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ANTI Q-FUZZY BI-IDEALS IN NEAR-SUBTRACTION SEMIGROUPS

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ABSTRACT. Our primary focus is to examine the notion of anti Q-fuzzy bi-ideals in near-subtraction semigroups. This is a continuation/furtherance of our earlier study regarding Q-fuzzy bi-ideals innear-subtraction semigroups. In this paper, we have attempted to define the notation of anti Q-fuzzy bi-ideals and investigated their properties in near-subtraction semigroups.

1. INTRODUCTION

The Concepts of fuzzy sets and fuzzy subsets, fuzzy logic finds roots in seminal work of L. A. Zadeh [4] in 1965. Fuzzy Logic and fuzzification is a transformative development in set theory, having be a ring in many latest scientific applications. Ideal of subtraction semigroup is thoroughly examined by K. H. Kim et.al. [3]. Anti Q-fuzzy bi-ideals of near-rings are researched and characterized by A. Balavickhneswari, V. Mahalakshmi [2]. Also the notation of Q-fuzzy bi-ideals of near-subtraction semigroups are researched and characterized by P. Annamalai Selvi and et.al [1].

Our present study is inspired by the above study and we have examined the concept of anti Q-fuzzy bi-ideals in near-subtraction semigroups and its characteristics.

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2. Preliminaries

In this section, we collect all basic concepts of near-subtraction semigroups, which are used in this paper. Throughout this paper, by a near subtraction semigroup, we mean only a zero-symmetric right near-subtraction semigroup.

Definition 2.1. *A family of a Q-fuzzy sets* $\{\mu_i/i \in \Omega\}$ *in* X*, the union of* $\{\mu_i/i \in \Omega\}$ *is defined by,* $\cup_{i\in\Omega}\mu_i(x,q) = sup\{\mu_i(x,q)/i \in \Omega\}$*,*$\forall x \in X$*,*$q \in Q$ *and the intersection of* $\{\mu_i/i \in \Omega\}$ *is defined by,* $\cap_{i\in\Omega}(x,q) = inf\{\mu_i(x,q)/i \in \Omega\}$*,* $\forall x \in X$*,*$q \in Q$*.*

Definition 2.2. *Let* $f : X \rightarrow X'$*. Let* μ *and* λ *be a Q-fuzzy sets of* X*and* X' *respectively. Then* $f(\mu)$*, the image of* μ *under f, is a subset of* X' *defined by:*

$$f(\mu)(b,q) = \begin{cases} (a,q) \in f^{-1}\inf_{b,q}\mu(a,q) & \textit{if} f^{-1}(b,q) \neq \emptyset \\ 0 & \textit{otherwise} \end{cases}$$

and pre-image of λ *under f is a Q-fuzzy subset of* X*, defined by* $f^{-1}(\lambda(x,q)) = \lambda(f(x,q))$*, for all* $x \in X$*,* $q \in Q$ *and* $f^{-1}(y,q) = \{(x,q)/x \in X, q \in Q, f(x,q) = (y,q)\}$ *and also referred the notations of* $(\mu \cap \lambda)$*,* $(\mu - \lambda)$*,* $(\mu\lambda)$ *&* $(\mu * \lambda)$ *in [1].*

In this paper, f_I is the characteristic function of the subsets I of X, and the characteristic function of $X \times Q$ is denoted by $\chi : X \times Q \rightarrow [0,1]$ and it is mapping each element of $X \times Q$ to 1.

Definition 2.3. *For any Q-fuzzy set* μ *in X and* $t \in [0,1]$*, we define* $L(\mu;t) = \{(x,q)/x \in X,\ q \in Q,\ \mu(x,q) \leq t\}$*, which is called a lower t-level cut of* μ*.*

Definition 2.4. *A mapping* $f : X \rightarrow X'$ *is called a homomorphism if* $f(x-y) = f(x) - f(y)$ *and* $f(xy) = f(x)f(y)$*, for all* $x, y \in X$*.*

Definition 2.5. *A mapping* $f : X \rightarrow X'$ *is called an anti-homomorphism if* $f(x-y) = f(y) - f(x)$ *and* $f(xy) = f(y)f(x)$ *for all* $x, y \in X$*.*

Definition 2.6. *A mapping* $\mu : X \times Q \rightarrow [0,1]$*, where X is an arbitrary non-empty set is called Q-fuzzy set in X.*

Definition 2.7. *A Q-fuzzy subset* μ *is called Q-fuzzy ideal of X if* $\forall x, y \in X$ *and* $q \in Q$ *it hold:*

(i) $\mu(x-y,q) \geq min\{\mu(x,q), \mu(y,q)\}$

(ii) $\mu(xi - x(y - i), q) \geq \mu(i, q)$ *and*
(iii) $\mu(xy, q) \geq \mu(x, q)$.

