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Review

Research trends of aqua medicines, drugs and chemicals (AMDC) in Bangladesh: the last decade's (2011-2020) story to tell

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Abstract: Aquaculture medicines, drugs, and chemicals or simply AMDC, are critical in protecting aquaculture farmers from disease in farmed animals and economic losses. The AMDC is now a well-established industry in Bangladesh, and each year, new products that benefit farmers are launched. This review examined published research information on AMDC over the last decade (2011-2020) and discovered that 41 research publications from various parts of Bangladesh were published, citing the names of 1484 AMDC products. It was discovered that 19 generic antibiotics are well established and widely used in different regions' aquaculture, including shrimp aquaculture. Although some researchers expressed concern about the use of antibiotics in aquaculture, they believe that with proper withdrawal periods and the application of small doses, farmers may avoid economic losses. However, the pathway of the antibiotic introduction in aquaculture setup in Bangladesh was unknown to the researchers, through this review, we revealed the pathway of antibiotics introduction in aquaculture. Additionally, this review revealed that various AMDC products, including oxygen suppliers, growth promoter supplements, disinfectants, raw chemicals, probiotics, pond preparation and management AMDC, and toxic gas removal AMDC, are readily available in various markets throughout Bangladesh. The observation implied that research on the efficacy of various AMDC products in Bangladesh's agro-ecological zones could be conducted, which would aid researchers in deciphering the true nature of AMDC in sub-tropical climates.

Keywords: AMDC research; aqua drugs; aqua medicines; aqua chemicals; antibiotics; Bangladesh

1. Introduction

Successful and profitable aquaculture solely depends on some management norms, including seed selection, pond preparation, nursing, stocking density selection, feeding, routine checkup, disease management, water quality management, and lucrative final product to the end consumer (Biswas *et al*., 2018; Faruk *et al*., 2018; Sarker *et al.*, 2020; Sharif and Al-Asif, 2015). Some extensive aquaculture setup simply used to overlook the disease of aquaculture organisms, whereas they might face economic loss due to high mortality in disease and infections (Leung and Bates, 2013). Preventing mortality and economic loss, some specialist suggested

providing vaccines to the fishes or culture organism for particular disease resistance (Assefa and Abunna, 2018); for example, lake virus in tilapia (Zeng *et al*., 2021) and koi herpesvirus (Embregts *et al*., 2019). This vaccination program requires huge workflow, infrastructures, budgets and times for countries like Bangladesh; not last but least, the lack of experts on vaccination implication and research remain questionable. Aquaculture is a booming industry in Bangladesh, as the country's inland production is just lower than mainland China and this industry consider a second export contribution provider for the country (Shamsuzzaman *et al*., 2020, 2017). Adaptation of vaccine technology for particular fish species will be wise for long run consideration; but to keep stabilize the national production, export and connecting to the new global market, the disease management, and cure of affected animal should be crucial which will prevent the economic loss to the farmer of the country.

If we look back to the previous decades, while the country's aquaculture sectors start as a new emergence, the disease was one of the major challenges for the farmers who wanted to get a handsome profit from their farm (Aftabuddin *et al*., 2016; Faruk *et al*., 2004). We should not forget that aquaculture is a profit-making business along with serving the nation by providing animal protein. Mitigation of any sort of problem needs to handle professionally. The rural fish rearing ponds face less diseases and health problems due to low stocking densities and uninterrupted water bodies; while to make profit, aquaculturists often stocks the culture organisms in a high density, although there are some guides to stock the culture organisms (Hasan *et al*., 2010; M'balaka *et al*., 2012).

Aquaculture pond and water quality management also play a crucial role in a successful operational cycle; thus, some experts obviously suggested the biofloc and re-circulatory aquaculture system (RAS) (Appiah-Kubi, 2012; Crab *et al*., 2012). Even though RAS is reliable, disease preventive and profitable, the drawback of this technology is too expensive and it is difficult for our rural farmer to implement.

Nevertheless, the disease problems still remained unsolved in the Bangladeshi aquaculture industry, where experts always suggested the proper management is the key to fruitful and efficient operation; and however, they also suggested taking the support of available medication from the local market (Chowdhury *et al*., 2015).

The early stage of aqua medicine, drugs and chemicals were supported by village quack doctors who eventually treat the homestead animals such as cow, buffalo, etc., where they simply suggested applying lime ($CaCO_3$) in the pond water to solve all health problems. However, this idea was worked at that time due to these ponds and animal was solely reared for non-commercial purposes.

The establishment of different universities opened a wide door to treat our aquatic (mostly non-visible) reared animals. At the first stage, experts suggested the available veterinary drugs to treat aquatic animals; but while the companies or importer realized this sector might boom in the near future they brought aquaculture specific drugs, medicines and chemicals (Hoq *et al*., 2011; Ullah *et al*., 2020).

The big shot in the market remains the first comers; while some of the companies launched their agro-vet divisions, and aquaculture drugs were still overlooked for their lack of relevant expertise and negligence. Nowadays, most of the giant pharmaceutical companies have their animal health division to support the farmer of the country.

The rest of the chemicals which were used in Bangladesh for aquaculture purposes, they remained on the hand of old-fashioned businessmen, for example, lime, mustard oil cake, tea seed cake. But the situation was changed while one of the companies (ACI Animal health) imported powder lime (CaO) from Vietnam. The farmer instantly appreciated this product, and they started to use it in their culture pond (Rahman *et al*., 2017). With this example, it can be said that our chemical importer, businessmen, and companies really thinking about the advancement of this sector.

