International Journal of Research and Review
www.ijrrjournal.com E-ISSN: 2349-9788; P-ISSN: 2454-2237

Review Article

Effect of Groundwater Iron and Other Micronutrients on Anaemia in Bangladesh: A Review

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ABSTRACT

Anaemia is a predominant public health problem throughout the world and in Bangladesh; it has been a growing concern especially for the rural population during the last few decades. This review paper thoroughly explores the important findings from various studies carried out in Bangladesh focusing on the contribution of numerous micronutrients on the anaemia status. Iron deficiency is the potential contributor to anaemia, however, the correlation of other micronutrients like vitamin A, vitamin $B_{12,}$ riboflavin, and folic acid with anaemia prevalence has also been documented in several studies. Serum ferritin level and iron store in the body was found in higher concentration in population belonging to areas, where groundwater is enriched with iron in highly bioavailable ferrous form compared to the low groundwater iron areas. Consumption of iron rich groundwater indicated significant iron overload risk. As a result, it has been suggested that prior to conducting any iron supplementation program for combating anaemia, serum ferritin concentration should be properly measured to avoid the risk of iron overload. It has also been confirmed from several reports that the status of iron in the body is better improved when accompanied by other micronutrients. Therefore, we come to conclude that multiple micronutrients together with iron would play potential role in improving the anaemia situation in Bangladesh.

Key words: Anaemia, Micronutrients, Iron Deficiency, Serum Ferritin, Groundwater Iron.

INTRODUCTION

Anaemia, a predominant public health problem, affects approximately 1.62 billion people throughout the world. [1,2] It is a common blood disorder in which either the blood hemoglobin (Hb) concentration or the number of red blood cells (RBC) falls below an established cut-off value. As a consequence of anaemia, the oxygen carrying capacity of blood throughout the body is impaired. [3] Children, adolescent girls, and women of reproductive age are high risk groups for developing anaemia, [4,5] although it may develop at any stage of the life cycle. [1] The highest prevalence of anaemia is recorded in preschool age children (47.4%) with lowest in men (12.7%). The prevalence rates for non-pregnant and pregnant women are 30.2% and 41.8% respectively. [1,6] Although, a number of factors may contribute to anaemia, it mainly occurs due to iron deficiency. [3,7,8] Iron deficiency constitutes approximately 50% cases of anaemia globally, [9] but this proportion may vary among population groups and areas based on local conditions. [9,10] The risk of anaemia is also increased due to other haemopoietic micronutrient deficiencies like folate, riboflavin, vitamin A and B. [7] In Africa and sub-Sahara Africa, infectious diseases such as malaria, tuberculosis, and HIV/AIDS contribute to anaemia. [4,7] Anaemia also occurs due to excessive blood loss resulting from hookworm infection and schistosomiasis. [7,11] Inherited mutation of the globin genes causes genetic or inherited Hb disorder leading to qualitative and quantitative abnormalities of globin synthesis. This factor enhances the risk of anaemia particularly in Mediterranean and Southeast Asian countries. [4,7,12] Several others underlying factors, responsible for anaemia, have been reported by many researchers such as irregular eating habits, consumption of traditional carbohydrate based diet lacking iron rich animal products, [2] parent's education, [13] father's occupation, [14] body mass index, [15] age, [15,16] malaria, [16] helminthes infestation, [15,16] menstruation 'when marked as heavy', [16] and post-meal tea consumption. [13]

Consequences of growth retardation [17] together with impaired physical and cognitive performance [18] have been found in adolescents due to anaemia. Iron is an essential nutrient for neurotransmitter which plays role in cognition; while hypoxia with decreased cardiac output develops in scarcity of Hb. [19] Higher behavioral disturbances together with reduced learning capacities and suboptimal school performance have also been documented among anaemic school children. [20] Moreover, there is an increased risk of morbidities and mortality for both mother and child, when adolescent girls with anaemia tend to commence their pregnancy. [21] Numerous morbidities including miscarriage, [22] placental abruption, [23] preterm delivery, [24] and low birth weight [25] have been associated in women of reproductive age (15–49) with anaemia. Persons with anaemia have a lower capacity to perform physical work [26] and are more prone to infectious diseases. [27] The risk of anaemia and hematological response may be influenced by the presence of multiple micronutrient deficiencies. [28]

Bangladesh is an anaemia prevalent country, where a significant proportion of people suffer from anaemia in rural areas compared to urban areas. [29] Several studies have been carried out throughout Bangladesh during the past few decades focusing on pregnant, non-pregnant, adolescent boys and girls particularly in rural Bangladesh. Attention has been paid on iron, micronutrients, dietary habit, socio-economic condition, groundwater iron etc. In this review paper, we are interested to thoroughly investigate the insights into the effect of groundwater iron and other micronutrients on anaemia by reviewing the available literature.

