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Scientific Research and Essays

Review

Journey of kenaf in Malaysia: A Review

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Kenaf is an industrial crop with high potential for cultivation in a tropical climate. It is a source of raw material for fiber-based industries and paper production. Considerable research has been conducted to explore its adaptability and utilization in Malaysia since 2000, under the supervision of governmental and private organizations. A number of technologies and expertise among researchers have been developed to enhance kenaf production in Malaysia. However, international documentation of the research is limited, which is important for rectification to provide a comprehensive knowledge base for all tropical and subtropical countries. The main objective of this review is to provide an overview of the results of Malaysian research on kenaf. In addition, the past, present and likely future trends in kenaf research in Malaysia as a representative tropical region are summarized.

Key words: Industrial crop, tropical, agronomy, Kenaf

INTRODUCTION

The total area of Malaysia is about 328,600 km^2 of which Peninsular Malaysia is 131,600 km^2, Sabah is 73700 km^2 and Sarawak is 123,300 km^2. Peninsular Malaysia is separated from Sabah and Sarawak by 720 km (EAPAP, 1994). The Malaysian Agriculture is characterized by two distinct sectors, namely, the plantation sector and the smallholders' sector. Major crops planted are oil palm, rubber, rice, coconut and mixed horticulture. In addition, Malaysia is third largest exporter of timber in the world (Paridah et al., 2007).

Increased demand for timber industries ultimately has increased the rate of deforestation. About 76.3% of the land area of Malaysia was under forest in 2006, but declined to 62% in 2009 (Harun et al., 2009). Subsequently, deforestation will decrease the biodiversity of agricultural lands, which is detrimental for the environment and future improvement of crop.

To counter the issues of deforestation and biodiversity preservation, it is necessary to produce a non-wood crop that can fulfill the requirement for raw material from which

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paper and other products can be produced without causing destruction of forests and damage to environment.

Kenaf project in Malaysia was initiated way back in 1999 by the National Economic Action Council (NEAC) (Now known as National Economic Advisory Council) under the directive of YAB Prime Minister. NEAC formed a steering committee to study the potential of growing Kenaf in Malaysia as another industrial crop.

In early 2000, Malaysian Agricultural Research and Development Institute (MARDI) was directed by NEAC to co-ordinate a fast track research and development into the project. Since then, MARDI had successfully researched on variety screening, agronomic practices for Kenaf cultivation, harvesting and mechanization, retting, fiber processing, and some downstream applications such as animal feed and bio composite.

The Government has identified Kenaf as a potential crop (Extracts 1.1 and 1.2) to replace tobacco especially where the major tobacco growing areas are located. The ASEAN Free Trade Area or AFTA, which comes into effect in 2010, could result in lower prices and a reduction in import duties for tobacco. AFTA, to a certain extent, could negatively impact the competitiveness of Malaysian tobacco planters, whose cost of production is almost double compared with their peers in Thailand and Indonesia (Edeerozey et al., 2007; Mossello, 2010a).

Research on kenaf in Malaysia was initiated with evaluation of kenaf adaptability, identification of suitable cultivars for industrial and agriculture usage, agronomical management and inputs, end products and cost production in Malaysia (Asfaliza et al., 2001; Aminah et al., 2006; Ashori, 2006).

Presently, kenaf research focus on the production of biofuel, biocomposite materials and bio products (Aminah et al., 2004). The outcomes of kenaf research are of relevance for tropical countries in general, but the published Malaysian research on kenaf and its international accessibility are limited. The aim of this article is to provide a guideline for development of the kenaf industry in tropical regions. Subsequently, in this study, each area of kenaf research that has been considered in Malaysia will be discussed.

TAXONOMY AND MORPHOLOGY RESEARCCH OF KENAF IN MALAYSIA

Kenaf (*Hibiscus cannabinus*) is a herbaceous, annual, short-photoperiod plant that contains high-quality cellulose. The genus *Hibiscus* has a cosmopolitan distribution and contains more than 400 species. It is divided into six sections: *Furcaria*, *Alyogyne*, *Abelmoschus*, *Ketmia*, *Calyphylli* and *Azanzae*. Kenaf is classified in section *Furcaria*. The diversity in the number of chromosomes and genomes found in this section is unusual in the plant kingdom. Morphological and anatomical characters are helpful for selection of suitable kenaf genotypes for fiber and paper production. Kenaf has a large, light yellow, bell-shaped flower with a widely open corolla. The flowers are 8 to 10 cm in diameter with five petals (H'ng et al., 2009).