Research on aqua medicines, drugs and chemicals (AMDC) in Bangladesh was initiated by some research groups from Bangladesh Agricultural University. The first stage of these AMDC research was about to report the available drugs, chemicals, and medicines used in the rural aquaculture (Faruk *et al.*, 2004; Aktar *et al.*, 2020), on time being antibiotic resistance and use of antibiotic in animal become concern issues; while nowadays researchers in Bangladesh are really putting effort to examine the efficacy of the antibiotics, resistance capacity of different antibiotics in fishes and different aspects of antibiotics in aquaculture (Faruk *et al*., 2021; Lulijwa *et al*., 2020). The recent studies suggested that antibiotic use in aquaculture and aquatic ecosystem might be lead to the resistance of this substance (Hossain *et al.*, 2018; Rahman *et al*., 2009). On the other hand, veterinary farm (Dairy, cattle and poultry) waste products are widely used fertilizer in Bangladesh such as cow dung; however recent studies suggested that the use of antibiotic in poultry and cattle is becoming antimicrobial drug resistance, while use of these waste products (cow dung and poultry litter) in aquaculture setup increasing the probability of antibiotic resistance pathogens in aquaculture (Kabir *et al*., 2019; Sobur *et al*., 2019; Sarker *et al*., 2020; Alam *et al*., 2020; Neogi *et al*., 2020; Haque *et al*., 2021). In a long run which might be a threat to the industry. In the present review, we scrutinize all information regarding the use of

AMDC in Bangladesh, the research trends aspects, the antimicrobial pathways to the aquaculture setup and discussed the gap of AMDC research in Bangladesh.

2. Literature search strategy

The available literature on aqua medicines, drugs and chemicals (AMDC) were accumulated mainly from published articles from the periods of 2011 to 2020. The literature search was performed with Google Scholar web search using "Publish or Perish" software from January 2021 to May 2021 (Harzing, 2007). The specific keywords were inserted and search for the documents ("Bangladesh" AND ("Aqua medicines" OR "Aqua drugs" OR “aqua chemicals” OR "fish drugs" OR "fish medicines" OR "fish chemicals")). We extracted the papers related to aqua medicines, drugs and chemicals (AMDC) in Bangladesh from 2011 to 2020.

3. Animal health companies and business

Veterinary medicines companies and businesses have been well established in Bangladesh compared to aqua medicines and drug companies which are still young in this country. The previously published documents cited their names, products and activities in different regions (Chowdhury *et al*., 2015; Rahman *et al*., 2017; Sarker *et al.*, 2018; Ullah *et al*., 2020). We scrutinized some of the nationwide and local companies (Table 1), which reflects most human health pharmaceuticals companies remains the top market share holder of aqua-drug and aqua medicines. As previously mentioned, some companies are related to trading old-fashioned chemical commodities (Chowdhury *et al*., 2015; Rahman *et al*., 2017; Ullah *et al*., 2020); for instance, ACI Animal health has a distribution channel of lime (CaO). It is observed that some companies have other consumer products such as raw salt (NaCl) so that their business coverage in terms of medicinal, drugs and chemical products were found huge.

According to the published literature and personal communication with the relevant companies, it is revealed that ACI Animal Health found one of the leading companies having 27% of the market share. Other companies, such as Eon Animal Health, Square Agrovet Division, SK+F Animal Health, etc., have a significant market share of AMDC (aqua medicines, drugs and chemicals) (Figure 1).

4. Research trends of AMDC in the last decade

The extensive literature search on the AMDC (aqua medicines, drugs and chemicals) research revealed that the first published documents were traced on the last decade in 2011 by Hoq *et al*. (2011) and Khan *et al*. (2011) from the Mymensingh region. There was an interval of AMDC research publication found in 2013; but from the following year, the journey continued, and the last publication of the previous decade was traced by the research of Ullah *et al*. (2020), mainly from the Noakhali district of south-eastern Bangladesh. The trend analysis of AMDC research found a positive and sharp increase at the last of the decade; it is presumed that the new decade (2021-2030) will contribute a large number of research publications on different aspects (Figure 2).

4.1. Area wise research trends of AMDC in the last decade

According to AMDC research, the most documents were published in the Khulna region (34%; 14 documents), followed by Mymensingh (20%; 8 documents), Chattogram (15%; 6 documents), and Rajshahi (12%; 5 documents) (Figure 3). The Khulna division has a high number of publications due to the presence of universities (Khulna University, Jashore University of Science and Technology, and Khulna Agricultural University), Bangladesh Fisheries Research Institute (BFRI) stations, major shrimp producing regions, and the hatchery industry in this area. Mutual interest between businessmen and research institutions created a bridge for the successful establishment of aquaculture operations in that region (Hasan *et al*., 2015). However, Mymensingh is located very close to the country's capital city Dhaka, making it the most convenient region for feeding the megacity's millions of residents. Freshwater aquaculture production, particularly Pangas, tilapia, and koi, are very high in this region. The headquarters of BFRI and Bangladesh Agricultural University is also located here, encouraging researchers to conduct AMDC research on various topics in this area. On the other hand, Cumilla is one of the closest districts to the capital city of Dhaka, and the freshwater aquaculture industry is thriving there; numerous animal feed and pharmaceutical companies have established regional offices in Cumilla, and the aquaculture disease consultants are primarily university graduates who share their professional expertise and interests with farmers and businessmen, thereby avoiding some impediments (Rahman *et al*., 2017; Ullah *et al*., 2020) (Figure 4).

4.2. Total AMDC reported

The literature from 2011 to 2020 reported 1484 names, types, and generics of AMDC from different part of Bangladesh. Among the literature, in 2020, the highest number of AMDC were reported (Das *et al*., 2020; Hasan *et al*., 2020; Ullah *et al*., 2020), followed the year 2017 (208 AMDC), 2014 (196 AMDC), 2019 (189 AMDC) and it is observed some reported AMDC in every year except 2013; due to lack of any published document in 2013, we did not find any AMDC in that year (Figure 5). The result of this analysis gives an understandable trend that, the farmer's preferences of AMDC is raising in a different part of the country.

On the other hand, the reported AMDC from the Chattogram district is comparatively higher (455 AMDC) than in any other part of the country. This is because aquaculture farmers in the Chattogram district have adapted to new technology at a much faster rate (455 AMDC) than in any other part of the country (Figure 6). In another light, the aquaculture setups in Chattogram, particularly in Cumilla and Noakhali, are extremely intensive in nature, with frequent outbreaks of disease and mismanagement, necessitating the use of AMDC by farmers.