Definition 2.8. *A Q-fuzzy set μ in X is a Q-fuzzy bi-ideal of X if for $\forall x, y, z \in X$ and $q \in Q$ it hold:*

(i) $\mu(x - y, q) \geq min\{\mu(x, q), \mu(y, q)\}$
(ii) $\mu(xyz, q) \geq min\{\mu(x, q), \mu(z, q)\}$.

Definition 2.9. *A Q-fuzzy subset μ is called an anti Q-fuzzy ideal of X if it satisfies:*

(i) $\mu(x - y, q) \leq max\{\mu(x, q), \mu(y, q)\}$
(ii) $\mu(xi - x(y - i), q) \leq \mu(i, q)$ *and*
(iii) $\mu(xy, q) \leq \mu(x, q)$, *for all $x, y \in X$ and $q \in Q$.*

3. Anti Q-fuzzy bi-ideal in near-subtraction semigroups

Definition 3.1. *A Q-fuzzy set μ in X is said to be an anti Q-fuzzy bi-ideal of X if for all $x, y, z \in X$ and $q \in Q$ it hold:*

(i) $\mu(x - y, q) \leq max\{\mu(x, q), \mu(y, q)\}$
(ii) $\mu(xyz, q) \leq max\{\mu(x, q), \mu(z, q)\}$

Example 1. *Let $X = \{0, a, b, c\}$ with "$-$" and "$\bullet$" defined as*

-	0	a	b	c
0	0	0	0	0
a	a	0	a	a
b	b	b	0	b
c	c	c	c	0

$\bullet$	0	a	b	c
0	0	0	0	0
a	0	b	0	b
b	0	0	0	0
c	0	b	0	b

Define an anti Q-fuzzy subset $\mu : X \times Q \to [0, 1]$ by $\mu(0, q) = 0.5$, $\mu(a, q) = 0.6$, $\mu(b, q) = 0.7$, $\mu(c, q) = 0.8$. It is easy to verify that μ is an anti Q-fuzzy bi-ideal of X.

Theorem 3.1. *Let $\{\mu_i / i \in \Omega\}$ be a family of an anti Q-fuzzy bi-ideal of X, then $\cup_{i \in \Omega} \mu_i$ is also an anti Q-fuzzy bi-ideal of X, where Ω is any index set.*

Proof. Let $\{\mu_i/i \in \Omega\}$ be a family of an anti Q-fuzzy bi-ideals of X. Let $x, y, z \in X$, $q \in Q$ and $\mu = \cup_{i\in\Omega}\mu_i$. Then

$$\mu(x,q) = \cup_{i\in\Omega}\mu_i(x,q) = \sup_{i\in\Omega}\mu_i(x,q)$$

$$\begin{aligned}\mu(x-y,q) =& \sup_{i\in\Omega}\mu_i(x-y,q)\\ \leq& \sup_{i\in\Omega} max\{\mu_i(x,q),\mu_i(y,q)\}\\ =& max\{\sup_{i\in\Omega}\mu_i(x,q),\sup_{i\in\Omega}\mu_i(y,q)\}\\ =& max\{\cup_{i\in\Omega}\mu_i(x,q),\cup_{i\in\Omega}\mu_i(y,q)\}\\ =& max\{\mu(x,q),\mu(y,q)\}.\end{aligned}$$

Therefore, $\mu(x-y,q) \leq max\{\mu(x,q),\mu(y,q)\}$. Thus μ is an anti Q-fuzzy subalgebra of X.