In 1999, the evaluation of kenaf adaptability to the tropical climate of Malaysia was the primary concern of scientists and agriculturists. In this regard, many experiments have been conducted on morphological and physiological traits and for selection of suitable germplasm accessions and cultivation locations. Moreover, to understand plant physiological requirements and phenomena, the morphology and anatomy of different kenaf cultivars have been evaluated. Studies of kenaf fiber morphology studies indicated significant differences in fiber diameter; length morphology exist among kenaf cultivars (H'ng et al., 2009; Abdul Khalil and Suraya, 2010). A similar distribution of vessels and tissues with longer fibers and thicker fiber cell walls were observed in all accessions (Figures 1 and 2). The differences in fiber morphology and quality are caused by genetic inheritance and manipulation, environmental factors, management practices and agricultural inputs (Hazandy et al., 2009; Hossain et al., 2011). The determined chemical composition of kenaf met the standard established by Pulp and Paper Industry of Malaysia (Edeerozey et al., 2007; Abdul Khalil and Suraya, 2010; Abdul Khalil et al., 2010). Research on modification of morphological traits is ongoing in Malaysia to utilize kenaf fiber more efficiently.

EVALUATION OF KENAF ADAPTIBILTY IN MALAYSIA

For successful commercial cultivation of kenaf, selection of a suitable genotype with high growth rates and biomass production is essential. Plant growth and biomass production are strictly related to their physiological characteristics. In a study of the gas exchange of three kenaf accessions, Guatemala 4, V36 and Kohn Kean 6, no significant differences in net photosynthesis rate were observed (Tahery et al., 2011). For the Malaysian tropical climate, the cultivars Everglade71, HC2, HC78, Thai kenaf, V36, and V133 were recommended as commercially suitable genotypes (Figure 3) (Asfaliza et al., 2001; Idris et al., 2001; Aminah, 2003; Aini et al., 2009; Hossain et al., 2011).

It was recommended from the results of a number of studies that photoperiod-insensitive and late-flowering cultivars were suitable for the tropical climate of Malaysia (Hossain et al., 2011; Wong et al., 2001; Daud, 2006). The highest yield to be reported (9.68 t/ha) was obtained from the accession V36. The kenaf cultivars available in Malaysia are: V4, V12, V25, V33, V34, V36, V40, V41, V43 and V72. An evaluation of the yield of two cultivars found that V132 produced 101.6 pods per plant with 19.6 seeds per pod, whereas V133 produced 199.2 pods per

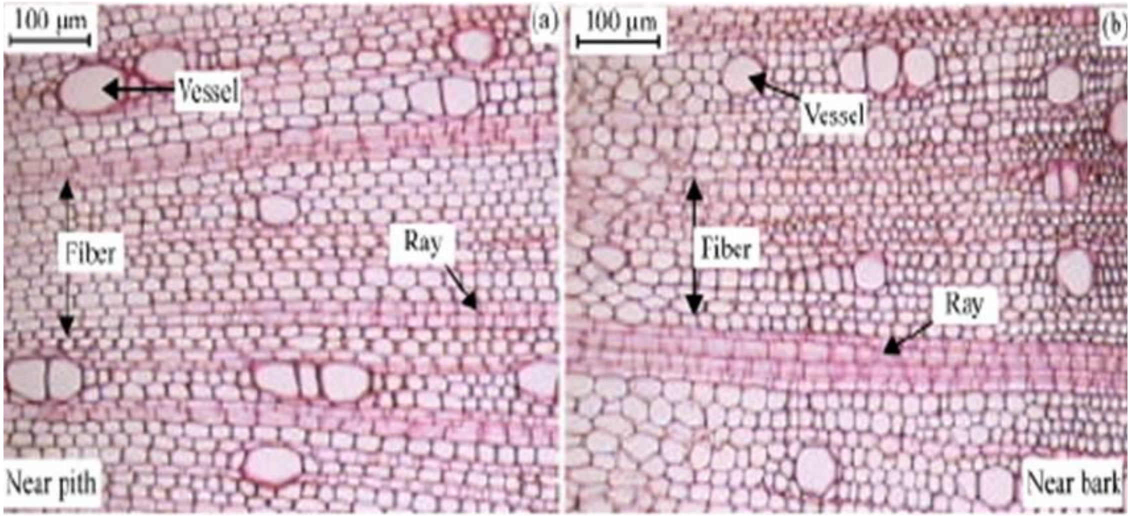

Figure 1. Cross section of kenaf near pith and bark (H'ng et al., 2010).