4.2.1. Antibiotics

The uses of antibiotics are not a pleasant phenomenon in aquaculture. The development of antimicrobial drug resistance, hypersensitive reaction, carcinogenicity, mutagenicity, teratogenicity, bone marrow depression, and disturbance of normal intestinal flora are all serious public health implications of antibiotic residues (Miranda *et al*., 2018; Okocha *et al*., 2018; Schar *et al*., 2020). However, uses of antibiotics in aquaculture is regulated by the conventional laws of the state for instance, National drug policy-2005, Fish feed and animal feed act-2010, National livestock development policy-2007, National strategy for ARC (Antimicrobial resistance containment)-2011 and Road map of a national action plan for ARC (Hosain *et al*., 2021). Nevertheless, several studies of last decades indicated several antibiotics of different generics and trade names were reported from different part of the country. We found alone in 2020, a total of 58 antibiotics were reported from different regions (Figure 7). At the same time, the farmers of Chattogram regions are the major user of antibiotics (56 antibiotics) (Figure 8). The problems of antibiotic uses in aquaculture are recently put into concern by the research of Lulijwa *et al*. (2020). The research of Lulijwa *et al*. (2020) provided the data of antibiotic uses in top aquaculture producer countries, including Bangladesh, China, India and Vietnam. However, they reported 19 antibiotics are being used in Bangladeshi aquaculture. The government needs to put this matter into a high priority and concern to impose strict regulation and monitoring at the field level. As Bangladesh is a top aquaculture producer and exporter in the world, if the importer countries will impose a ban on the export of aquaculture products, especially the shrimp and Pangas fillet, it will change our fisheries sector drastically. Another publication from Cumilla (Rahman *et al*., 2017) also reported 19 antibiotic generics while many of the antibiotics which are being used by farmers and suggested thru practitioner and consultant practically did not come out in the last decades documents.

4.2.2. Exposure pathway of antibiotics in aquaculture

Uses of antibiotics became burning issue in live food and meat production industries including aquaculture (Lulijwa *et al*., 2020). In whatever form we use antibiotics in live food production, it used to returns to the end user human and causes considerable complication to the human body, environment and aquatic ecosystems (Brunton *et al*., 2019; Rasul and Majumdar, 2017). The pathway analysis revealed that, antibiotic vendors with intentional medicinal uses purpose are the major source of antibiotics in aquaculture (Figure 9). However, the other reason might be uses of cow dung as fertilizer in aquaculture pond. Cow dung is widely used raw materials in the aquaculture setup (Jha *et al*., 2004). The recent study suggested that, use of antibiotics in cattle farm, and later on these cattle farm waste (waste disposal including cow dung, faecal waste and) served as fertilizer in aquaculture which might be severe source of antibiotic introduction of aquaculture setup (Kabir *et al*., 2019; Sobur *et al*., 2019). However, the most terrible scenario was reported by Ashrafun *et al*. (2019), where they revealed the tetracycline resistant *E. coli* and *Salmonella* spp. from different source, as tetracycline is widely used antibiotic in aquaculture industry of Bangladesh. So far indiscriminate uses of antibiotics are leading the aquaculture industry to the antimicrobial resistance bacterial species, which can be considered as dangerous phenomenon in long run. Another mentionable source of antibiotics in aquaculture pond is poultry and duck litter disposal in aquaculture pond for increment of phytoplankton and primary productivity of pond. Interestingly, recent research suggested that, some pathogenic bacteria which are available in all farms

environment found antibiotic resistance characters, such as *Aeromonas hydrophila* in broiler farm (Sarker *et al*., 2020), *Campylobacter* spp. in small scale commercial broiler farms (Alam *et al*., 2020), *Campylobacter* spp. in poultry farms and live bird markets (Neogi *et al*., 2020), *Salmonella* in small-scale commercial layer flocks (Haque *et al*., 2021), and *Campylobacter* species in ducks (Uddin, 2018). This phenomenon suggested that use of poultry litter in aquaculture might grow the antimicrobial resistance capacity for the pathogenic microbes in aquatic environments, which obviously will not be a wise idea for the practitioners and aquaculturists. The use of antibiotics in different fish feed are practiced globally, but this were rarely reported (Agoba *et al*., 2017), however this might be considered another source of antibiotics introduction in aquaculture pond. The waste of pharmaceuticals industry used to dispose directly in the river environments without any treatment; thus some aquaculture setup adjacent to rivers might be affected and the antibiotics might improve the resistance capacity of pathogens. We found some another causes of antibiotic introduction to the aquaculture ponds such as introduction of antibiotics through migratory birds, homestead waste having antibiotic residue disposal to the aquaculture ponds.

4.2.3. Other chemicals

The published documents over the last decades have provided invaluable information to aquaculturists, practitioners, businessmen, policymakers, think tanks, and a variety of other civil groups involved in the aquaculture industry. Apart from antibiotics, the supplier of supplemental oxygen is critical in preventing economic losses in aquaculture operations (Chowdhury *et al*., 2015). Companies sell the oxygen in granular and tablet form using different brand names, although the ingredients are similar (Table 2). We found many brand names of oxygen tablets from different companies which were reported in the last decade. Growth promoter, for example, various vitamins, minerals, feed premix, additives, fish oil etc. were reported in the last decade by different research groups; Rahman *et al*. (2017), Chowdhury *et al*. (2015), Adhikary *et al*. (2018) and Rahman *et al*. (2019). In the market, ACIMIX premix (combination of different minerals) and vitamin C are very popular, which helps to boost fish growth in a short period.

Disinfectant is one of the most used chemicals in the freshwater and brackish water aquaculture (Hasan *et al*., 2015; Uddin *et al*., 2020). Due to improper management of the culture setup, overstocking, introducing diseased fish, and various other factors causing diseases to spread in aquaculture ponds. Farmers are advised to use disinfectant and follow consultant guidance in such circumstances. In most cases, a lower pH in the culture setup is to blame for the disease. Liming at an appropriate dose may help raise the pH and completely eradicate existing pathogenic organisms in the aquaculture setup (Chowdhury *et al*., 2015). However, the most popular disinfectant in Bangladesh found BKC (Benzal konium chloride) chemical, where the active ingredients are n-Alkyl dimethyl benzyl ammonium chloride 40%, stabilized urea 60% (Chowdhury *et al*., 2015). The market research suggested that the trade name Timsen by Eon Animal Health found most popular among the farmer and aquaculture disease experts. We noticed other disinfectants, such as Virex (ACI Animal Health), Aquakleen (Square Agrovet division); whereas some old-fashioned chemicals work as a magic disinfectant, for example, bleaching powder reported by Rahman *et al*. (2017).