METHODS

All the reported studies on anaemia in Bangladesh from 2001 to 2018 have been included in this review paper for thorough investigation of the overall scenario.

RESULTS AND DISCUSSION

Groundwater iron plays a crucial role in controlling serum ferritin level, an indicator of iron deficiency anaemia (IDA). Numerous researchers and their coworkers have thoroughly investigated the role of groundwater iron on the serum ferritin level. The reports indicated that IDA was less prominent in areas with high groundwater iron concentration. Ahmed et al. [30] found the overall prevalence of anaemia, iron deficiency, and IDA among early pregnant women (gestational age <20 weeks) in high and low groundwater iron areas as 34.7%, 27%, and 13.4% respectively. In that study, prevalence was higher in areas with low groundwater iron. The higher prevalence in low groundwater iron areas was quite logical because mean (SD) daily iron intake from drinking water of the participants was found to be 1.77 mg/day (2.96 mg/day) compared to 11.11 mg/day (15.69 mg/day) in high groundwater iron areas. There is no national prevalence data on iron deficiency and IDA among pregnant women in recent years. However, in northwestern Bangladesh, a small scale survey conducted among early pregnant women showed the prevalence of anaemia as 19.3%, where iron deficiency was less than 1%. [31] The differences in the prevalence of anaemia and iron deficiency in the two studies may be attributed to the study location, gestational age of study participants, and cut-off of serum ferritin. [30,32]

Using data of national micronutrient survey 2011-12, Rahman et al. [33] conducted a research to explore the determinants of iron status and Hb especially focusing on groundwater iron level among three age groups: pre-school age children (PSAC: 6–59 months), school age children (SAC: 6–14), and non-pregnant non-lactating women (NPNLW: 15–49 years). Serum ferritin level in subjects from these three categories was found higher among the residents of predominantly high groundwater iron (PHGWI) areas. Despite higher level of household food insecurity, lower intake of dietary iron, lower household facilities, children (SAC) from PHGWI areas had higher serum ferritin level compared with predominantly low groundwater iron (PLGWI) areas. In urban SAC, the serum ferritin level was found lower, although their household expenditure was comparatively higher than rural stratum. Here, the authors predicted that lower usages of tube wells drinking water by urban SAC contributed to lower serum ferritin.

Merril et al. [34] found 16.7 mg/l groundwater iron concentration in a north-western district of Bangladesh. This level was more than 50 times the WHO-defined aesthetic limit (0·3 mg/l). That survey along with other reports indicated that dissolved iron in the aquifers of Bangladesh existed as ferrous form which is readily absorbed by the body through the gut. [34-36] The authors subsequently conducted a study in that area on reproductive age women, where they found 42 mg/day intake of iron from groundwater. [37] This daily intake was close to the tolerable upper intake level (45 mg/day) from foods, water, and supplements combined. [38] The authors finally correlated plasma ferritin and total body iron with groundwater iron concentration.

Bangladesh has no iron supplementation program for NPNLW. The iron supplementation status in pregnant women targeted under the government program is also unsatisfactory. Among rural pregnant women, only 15% take at least 100 tablets, while 46% take no tablets. Three or more antenatal visits are made by only 27% women, which account for scarce access to iron and folic acid supplementation. [39] It is understood that supplemental iron intake among the NPNLW study group was negligible failing to make a positive impact on ferritin status. Higher ferritin status in NPNLW might be resulted from the higher intake of iron rich groundwater even in the absence of significant supplementation. As a consequence, iron overload risk might arise. By exploring dietary intake data, Rahman et al. [33] claimed that dietary intake of iron was below the recommended level even though there was an increased consumption of foods such as meat, fish, and eggs. [40] Iron overload risk was found higher in women compared to children probably due to low water consumption (nearly half) by children than women. Dittmar et al. [41] reported that 99% of total iron in groundwater in Bangladesh was dissolved in readily absorbable ferrous form. Light, air, and temperature can hardly oxidize ferrous to ferric form since 60% of the drinking water in Bangladesh is consumed within 5 minutes of pumping from tube well. [42] The common habit of drinking freshly pumped water ensures the intake of iron in bioavailable ferrous form in Bangladeshi population. [42] Iron deficiency has been directly linked to groundwater iron level by many researchers. Therefore, in case of modest prevalence, the scope of iron supplementation program including micronutrient powders should be carefully considered as future micronutrient strategy in Bangladesh. [33] According to Rahman et al., [33] serum ferritin level exceeded the normal reference limit in 1/2 to 2/3 of children, although there is no WHO recommended limit of iron overload for young children. This study indicated that a significant proportion of children were at iron overload risk. Gastrointestinal distress, untoward shift in gut microbiota, and suppressed Zn absorption might result from this chronic exposure to excess iron in the body. [42,43]

