+} + Mg^{2+}) /2]}$

In the present study, the SAR values lies between 2.94 to 12.46 in the monsoon season. The maximum value of SAR identified as Good due to the concentration exceeds 10 and the SAR value falls below 10, it classified as Excellent. In the post monsoon and pre monsoon sample, except Kesare treatment plant, all the sampling station showed Excellent, but Kesare treatment plant values lies after 10, hence it can be termed as Good but it may not be suitable for irrigation purposes.

b) Residual Sodium Carbonate (RSC) : Residual sodium carbonate in irrigation water is used to indicate the alkalinity hazard for soil. It was calculated employing the following equation (Eaton, 1950) and simply expressed as milli equivalents per liter.

- $RSC= (CO_3^{2-} + HCO_3^{-}) – (Ca^{2+} + Mg^{2+})$

The classification of irrigation water according to RSC values, the water containing more than 2.5 meq/l are considered are not suitable for irrigation purposes. Less than 1.25 meq/l is considered as safe and 1.25-2.5meq/l are to be put in the marginal range of usage. The collected water samples UWW of Mysuru city, the wastewater of all the treatment plant except Kesare, falls within the safe range and can be used for irrigation. But the Kesare treatment plant lies above the 2.5meq/l it can't be used for the agriculture purpose due to the presence of more ionic concentration.

c) Permeability index (PI): Permeability is index used to evaluate the sodium hazards of irrigation water. This calculated employing the equation (Domenico, 1990)

- $PI = [(Na^{+} + HCO_3^{-}) /(Ca^{2+} + Mg^{2+} + Na^{+})] 100$

On the basis of the above calculation, the water sample can be classified as Class-I, Class-II and Class-III. In this study of UWW, the water samples have been classified as Class-I for five sampling stations since the values falls in the class-I category and Class-II for Vidyaranyapuram UWW plant but Class-I and Class-II water can be used for the agricultural purposes.

d) Kelly's ratio (KR): Kelly's ratio in water for irrigation purposes is also assessed on the bases of (Kelly, 1963) ratio of sodium verses calcium and of sodium verses magnesium. Where, concentrations of all ions have been expressed in meq/L. Water with a KR value <1 are considered suitable for irrigation, while those with greater ratios are rendered unsuitable and expressed as milli equivalents per liter.

- $KR= Na^{+}/ (Ca^{2+} + Mg^{2+})$

For the determination of water quality for the agricultural uses these kelly's ratio plays an important role. The analuzed results indicated that, the UWW of Mysuru city is considered as Safe for the agriculture purposes since the values comes within the prescribed range.

Conclusion

A worldwide comprehensive development plan is required for wastewater treatment technology in the aquaculture industry. Only a few countries have developed wastewater management plans for aquaculture for the protection of the environment and its natural resources. The presence of nutrients in the wastewater is considered as beneficial to agricultural and aquaculture practices. The contaminants present in the wastewater pose health risks directly to agricultural and aquaculture system and indirectly to the consumers as the long term application of the wastewater may result in the accumulation of toxic elements in fishes. In this way the heavy metals will circulate among the food chain and food web to cause adverse effects on human health as well as on soil health. In the present study an attempt has been made to study the characteristics of urban wastewater at wastewater treatment plant of Mysuru city, also heavy metal concentration was studied in fishes and wastewater. This research implies that, the untreated wastewater can be used for the aquaculture purposes was not suitable. secondary analyzed parameters like SAR, PI, KR, and % Sodium were clearly indicates the fate of semi-urban wastewater which is not suitable for the aquaculture.

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