The use of raw chemicals in aquaculture solely depends on lime, mustard oil cake, tea seed cake, Potassium permanganate, formalin, salt, malachite green, Methylene blue, diesel, kerosene etc. (Biswas *et al*., 2018). These chemicals are vastly available in the poison and seed for agriculture-related vending points, grocery stores and chemical shops. The use of the raw chemical is very vast, and they can be used from the eradication of unwanted organisms from culture setup to pond preparation, feeding setup, along disease treatments in aquaculture. In the last decade, many documents reported about the different raw chemicals, where recent publication of Das *et al*. (2020) reported the highest (7 chemicals) raw chemicals from aquaculture of Rangpur district in Bangladesh (Table 2). However, the appeal of the use of raw chemicals in aquaculture will retain the same due to its effectiveness and low cost.

Probiotics are other wings of AMDC, where it plays a vital role to prevent the disease introduction and outbreak by keeping the water quality in good form. However, the use of probiotics in farmers were not so widespread, but this technology used to adopt by most of the educated peoples who already familiar with this technology. The use of probiotics and other chemicals to prevent disease in aquaculture leads to the creation of biofloc technology theory, which is gaining popularity worldwide (Crab *et al*., 2012). We found many probiotics are

available and reported in the last decade, which can be considered a good sign that farmers are adopting new technology to increase production and reduce an economic loss (Akter *et al*., 2020; Chowdhury *et al*., 2015; Rahman *et al*., 2017).

Water quality management is one of the vital issues for successful aquaculture practice, while it requires regular monitoring and care (Hamli *et al*., 2013). This review revealed that many water quality maintaining products, including zeolite (ash of volcanic eruption), were very popular. It is also found that, based on single products (Zeolite), many local companies and importer is doing business nationwide. It is due to the zeolite is well known to the farmer, and it is comfortable to use in their aquaculture pond (Rahman *et al*., 2017; Chowdhury *et al*., 2015).

The use of Yucca (*Yucca schidigera*) extracts to remove ammonia from pond bottoms and water is extremely popular among farmers. While some experts have suggested using probiotics to remove toxic gases from culture ponds, there are situations while rapid gas removal is required, in which case extract of Yucca is found to be extraordinary. (Santacruz-Reyes and Chien, 2012, 2009). Interestingly dietary use of this plant extract in aquaculture also found effective somewhere else (Güroy *et al*., 2014; Tidwell *et al*., 1992).

Numerous gas removal products have been reported in the Bangladeshi market. In contrast, a recent publication indicated that the use of gas removal products (16 in total) are popular among farmers in Bogura (Akter *et al*., 2020) (Table 2).

Table 1. List of top animal health companies.

No.	Name of companies	No.	Name of companies
1	Eon Animal Health	16	Ultimate (BD) Ltd.
2	Square Agrovet Division	17	S.S.S Agro Care Ltd.
3	Novartis Pharmaceuticals Ltd.	18	Navana Limited
4	ACI Animal Health	19	Renata Animal Health
5	SK+F Animal Health.	20	VnF Agro Ltd.
6	The ACME Laboratories Ltd.	21	One Pharma Ltd.
7	Nature Care Ltd.	22	NAAFCO Pharma Ltd.
8	Fishtech (BD) Limited	23	Verno Bio-Solutions Ltd.
9	Penta Agrovet Ltd.	24	Nutri Health Ltd.
10	Organic Pharmaceuticals Ltd.	25	Advanced Agrotech (BD) Ltd.
11	First Care Agro Ltd.	26	Chemical Seller
12	Lion Overseas Trading Company	27	Promim Agro vet Industries
13	Catapol Bioscience Ltd.	28	PRAN Agro Business Ltd.
14	Avon Animal Health	29	Univet Ltd.
15	Century Agro Ltd.	30	Agrosol Bangladesh Company

Table 2. AMDC research conducted in last decade (2011-2020).

Years	Study location	Total aqua medicines	Antibiotics	Oxygen	Growth promoter	Disinfectants	Raw chemicals	Probiotics	Pond preparation and water quality management	Toxic gas removal	Source
2020	Noakhali	49	2	7	16	2	-	9	10	-	Ullah *et al*. (2020)
2020	Patuakhali	71	10	9	10	9	-	2	12	5	Hasan *et al*. (2020)
2020	Rangpur	81	9	10	10	9	7	8	10	9	Das *et al*. (2020)
2020	Bogura	79	11	10	8	12	-	9	13	16	Akter *et al*. (2020)
2020	Moulvibazar	46	5	12	11	5	-	-	8	5	Singha *et al*. (2020)
2020	Southern coastal region	17	2	3	2	2	-	3	5	-	Uddin *et al*. (2020)
2020	Bangladesh	19	19	-	-	-	-	-	-	-	Lulijwa *et al*. (2020)
2020	North-west region	4	-	-	-	-	4	-	-	-	Mondal *et al*. (2020)
2019	North Chattogram	75	13	10	10	10	-	6	15	5	Kawsar *et al*. (2019)
2019	Southwestern Region	65	7	7	13	6	-	5	9	6	Hossain *et al*. (2018)
2019	Jashore	1	-	-	-	-	1	-	-	-	Rahman *et al*. (2019)
2019	Mymensingh	5	-		-	-	5			-	Billah *et al*. (2019a)
2019	Mymensingh	5	-		-	-	5			-	Billah *et al*. (2019b)
2019	Jhenaidah	38	8	6	7	5	5	-	4	3	Rahman *et al*. (2019)
2018	Jashore	47	5	6	8	7	-	-	13	8	Adhikary *et al*. (2018)
2018	Jamalpur	53	9	7	20	6	-	-	11	-	Anwar *et al*. (2018)
2018	Mymensingh	3	-	-	-	-	2	-	1	-	Faruk *et al*. (2018)
2018	Jashore	35	3	-	1	6	3	-	22	-	Biswas *et al*. (2018)
2018	Jashore	2	-	-	-	-	2	-	-	-	Yeasmin *et al*. (2018)
2017	Mymensingh	1	1	-	-	-	-	-	-	-	Neowajh *et al*. (2018)
2017	Lalmonirhat	6	-	-	-	-	6	-	-	-	Vaumik *et al*. (2017)