Along with iron, several other micronutrients play crucial role in anaemia. In a study, Shamim et al. [31] reported 19.1% overall anaemia prevalence in 285 pregnant women in rural northwestern Bangladesh, where moderate and severe anaemia was only 2.1%. Approximately half of the women had at least one micronutrient deficiency with the most common being those of α-tocopherol, vitamin B_{12}, and Zn. During this physiological stage, concurrent deficiencies were responsible for reduced Hb concentration. Iron deficiency was unexpectedly lower in this group of population although meat consumption was rare and diets were rich in inhibitors of iron absorption. Chronic use of iron rich groundwater for cooking and drinking contributed to the low prevalence of iron deficiency (1%) in that area. [37] These participants experienced lower rate deficiencies in Fe (<1%), Zn (14.7%), folate (2.8%), and B_{12} (19.7%) compared to the study of Lindstrom et al., [44] where Fe, Zn, folate and B_{12} deficiencies were 8%, 55%, 18%, and 46% respectively among pregnant women in other parts of the country. Overall anaemia reported by Lindstrom et al. [44] was 28% that was lower (39%) than national anaemia survey by Helen Keller International (HKI). [45] Lindstrom et al. [44] provided plausible explanation that their study was a representation of early pregnancy but in HKI survey, the range of gestational age of pregnant women might vary. They also found iron deficiency and IDA less common in that early pregnancy period because demand of iron increases and iron store depletes in the later part of pregnancy period. [44] Although iron deficiency was very low, 28% prevalence of anaemia was found by Lindstrom et al. [44] The authors predicted that anaemia occurred due to high prevalence of vitamin B_{12} deficiency (46%) instead of iron deficiency. The assumption was supported by Fishman et al. [46] They also found high prevalence of infestation with *Ascaris* which was significantly associated with both folate and B_{12} deficiency. The authors explained high prevalence of vitamin B_{12} deficiency due to low consumption of animal rich foods, malabsorption, and inefficient uptake of vitamin B_{12} as a result of infestation with *Ascaris*. [47] They also mentioned that folate deficiency was not responsible for anaemia among the study participants, but the *Ascaris* infestation could increase the risk of folate deficiency.

Choudhury et al. [48] found almost similar Hb levels between two groups in an efficacy trial with a multiple micronutrients powder (MNP) or an iron folic acid (IFA) tablet once on daily basis for 10-14 weeks. By comparing food based nutrient powder with multiple micronutrient tablet, Gai et al. [49] reported no statistical difference in Hb levels between two groups of pregnant women. Choudhury et al. [48] also reported that among the study participants, 45% were anaemic at baseline and the change in Hb level was positive in MNP group, but in somewhat lesser extent compared to the IFA group. A relatively better Hb response in the IFA group was attributed to the difference in the absorption of iron from tablets than powders. A similar finding was reported by Hartman-Craven et al., [50] where relatively less bioavailable ferric pyrophosphate was used in the powders. However, Choudhury et al. [48] used more bioavailable ferrous fumerate, but Hb response was comparatively poorer than IFA tablets. [51,52] The authors considered timing and adherence to intervention as potential contributors to the difference in Hb response between two groups of pregnant women. The perception of people and negative experiences together with lower acceptability of food mixed with MNP were responsible for poor adherence to MNP. [53]

Similar to Choudhury et al., [44] Ahmed et al. [54] found that multiple micronutrient once (MMN-1) or twice (MMN-2) weekly or iron folic acid twice (IFA-2) weekly provided somewhat similar effect on Hb concentration and anaemia on adolescent girls. Numerous reports by Ahmed et al. [55] and other researchers on adolescent girls in Bangladesh showed similar findings. [56-58] After 52 weeks of supplementation, participants from both MMN-2 and IFA-2 groups achieved significant increase in serum ferritin concentration and decrease in prevalence of iron deficiency in comparison with MMN-1 group. However, riboflavin, vitamin A, and C deficiency was less common among girls who received MMN once or twice weekly compared to girls who received IFA twice weekly. These findings were supported by the fact that IFA contained only iron and folic acid. Besides, MMN-2 groups had greater improvement in those micronutrient status compared with MMN-1 group as they received the micronutrients in double amounts per week. Moreover, MMN-2 group achieved greater increase in RBC folic acid level compared to IFA-2 groups, although both of these groups received same dosage of folic acid (400 µg). MMN-1 group, who received lower amount of folic acid than other two groups, achieved least increase in RBC folic acid level. These findings suggested that combination of various micronutrients in the MMN tablet influenced the uptake of folic acid. All of these findings suggest that long term supplementation of either MMN or IFA twice-weekly can effectively reduce iron deficiency but as MMN contains other micronutrients, supplementation of MMN twice-weekly is more beneficial to improve the status of other micronutrients. Besides, effect of once-weekly supplementation with MMN was less than twice-weekly supplementation with MMN. The statuses of other micronutrients are better improved by MMN supplements compared to IFA supplements since IFA supplements lack other micronutrients.