$$\begin{aligned}\mu(xyz,q) =& \sup_{i\in\Omega}\mu_i(xyz,q)\\ \leq& \sup_{i\in\Omega} max\{\mu_i(x,q),\mu_i(z,q)\}\\ =& max\{\sup_{i\in\Omega}\mu_i(x,q),\sup_{i\in\Omega}\mu_i(z,q)\}\\ =& max\{\cup_{i\in\Omega}\mu_i(x,q),\cup_{i\in\Omega}\mu_i(z,q)\}\\ =& max\{\mu(x,q),\mu(z,q)\}.\end{aligned}$$

Therefore, $\mu(xyz,q) \leq max\{\mu(x,q),\mu(z,q)\}$. Hence $\mu = \cup_{i\in\Omega}\mu_i$ is an anti Q-fuzzy bi-ideal of X, where Ω is any index set. □

Theorem 3.2. *Let $f : X \to X'$ be an epimorphism of X. If λ is an anti Q-fuzzy bi-ideal of X', then$f^{-1}(\lambda)$ is an anti Q-fuzzy bi-ideal in X.*

Proof. Let λ be an anti Q-fuzzy bi-ideal of X'. For $x, y, z \in X$ and $q \in Q$,

$$\begin{aligned}f^{-1}(\lambda)(x-y,q) =& \lambda(f(x-y,q))\\ =& \lambda(f(x,q)-f(y,q))\\ \leq& max\{\lambda f(x,q),\lambda f(y,q)\}.\end{aligned}$$

Therefore $f^{-1}(\lambda)(x-y,q) \leq max\{f^{-1}(\lambda)(x,q), f^{-1}(\lambda)(y,q)\}$.

$$\begin{aligned} f^{-1}(\lambda)(xyz,q) =& \lambda(f(xyz,q)) \\ =& \lambda\{f(x,q)f(y,q)f(z,q)\} \\ \leq& max\{\lambda f(x,q), \lambda f(z,q)\}. \end{aligned}$$

Therefore, $f^{-1}(\lambda)(xyz,q) \leq max\{f^{-1}(\lambda)(x,q), f^{-1}(\lambda)(z,q)\}$. Hence $f^{-1}(\lambda)$ is an anti Q-fuzzy bi-ideal in X. □

Theorem 3.3. *Let $f : X \to X'$ be an epimorphism of X. If μ is an anti Q-fuzzy bi-ideal in X, then $f(\mu)$ is an anti Q-fuzzy bi-ideal in X'.*

Proof.

(i) Let μ is an anti Q-fuzzy bi-ideal in X and $y_1, y_2, y_3 \in X'$ and $q \in Q$. Then we have:

$$(x,q) \in f^{-1} \inf_{y_1-y_2,q} (x,q) \subseteq (x_1,q) \in f^{-1}(y_1,q)$$

$$(x_2,q) \in f^{-1} \inf_{y_2,q} (x_1 - x_2, q)$$

$$f(\mu)(y_1-y_2,q) = (x,q) \in f^{-1} \inf_{y_1-y_2,q} \mu(x,q) \leq (x_1,q) \in f^{-1}(y_1,q)$$

$$(x_2,q) \in f^{-1} \inf_{(y_2,q)} \mu(x_1-x_2,q) \leq (x_1,q) \in f^{-1}(y_1,q)$$

$$(x_2,q) \in f^{-1} \inf_{(y_2,q)} max\{\mu(x_1,q), \mu(x_2,q)\} = max\{(x_1,q) \in f^{-1} \inf_{(y_1,q)} \mu(x_1,q)$$

$$(x_2,q) \in f^{-1} \inf_{(y_2,q)} \mu(x_2,q)\}.$$

Therefore, $f(\mu)(y_1-y_2,q) \leq max\{f(\mu)(y_1,q), f(\mu)(y_2,q)\}$. Thus $f(\mu)$ is an anti Q-fuzzy subalgebra in X'.