2017	Comilla	143	19	20	27	18	-	11	25	9	Rahman *et al*. (2017)
2017	Sylhet	53	8	10	10	10	-	-	-	5	Uddin *et al*. (2017)
2017	North-west	1	-	-	-	-	1	-	-	-	Islam *et al*. (2017)
2017	Brahmanbaria	1	-	-	-	-	1	-	-	-	Hossain *et al*. (2017)
2017	Jashore	3	-	-	-	-	3	-	-	-	Rahman *et al*. (2017)
2016	Bagerhat	5	-	-	-	-	5	-	-	-	Shabuj *et al*. (2016a)
2016	Jashore	4	-	-	-	-	4	-	-	-	Shabuj *et al*. (2016b)
2016	Jashore	4	-	-	-	-	1	-	3	-	Hossain *et al*. (2016)
2015	Jashore	3	-	-	-	-	3	-	-	-	Yeasmin *et al*. (2016)
2015	Sylhet	69	8	8	14	7	-	-	-	5	Chowdhury *et al*. (2015)
2015	North-Eastern	52	5	6	5	5	6	-	6	6	Rahman *et al*. (2015)
2015	Narail	24	3	3	4	3	-	-	7	-	Hasan *et al*. (2015)
2014	Shatkhira	35	5	4	6	4	-	5	4	-	Alam and Rashid (2014)
2014	Patuakhali	38	7	7	-	7	-	-	9	-	Sharker *et al*. (2014)
2014	Mymensingh	45	8	8	5	10		-	9	-	Islam *et al*. (2014)
2014	Khulna and Bagerhat	46	12	10	-	8	-	-	11	-	Ali *et al*. (2014)
2014	Bogra	32	-	-	-	6	-	-	8	7	Hossain *et al*. (2014)
2012	south-west coast	122	15	18	26	12	-	13	24	-	Shamsuzzaman and Biswas (2012)
2011	Mymensingh	43	11	5	3	14	-	-	7	-	Khan *et al*. (2011)
2011	Mymensingh	59	6	8	24	5	-	-	17	-	Hoq *et al*. (2011)

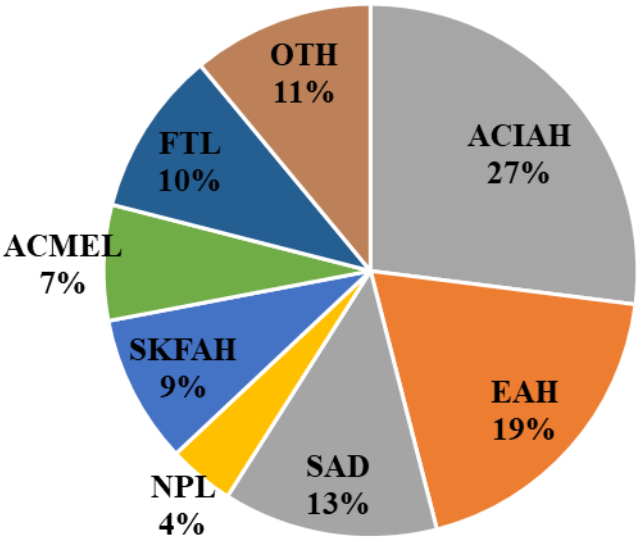

Figure 1. Market share of AMDC (aqua medicines, drugs and chemicals) products in Bangladesh by different companies. (ACIAH= ACI Animal Health; EAH= Eon Animal Health; SAD= Square Agrovet Division; NPL = Novartis Pharmaceuticals Ltd; SKFAH= SK+F Animal Health; ACMEL= ACME Laboratories Ltd; FTL= Fishtech (BD) Limited; and OTH= Others).

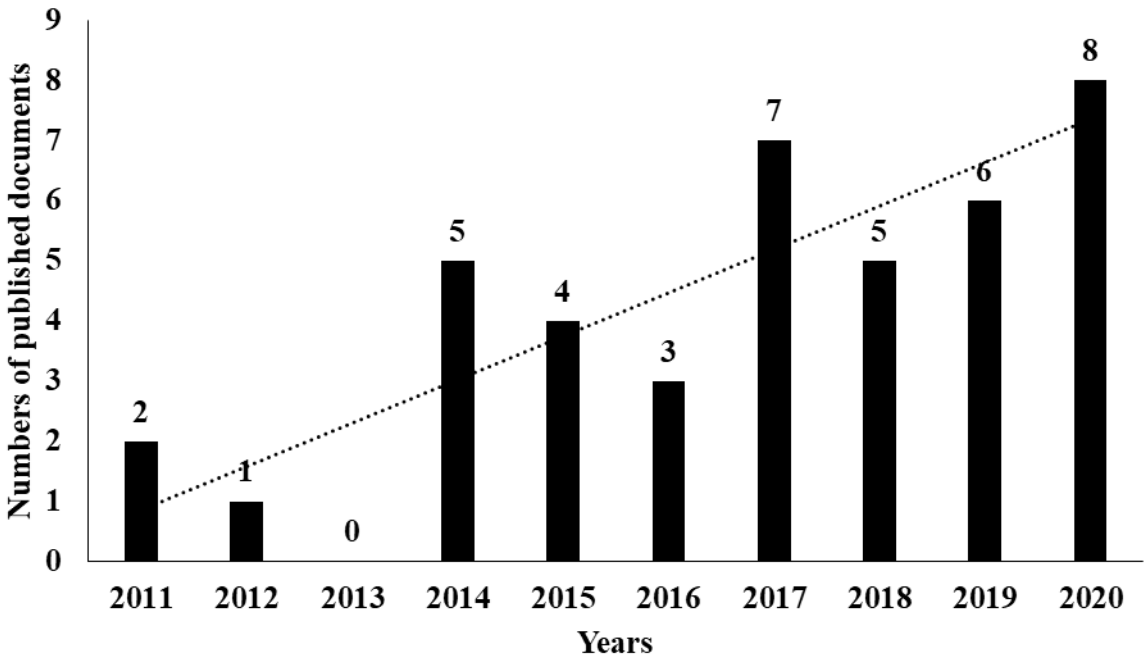

Figure 2. Research trends and available published documents on AMDC (Aqua medicine, drugs and chemical) from 2011-2020.