Ahmed et al. [59] conducted a study among adolescent schoolgirls to reveal the condition of several micronutrient deficiencies, which have potential role on hematopoiesis. They reported that about two-thirds of the girls were mildly anaemic (Hb between 110 g/l and <120.0 g/l) and serum ferritin concentration (<20 mg/l) revealed that 48% of the anaemia occurred mainly due to iron deficiency. Therefore, these findings indicated that anaemia among more than half of the participants was not only due to iron deficiency. Additionally, folic acid, vitamin B_{12}, and B_2 deficiencies were found among 25%, 7%, and 89% of the study participants respectively. Also 12% girls were at risk of being folic acid deficient (RBC folate between 317 and 363 nmol/l). Folic acid and vitamin B_{12} play predominant role in DNA synthesis and therefore deficiency of these vitamin may lead to megaloblastic anaemia. [46,60] Furthermore, 89% girls were found to have riboflavin (vitamin B_2) deficiency, which might lead to anaemia as vitamin B_2 plays important role in mobilization of stored iron from liver. [61]

Ahmed et al. [62] conducted a cross sectional study among adolescent school boys in Dhaka City to investigate the prevalence of anaemia and vitamin A deficiency and factors associated with the deficiency. Anaemia was found among 7% of boys, whereas Shahabuddin et al. [63] reported the prevalence of 94% among adolescent boys in rural Bangladesh. The study participants of Ahmed et al. [62] came from relatively better socio-economic condition and therefore provided the favorable scenario of the society. The authors also found that anaemia prevalence was higher (11%) among older boys (14-16 years) and lower (3.5%) among younger (11-13 years) boys. Inadequate iron reserves fail to meet the demand in older boys during the growth spurt as well as haematopoiesis. [62] Vitamin A status was inadequate (<1.05 µmol/l) in 22% of urban adolescent school boys in comparison with urban adolescent girls (11%) in Dhaka City. [64] According to this study, a number of independent factors such as vitamin A status, BMI, age, parent's occupation, intake of fruits and meat significantly influenced the Hb levels of the boys. It has been reported in literature that the presence of haem iron in meat and citrus fruits promote the absorption of non-haem iron. [65] Association of serum vitamin A with Hb level was also found in adolescent school girls in Bangladesh. [64,66]

Another study previously conducted on non-pregnant teenagers by the author revealed that supplementation of iron and folic acid were more effective in increasing Hb concentration when incorporated with vitamin A compared to supplementation with iron and folic acid only. [67] Vitamin A influences the metabolic activity of iron, which ultimately affects Hb formation. [68]

In a study reported by Ahmed et al. [69] on rural Bangladeshi pregnant women, the prevalence of anaemia (Hb<11 g/dl) and vitamin A deficiency (serum retinol<30 µg/dl) was found about 40% and 45% respectively. In that study, 8.6% participants had subclinical vitamin A deficiency (serum retinol<20 µg/dl), while 87% lactating women in that population had vitamin A intake less than their recommended daily allowance (RDA). [70] The study revealed that low serum vitamin A level increased the risk of anaemia by two-folds among the studied pregnant women.

CONCLUSION

This review paper has successfully summarized the available literatures to identify the potential contribution from several micronutrients along with iron on the anaemia prevalence in Bangladesh. Adolescent girls and boys, pregnant and non-pregnant women, and children from rural areas have been given major focus in the reported studies. Availability of iron in the aquifers as readily absorbable ferrous form in some high groundwater iron areas in Bangladesh contributed to higher serum ferritin status in the studied population, although the dietary intake of iron was below the recommended level. The importance of other micronutrients like vitamin A, vitamin B_{12}, riboflavin, and folic acid has also been experimentally understood by many researchers. We, therefore, suggest that people throughout the country should be encouraged through social awareness programs to ensure the proper balance of several essential micronutrients including iron in their diet by appropriate selection of food for reducing the severity of anaemia problem in Bangladesh.

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How to cite this article: Dey M, Dey SC, Alim SR et. al. Effect of groundwater iron and other micronutrients on anaemia in Bangladesh: a review. International Journal of Research and Review. 2018; 5(12):378-386.

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