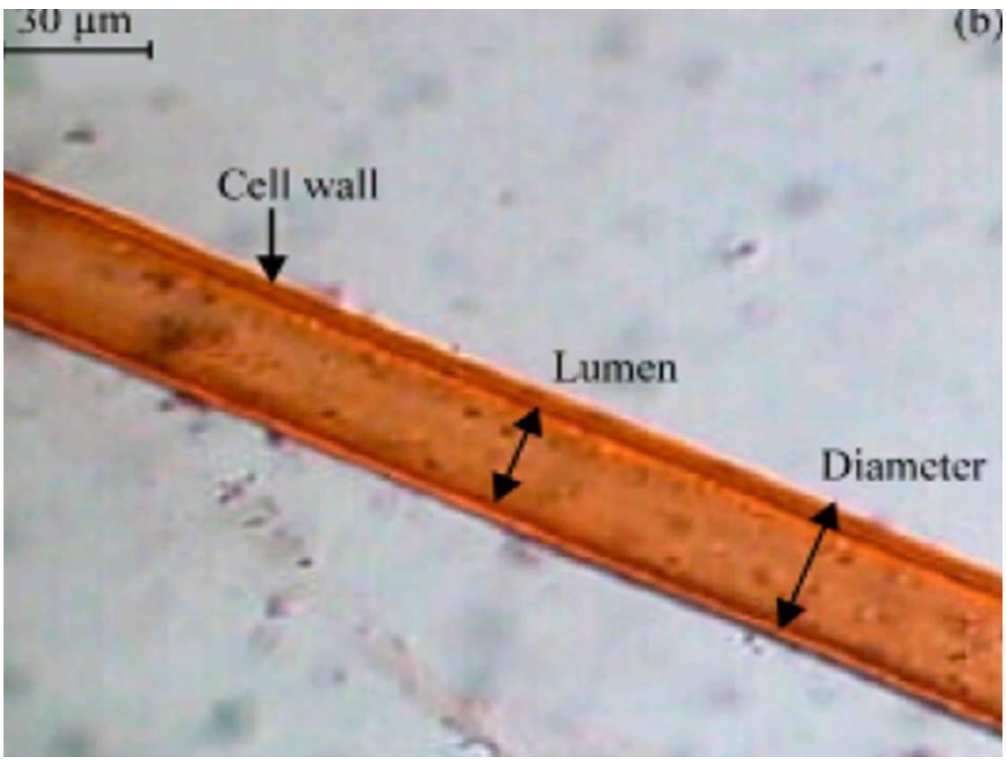

Figure 2. Core Fiber of kenaf microscopic image (H'ng et al., 2009).

plant with 20.4 seeds per pod (Asfaliza et al., 2001). Climatic factors can affect seed production of kenaf in Malaysia (Othman et al., 2006). Recently, HC2 and V133 were investigated as promising genotypes for seed forage and fiber production, especially on the BRIS soils of Malaysia (Aminah, 2003; Aminah et al., 2006; Aini et al., 2009; Hossain et al., 2011).