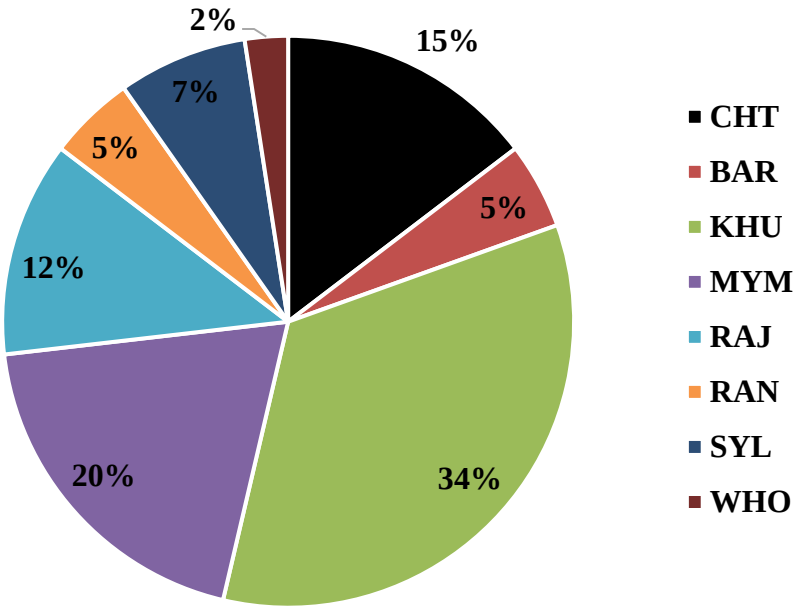

Figure 3. Region wise available published documents (2011-2020) on AMDC (Aqua medicine, drugs and chemical). (CHT=Chattogram; BAR= Barishal; KHU= Khulna; MYM= Mymensingh; RAJ= Rajshahi; RAN= Rangpur; SYL= Sylhet; WHO= Whole country).

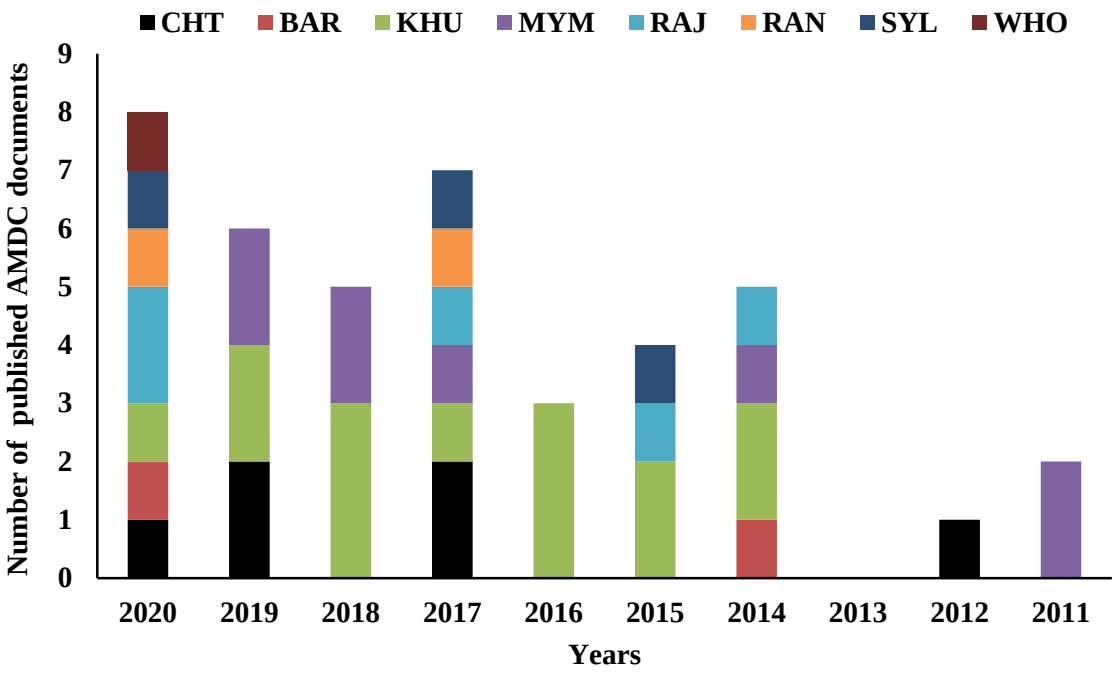

Figure 4. Number of published documents on AMDC (Aqua medicine, drugs and chemical) from different regions (2011-2020). (CHT=Chattogram; BAR= Barishal; KHU= Khulna; MYM= Mymensingh; RAJ= Rajshahi; RAN= Rangpur; SYL= Sylhet; WHO= Whole country).

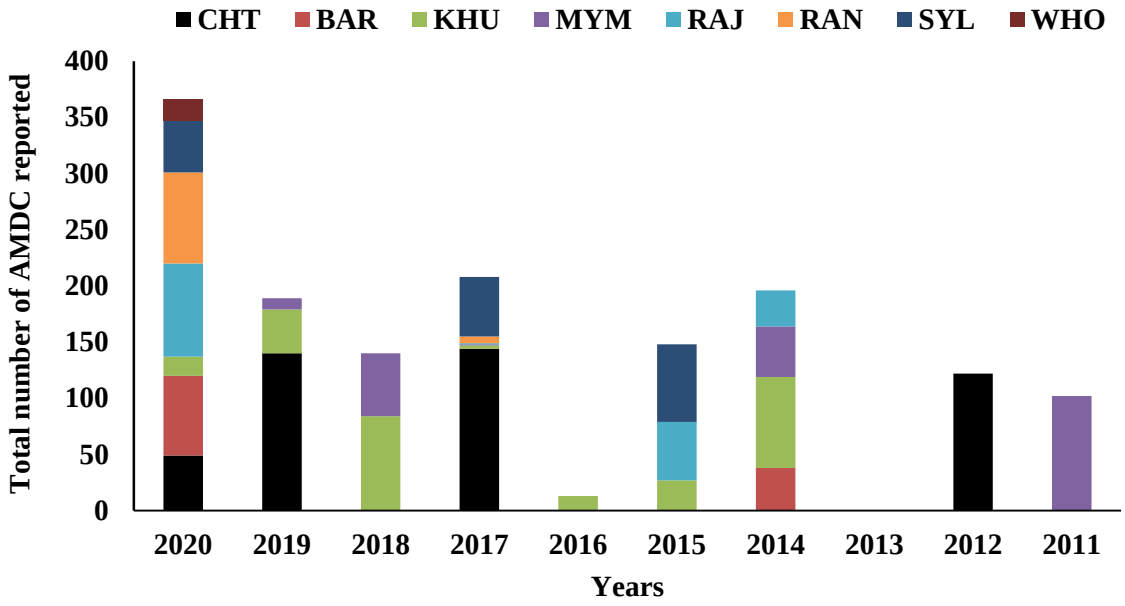

Figure 5. Number of total AMDC (Aqua medicine, drugs and chemical) reported from different regions (2011-2020). (CHT=Chattogram; BAR= Barishal; KHU= Khulna; MYM= Mymensingh; RAJ= Rajshahi; RAN= Rangpur; SYL= Sylhet; WHO= Whole country).