(ii) Let $y_1, y_2, y_3 \in X'$ and $q \in Q$. Then we have:

$$f(\mu)(y_1y_2y_3,q) = (x,q) \in f^{-1} \inf_{(y_1y_2y_3,q)} \mu(x,q) \leq (x_1,q) \in f^{-1}(y_1,q)$$

$$(x_3,q) \in f^{-1} \inf_{(y_3,q)} \mu(x_1x_2x_3,q) \leq (x_1,q) \in f^{-1}(y_1,q)$$

$$(x_3,q) \in f^{-1} \inf_{(y_3,q)} max\{\mu(x_1,q), \mu(x_3,q)\} = max\{(x_1,q) \in f^{-1} \inf_{(y_1,q)} \mu(x_1,q)$$

$$(x_3,q) \in f^{-1} \inf_{(y_3,q)} \mu(x_3,q)\}.$$

Therefore, $f(\mu)(y_1y_2y_3,q) \leq max\{f(\mu)(y_1,q), f(\mu)(y_3,q)\}$. Hence $f(\mu)$ is an anti Q-fuzzy bi-ideal in X'.

□

Theorem 3.4. *Let μ be an anti Q-fuzzy subalgebra of X, then μ is an anti Q-fuzzy bi-ideal of X iff $\mu X\mu \supseteq \mu$.*

Proof. Assume that μ is an anti Q-fuzzy bi-ideal of X. To pove: $\mu X\mu \supseteq \mu$, let $x', x, y, x_1, x_2 \in X$ and $q \in Q$ such that $x' = xy$ and $x = x_1x_2$. Now,

$$\begin{aligned}(\mu X\mu)(x', q) &= \inf_{x'=xy} max\{(\mu X)(x, q), \mu(y, q)\}\\ &= \inf_{x'=xy} max\{\inf_{x=x_1x_2} max\{\mu(x_1, q), X(x_2, q), \mu(y, q)\}\}\\ &= \inf_{x'=xy} max\{\inf_{x=x_1x_2} max\{\mu(x_1, q), 1, \mu(y, q)\}\}\\ &= \inf_{x'=x_1x_2y} max\{\mu(x, q), \mu(y, q)\}\\ &\geq \inf_{x'=x_1x_2y} \mu(x_1x_2y, q)\,.\end{aligned}$$

Therefore, $(\mu X\mu)(x', q) \geq \mu(x', q)$. Hence $\mu X\mu \supseteq \mu$.

Conversely, assume that $\mu X\mu \supseteq \mu$. To prove: μ is an anti Q-fuzzy bi-ideal of X, let $x, y, z \in X$ and $q \in Q$. Now,

$$\begin{aligned}\mu(xyz, q) &\leq \mu X\mu(xyz, q)\\ &= \inf_{xyz=ab} max\{\mu X(a, q), \mu(b, q)\}\\ &\leq max\{(\mu X)(xy, q), \mu(z, q)\}\\ &\leq max\{\mu(x, q), X(y, q), \mu(z, q)\}\\ &= max\{\mu(x, q), 1, \mu(z, q)\}\\ &= max\{\mu(x, q), \mu(z, q)\}\,.\end{aligned}$$

Therefore, $\mu(xyz, q) \leq max\{\mu(x, q), \mu(z, q)\}$. Hence μ is an anti Q-fuzzy bi-ideal of X. □

Theorem 3.5. *Let X and X' be two near-subtraction semigroups. Let a mapping $f : X \to X'$ be a homomorphism. If μ is an anti Q-fuzzy bi-ideal of X' and $L(\mu; t)$ is a bi-ideal of X', then $L(f^{-1}(\mu); t)$ is a bi-ideal of X.*

Proof. Let $f : X \to X'$ be a homomorphism, μ is an anti Q-fuzzy bi-ideal of X' and $L(\mu; t)$ is a bi-ideal of X'. Let $x, y \in L(f^{-1}(\mu; t)$ and $q \in Q$. Then we have:

$$f^{-1}(\mu)(x, q) \leq t$$

$$f^{-1}(\mu)(y, q) \leq t \Rightarrow \mu(f(x, q)) \leq t$$

$$\mu(f(y, q)) \leq t\,.$$

Now,

$$\begin{aligned} f^{-1}(\mu)(x - y, q) =& \mu(f(x - y, q)) \\ =& \mu(f(x, q) - f(y, q)) \\ \leq& max\{\mu(f(x, q)), \mu(f(y, q))\} \\ =& \max\{t,\, t\} = t\,. \end{aligned}$$

Therefore, $f^{-1}(\mu)(x - y, q) \leq t$. We get $x - y \in L(f^{-1}(\mu); t)$. Hence $L(f^{-1}(\mu); t)$ is a subalgebra of X.