Kenaf cultivation on beach ridges interspersed with swales (BRIS)

The large scale production of kenaf was still hard to obtain because most of the recommended commercial production area (BRIS soils) was under tobacco cultivation. The National Kenaf and Tobacco Board

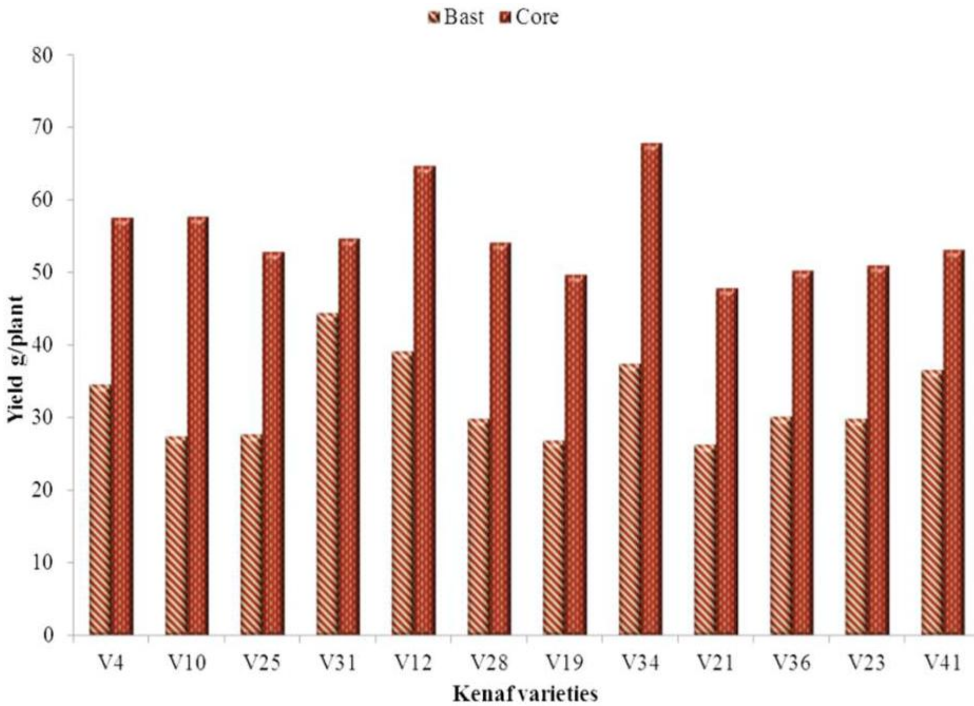

Figure 3. Dry matter yield of bast and core (g/plant) of 12 varieties harvested at 150 days in Malaysia (Daud, 2006).

planned the development of kenaf as an ecofriendly crop cultivation to replace the current tobacco production from BRIS soils by 2010 (Daud, 2006). The decision was made due to uncompetitive tobacco industry as compared to other countries and Tobacco Board has been instructed to undertake replacement of the tobacco by cultivating alternative crops according to their suitability. So, in 2006, the new research projects funded by National Kenaf and Tobacco Board (NKTB), Malaysian Timber Industry Board (MTIB), and Malaysian Agricultural Research and Development Institute (MARDI) and other related agencies and Ministries were approved on the cultivation of kenaf on BRIS soils (Aminah et al., 2006).

During the initial stage of this program, Kenaf was planted on BRIS soil specifically to replace tobacco through contracted farming method. Some BRIS areas were planted with Kenaf on different soil type in the area namely Kelantan and Terengganu.

Kenaf was reported to produce up to 15 tons/ha of stem production on fertile soils as oppose to 7 tons/ha on BRIS soil. It was concluded after a number of trials of Kenaf cultivation on BRIS that Kenaf is adapted to a wide range of soil types, but performs best on the fine to medium textured clay or loamy, well drained, fertile soils. Due to its high adaptability with all ranges of soils; Kenaf can be potentially planted on BRIS soil which is poor in water holding capacity and nutrient availability due to sandy texture in nature. Therefore these soils must be amended to produce higher yields. However, Kenaf can produce high productivity with the application of optimum fertilization and irrigation system (Alternatives Field Crops Manual, 1991).

Kenaf cultivation for seed production

Seed availability is a fundamental factor to ensure successful development of a novel crop. Insufficient and irregular supply of seed will obstruct planning and can cause setback to development of any industrial or agricultural project. To ensure seed availability to satisfy the strong industrial demand, many investigations of seed production and quality have been conducted. Many factors such as cultural practices, handling, harvesting, and environmental conditions can affect seed production.