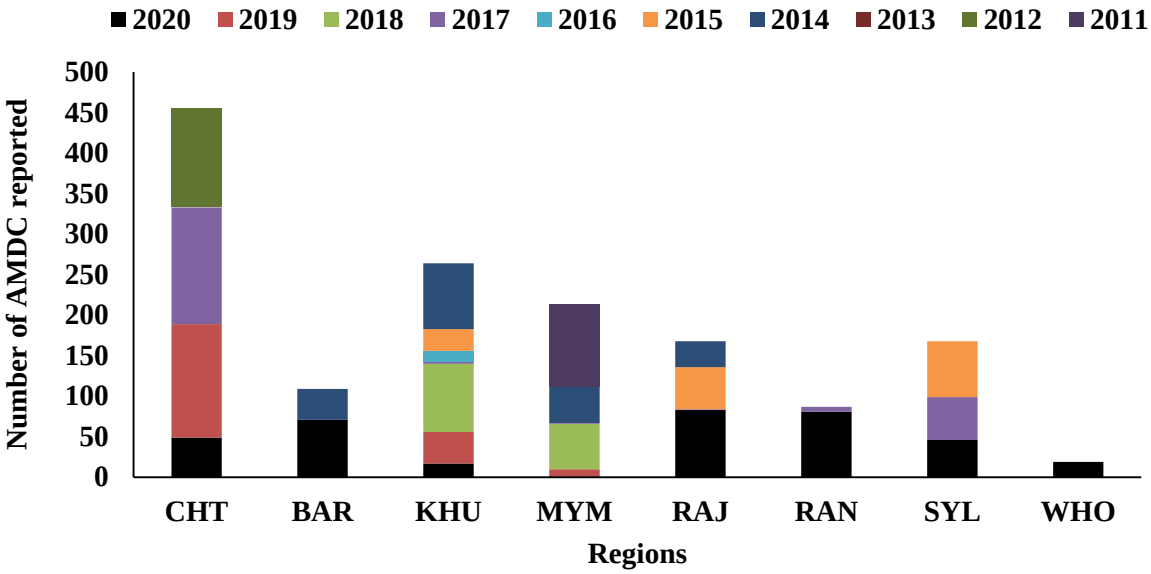

Figure 6. Year wise number of total AMDC (Aqua medicine, drugs and chemical) reported from different regions (2011-2020). (CHT=Chattogram; BAR= Barishal; KHU= Khulna; MYM= Mymensingh; RAJ= Rajshahi; RAN= Rangpur; SYL= Sylhet; WHO= Whole country).

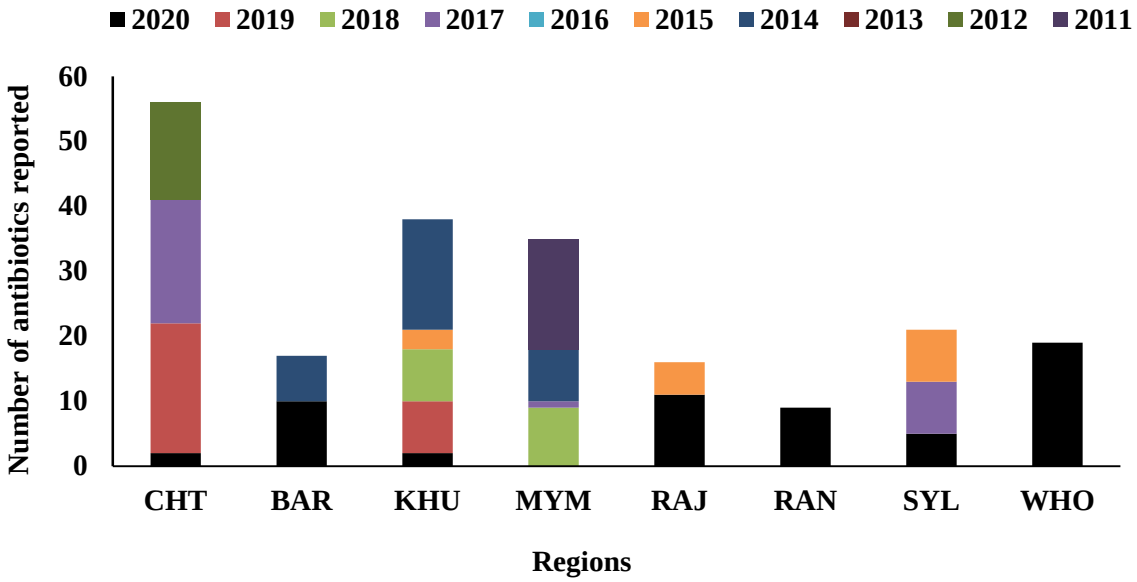

Figure 7. Number of total antibiotic reported from different regions (2011-2020). (CHT=Chattogram; BAR= Barishal; KHU= Khulna; MYM= Mymensingh; RAJ= Rajshahi; RAN= Rangpur; SYL= Sylhet; WHO= Whole country).