Let $x, z \in L(f^{-1}(\mu); t)$ and $y \in X$. Then we have:

$$f^{-1}(\mu)(x, q) \leq t$$

$$f^{-1}(\mu)(z, q) \leq t \Rightarrow \mu(f(x, q)) \leq t$$

$$\mu(f(z, q)) \leq t\,.$$

Now,

$$\begin{aligned} f^{-1}(\mu)(xyz, q) =& \mu(f(xyz, q)) \\ =& \mu(f(x, q)f(y, q)f(z, q)) \\ \leq& max\{\mu(f(x, q)), \mu(f(z, q))\} \\ =& \max\{t,\, t\} = t\,. \end{aligned}$$

Therefore, $f^{-1}(\mu)(xyz, q) \leq t$. We get $xyz \in L(f^{-1}(\mu); t)$. Hence $L(f^{-1}(\mu); t)$ is a bi-ideal of X. □

Theorem 3.6. *Let μ be a Q-fuzzy set of X. Then μ is an anti Q-fuzzy bi-ideal of X iff μ^c is a Q-fuzzy bi-ideal of X.*

Proof. Assume that μ is an anti Q-fuzzy bi-ideal of X. To prove that μ^c is a Q-fuzzy bi-ideal of X, let $x, y, z \in X$ and $q \in Q$. Now,

$$\begin{aligned}\mu^c(x-y,q) =&1-\mu(x-y,q)\\ \geq&1-max\{\mu(x,q),\mu(y,q)\}\\ =&min\{1-\mu(x,q),1-\mu(y,q)\}\,.\end{aligned}$$

Therefore, $\mu^c(x-y,q) \geq min\{\mu^c(x,q),\mu^c(y,q)\}\,.$
Now,

$$\begin{aligned}\mu^c(xyz,q) =&1-\mu(xyz,q)\\ \geq&1-max\{\mu(x,q),\mu(z,q)\}\\ =&min\{1-\mu(x,q),1-\mu(z,q)\}\\ =&min\{\mu^c(x,q),\mu^c(z,q)\}\,.\end{aligned}$$

Therefore, $\mu^c(xyz,q) \geq min\{\mu^c(x,q),\mu^c(z,q)\}$. Hence μ^c is a Q-fuzzy bi-ideal of X.

Conversely, assume that μ^c is a Q-fuzzy bi-ideal of X. To prove: μ is an anti Q-fuzzy bi-ideal of X, let $x, y, z \in X$ and $q \in Q$. Now,

$$\begin{aligned}\mu(x-y,q) =&1-\mu^c(x-y,q)\\ \leq&1-min\{\mu^c(x,q),\mu^c(y,q)\}\\ =&max\{1-\mu^c(x,q),1-\mu^c(y,q)\}\,.\end{aligned}$$

Therefore $\mu(x-y,q) \leq max\{\mu(x,q),\mu(y,q)\}$. Now,

$$\begin{aligned}\mu(xyz,q) =&1-\mu^c(xyz,q)\\ \leq&1-min\{\mu^c(x,q),\mu^c(z,q)\}\\ =&max\{1-\mu^c(x,q),1-\mu^c(z,q)\}\,.\end{aligned}$$

Therefore $\mu(xyz,q) \leq max\{\mu(x,q),mu(z,q)\}$. Hence μ is an anti Q-fuzzy bi-ideal of X. □

Theorem 3.7. *Let μ be a Q-fuzzy set of X. Then μ is an anti Q-fuzzy bi-ideal of X iff the lower level cut $L(\mu;t)$ of X is a bi-ideal of X for each $t \in [\mu(0),1]$.*

Proof. Let μ is an anti Q-fuzzy bi-ideal of X. Let $x, y \in L(\mu; t)$ and $q \in Q$. Then $\mu(x, q) \leq t$ and $\mu(y, q) \leq t$. Now,

$$\mu(x - y, q) \leq max\{\mu(x, q), \mu(y, q)\} = max\{t, t\} = t\,.$$

Therefore, $\mu(x - y, q) \leq t$, we get $x - y \in L(\mu; t)$. Hence $L(\mu; t)$ is a subalgebra of X.