In June 2000, the Malaysian Agriculture Research Development Institute (MARDI) initiated a research project on seed production at various locations in Malaysia to determine the most suitable climate and photoperiod for seed germination. The research established that temperature, rainfall and day length are important factors for kenaf flowering and seed production. In tropical countries such as Malaysia, the normal day length is 12 h and high humidity prevails for much of the year. Therefore, cultivation in the dry season is strongly recommended for seed production in tropical areas (Halimathul Saadiah, 2001; Halimathul Saadiah et al.,

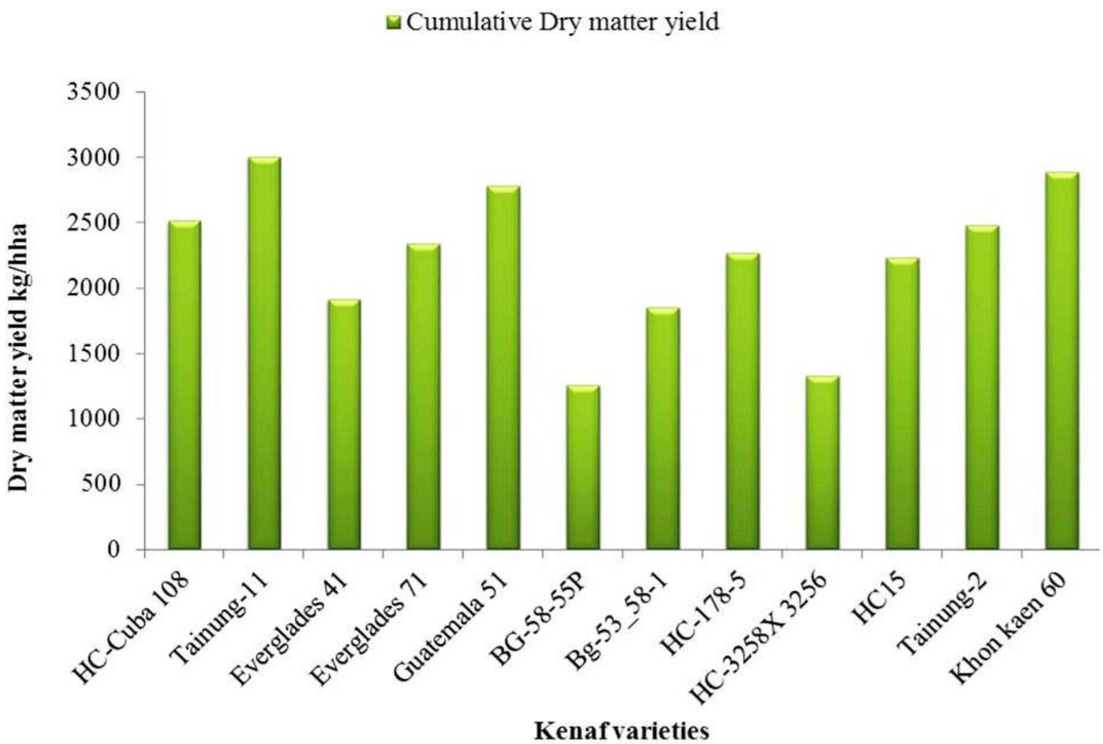

Figure 4. Mean dry matter yield of kenaf for forage production in Malaysia (Wong et al., 2001; Daud, 2006).

2006). The seeds require 60 to 90 days to mature after fertilization. The Plant Breeding Research Department of Malaysia has carried out research on kenaf hybridization techniques, but did not raise novel hybrids (Othman et al., 2006; Shukor et al., 2009). In addition, propagation from shoot apices and stem nodes has been investigated by various researchers and 70% plant survival was achieved after transplanting (Ayadi et al., 2011; Hossain et al., 2011a). An agronomic assessment of kenaf cultivars suggested that kenaf seed should be produced in the northern region of Malaysia because of the longer dry period (Halimathul Saadiah, 2001).