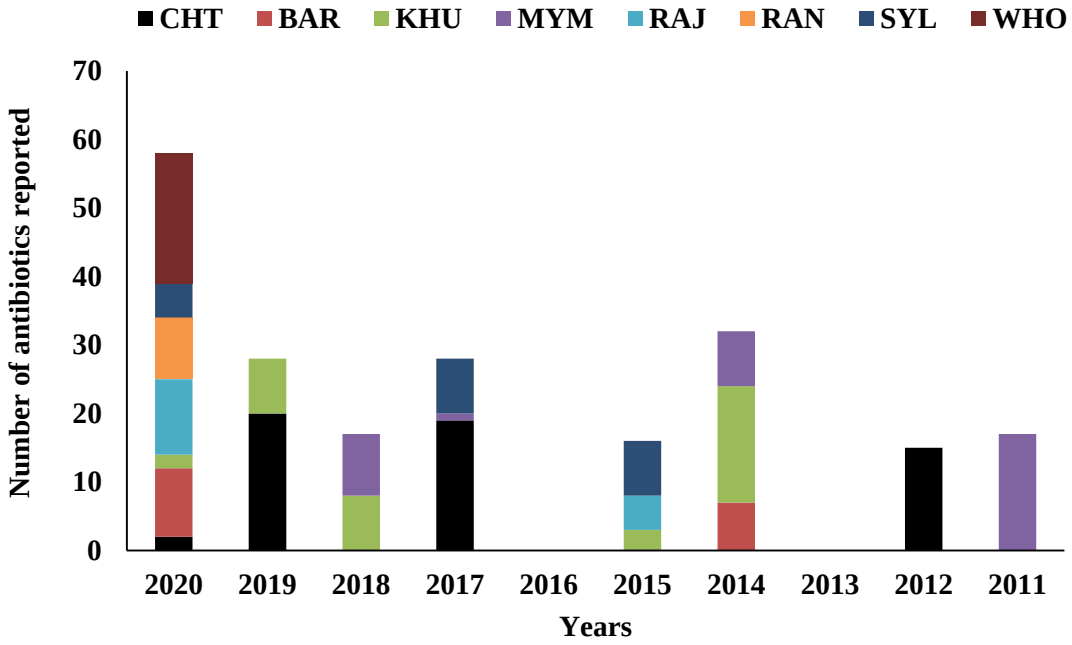

Figure 8. Year wise number of total antibiotic reported from different regions (2011-2020). (CHT=Chattogram; BAR= Barishal; KHU= Khulna; MYM= Mymensingh; RAJ= Rajshahi; RAN= Rangpur; SYL= Sylhet; WHO= Whole country).

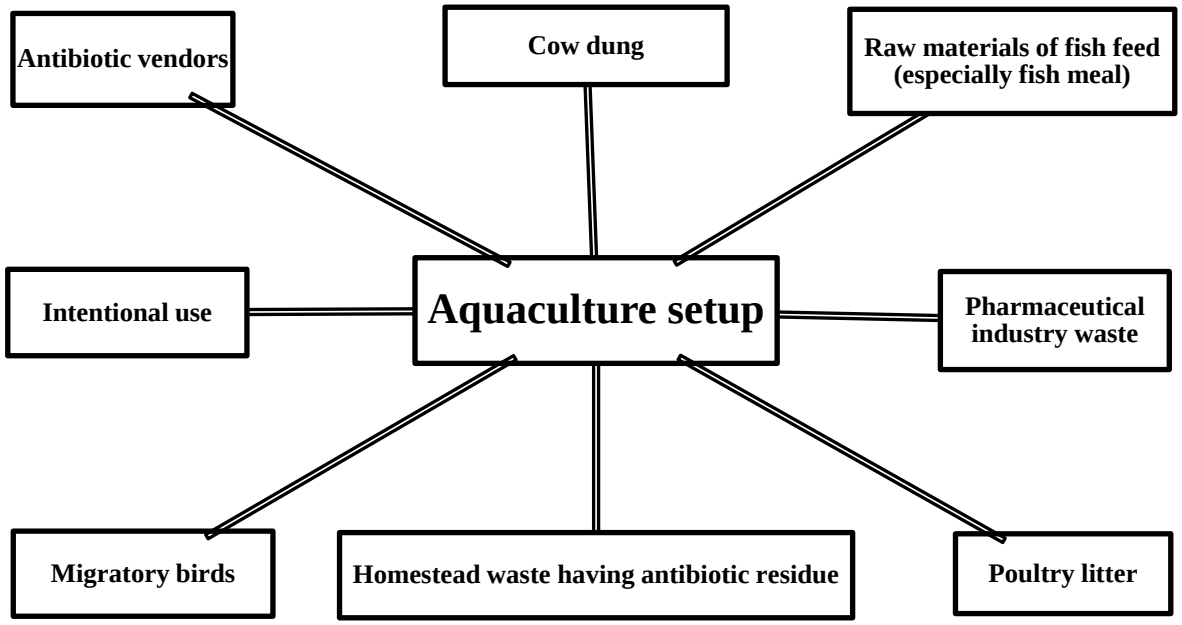

Figure 9. The possible exposure pathway of antibiotics in aquaculture setup (Chowdhury *et al*., 2015; Furtula *et al*., 2010; Han *et al*., 2017; Ngogang *et al*., 2021; Pruden *et al*.,2013; Shobrak and Abo-Amer, 2014; Thai *et al*., 2018; Ullah *et al*., 2020; Yeom *et al*., 2017).

5. Conclusions

Aqua medicines, drugs, and chemicals (AMDC) research trends indicated that use of AMDC increases significantly among farmers, while aquaculture is also gaining popularity among new entrepreneurs. Young entrepreneurs are becoming more involved in aquaculture and embracing new technologies. While the product profiles of various AMDC companies provide insight into the products' performance, the researchers are unaware of efficacy results on the following products in various Bangladeshi agro-ecological zones, which can be interpreted as a significant research gap in the area of AMDC products and research. While these AMDC products were imported from various tropical and temperate aquaculture countries, and the results were satisfactory to farmers and consultants, more attentions are required before importing any new AMDC products into Bangladesh in accordance with the country's existing agrochemical laws.

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Conflict of interest

None to declare.

Authors' contribution

Conceptualization: Abdulla-Al-Asif, Amir Hossain and S. M. Lutful Kabir; methods: Abdulla-Al-Asif; data collection: Abdulla-Al-Asif and Amir Hossain; statistics and presentation: Abdulla-Al-Asif; writing, original-draft preparation: Abdulla-Al-Asif; writing, review and editing: Hadi Hamli, Saiful Islam and S. M. Lutful Kabir. All authors have read and agreed to the published version of the manuscript.

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