Let $x, z \in L(\mu; t)$ and $y \in X$, $q \in Q$. Then $\mu(x, q) \leq t$ and $\mu(z, q) \leq t$. Now,

$$\mu(xyz, q) \leq max\{\mu(x, q), \mu(z, q)\} = max\{t, t\} = t\,.$$

Therefore, $\mu(xyz, q) \leq t$. We get $xyz \in L(\mu; t)$. Hence $L(\mu; t)$ is a bi-ideal of X.

Conversely, assume that $L(\mu; t)$ is a bi-ideal of X. To prove that μ is an anti Q-fuzzy bi-ideal of X, suppose μ is not an anti Q-fuzzy bi-ideal of X. Let $x, y \in X$ and $q \in Q$ $\mu(x - y, q) > max\{\mu(x, q), \mu(y, q)\}$. Choose t such that $\mu(x - y, q) > t > max\{\mu(x, q), \mu(y, q)\}$. Then we get $x, y \in L(\mu; t)$, but $x - y \notin L(\mu; t)$, which is a contradiction. Hence $\mu(x - y, q) \leq max\{\mu(x, q), \mu(y, q)\}$.

Let $x, y, z \in X$ and $q \in Q$ $\mu(xyz, q) > max\{\mu(x, q), \mu(z, q)\}$. Choose t such that $\mu(xyz, q) > t > max\{\mu(x, q), \mu(z, q)\}$. Then we get $xyz \in L(\mu; t)$, but $xyz \notin L(\mu; t)$, which is a contradiction. Hence $\mu(xyz, q) \leq max\{\mu(x, q), \mu(z, q)\}$. Hence μ is an anti Q-fuzzy bi-ideal of X. □

Theorem 3.8. *Let $\{\mu_i/i \in \Omega\}$ be a family of an anti Q-fuzzy bi-ideal of a near-subtraction semigroup X. Then $\cap_{i\in\Omega}\mu_i$ is also an anti Q-fuzzy bi-ideal of X, where Ω is any index set.*

Proof. Let $\{\mu_i/i \in \Omega\}$ be a family of an anti Q-fuzzy bi-ideals of X. Let $x, y, z \in X$ and $q \in Q$ and $\mu = \cap_{i\in\Omega}\mu_i$. Then:

$$\mu(x, q) = \cap_{i\in\Omega}\mu_i(x, q) = \inf i \in \Omega\mu_i(x, q)$$

$$\begin{aligned}\mu(x - y, q) &= \inf_{i\in\Omega} \mu_i(x - y, q)\\ &\leq \inf_{i\in\Omega} max\{\mu_i(x, q), \mu_i(y, q)\}\\ &= max\{\inf_{i\in\Omega} \mu_i(x, q), \inf_{i\in\Omega} \mu_(i)(y, q)\}\\ &= max\{\cap_{i\in\Omega}\mu_i(x, q), \cap_{i\in\Omega}\mu_i(y, q)\}\\ &= max\{\mu(x, q), \mu(y, q)\}\,.\end{aligned}$$

Therefore, $\mu(x-y,q) \leq max\{\mu(x,q),\mu(y,q)\}$. Thus μ is an anti Q-fuzzy subalgebra of X.

$$\begin{aligned}\mu(xyz,q) &= \inf_{i\in\Omega}\mu_i(xyz,q) \\ &\leq \inf_{i\in\Omega} max\{\mu_i(x,q),\mu_i(z,q)\} \\ &= max\{\inf i\in\Omega\mu_i(x,q), \inf i\in\Omega\mu_i(z,q)\} \\ &= max\{\cap_{i\in\Omega}\mu_i(x,q), \cap_{i\in\Omega}\mu_i(z,q)\} \\ &= max\{\mu(x,q),\mu(z,q)\}\,.\end{aligned}$$

Therefore, $\mu(xyz,q) \leq max\{\mu(x,q),\mu(z,q)\}$. Hence $\mu = \cap_{i\in\Omega}\mu_i$ is an anti Q-fuzzy bi-ideal of X, where Ω is any index set. □

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