Kenaf cultivation for fiber production

Kenaf germplasm has been screened not only for seed production, but also evaluated for fiber production potential. Photosensitivity is the main factor that has a direct effect on kenaf growth and yield in Malaysia. Kenaf needs 12.5 h of daylight per day to flower. However, the Malaysian day is only 12 h long, which can result in the early flowering of some cultivars. Early flowering can reduce plant growth and fiber yield. Some studies have indicated that manipulation of agronomical practices and vegetative growth factors, such as planting and harvesting date, fertilizer type, pesticide application and planting density, can result in higher fiber yields of kenaf (Asfaliza et al., 2001; Idris et al., 2001; Aminah et al., 2004; Ashori et al., 2006; Othman et al., 2006; Wong et al., 2001). In most fiber production systems the final desirable plant production density was 185,000 to 370,000 plants/ha of single-stalked plants (Aminah et al., 2004). High population density could favor higher fiber yields, although the individual plant yield was higher with a lower population density (Aminah et al., 2004; Baldwin and Graham, 2006). The results of several studies of fiber yield showed that Malaysia can produce high yields of dry matter and fiber on an industrial scale (Halimathul Saadiah et al., 2006; Bai and Yu, 2011) (Figure 5). It was concluded that late-flowering and leafy cultivars are suitable for fiber and seed production, whereas early-flowering cultivars can be used as forage (Aminah et al., 2006; Raji, 2007; Wong et al., 2001). The screening of novel genotypes for seed and fiber production is ongoing in collaboration with researchers in China, Bangladesh and Malaysia under the UNIDO project (Aminah, 2003; Hossain et al., 2011a; Hossain et al., 2011b; Daud, 2006).

Kenaf cultivation for forage production

The results of growth and yield experiments on early-maturing cultivars conducted by MARDI indicated good potential for kenaf cultivation in Malaysia for forage use (Figure 4). Crude protein content of kenaf plants at four weeks after planting was 30.4%, which declined by up to

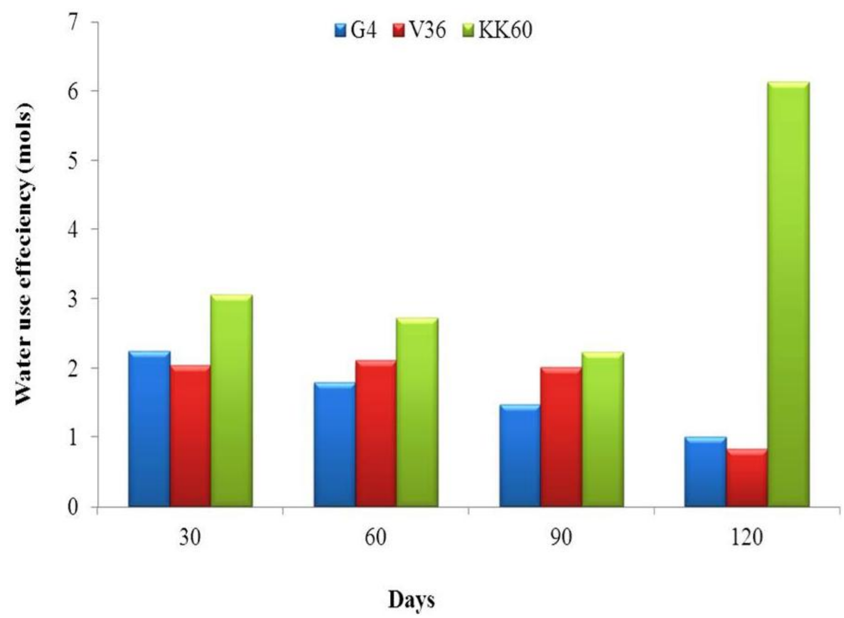

Figure 5. Water use efficiency of three kenaf varieties at different stages of growth (Tahery, 2011).

20% until the eighth week (Liang et al., 2003). Kenaf is considered to be a high-protein feed that is highly digestible (Aminah, 2003; Aminah et al., 2006). The feeding of ground and pelleted kenaf hay is encouraged as compared with chopped or whole plants. Furthermore, kenaf feed has positive effects on the growth, milk yield and milk quality of goats (Liang et al., 2003).

MANAGEMENT PRACTICES

Kenaf plant spacing and population

Kenaf production is highly dependent on climatic and agronomical factors, such as plant population density, irrigation, pest and insect management, and mechanization. Plant population density has a significant effect on kenaf production. Increased spacing (30 cm between rows and 5 cm between plants) of kenaf plants resulted in larger stems and a taller stand compared with more closely spaced plants. However, a higher population density tends to produce shorter stem stalks because of crowding effects. In contrast, kenaf stem core production was decreased at a low population density (Aminah, 2003; Aminah et al., 2004, 2006).

Water requirements

Research on the water requirements of kenaf revealed that plants need 12 mm of water per day for seed germination and initial crop establishment. The fiber quality and root length can be affected by fluctuation of the water table level. Kenaf plants can grow to a height of 3.2 m under an adequate water regime (Kassim, 2001; Tahery, 2011). The water requirements vary among cultivars at different developmental stages as a result of environmental factors (temperature and humidity) and physiological factors such as transpiration and photosynthesis (Tahery, 2011).

Weed and pest control

High humidity and rainfall during the growing season can result in fungal disease on kenaf crops. Kenaf is susceptible to fungal pathogens such as *Phytophthora*, nematode infestation, *Dysderus cingulatus*and *Aphis gossypii* Glover, which attacks seedlings 4 weeks after germination (Figure 6). These diseases and pests can damage young shoots, flower buds and developing fruits. Use of pesticides is crucial for plant protection (Aminah et al., 2006; Wong et al., 2001). The presence of a high population density of nematodes was reported in a number of field experiments on kenaf (Daud, 2006). Spray application of furadan to control nematodes is recommended after four weeks of germination (Daud, 2006).

Weed control is also essential for kenaf crop management. The critical period for weed control is during crop establishment. Pre-emergence herbicides could be used to control emerging weeds. The major weed species in the kenaf growing area are *Digitariaadscendens*, *Borreria alata*, *Cyperus rotundus*, *Cleome* sp., *Cynodon dactylon*, and *Calapogonium* sp. Flufenacet applied as a pre-emergence herbicide and fluazifop-butyl applied as an early post-emergence

Figure 6. Effects of disease and pest on kenaf (A) *Dysderus cingulatus* nymphs attack (B) phytopthora stem rot (Mardi, 2004).

herbicide are recommended by MARDI (Azmi, 2001). Bentazon was tested as a suitable late post-emergence herbicide for control of sedges and broadleaf weeds (Azmi, 2001). Limited information on pest and weed management is available; therefore there is a need to conduct additional studies on this aspect of kenaf production.

Nutrient requirements

The nutrient requirement of a crop is dependent on climatic conditions and soil properties. Kenaf is considered to be a nutrient-demanding crop. Previous research has investigated the effects of different levels of macronutrients. Different concentrations of nitrogen (N) fertilizer did not result in any significant differences in plant growth, biomass and foliage production (Figure 7) (Zainul and Mansur, 2001; Othman et al., 2006). However, application of N with phosphorus (P) at the rate of 100 N:200 P kg/ha showed significant positive effects on yield and growth of kenaf plants (Zainul, 2004). The recommended application rate for kenaf in Malaysia is 80 to 100 kg N/ha, 150 to 200 kg P/ha, and 100 kg K/ha (Hossain et al., 2011). Fiber production and quality were not affected by application of only N, whereas combined application of N and P showed small but non-significant effects (Daud, 2006).

The effects of different concentrations of organic carbon (C) on kenaf fiber quality and biomass production were determined by Hossain et al. (2011). Some significant effects on morphology and growth of kenaf were observed in response to 20 t C/ha, but high concentrations (more than 20 t/ha) reduced fiber production and quality (Hossain et al., 2011a). The nutrient requirements for kenaf production were found to vary among production areas because of variability in soil properties. Studies of kenaf cultivation on BRIS soils suggested an optimal N application rate of 300 kg N/ha (Othman et al., 2006).

The water regime and seasons are also important factors that affect kenaf yield responses to fertilizer concentrations. For example, application of N in wet seasons had a more significant effect than application during dry seasons (Aini et al., 2009; Hazandy et al., 2009). Use of organic manure such as chicken dung is also recommended for kenaf production on sandy and BRIS soils. Increases in forage yield by up to 27% have been reported by fertilizer optimization in various kenaf production trials conducted on BRIS soils in Malaysia (Aminah, 2003; Shukor et al., 2009; Hazandy et al., 2009; Hossain et al., 2011). However, there is a need for further detailed research on the fertilizer requirements of kenaf plants in different locations and soil types in Malaysia.

Mechanization

Harvesting is the most critical aspect of kenaf production. Manual harvesting of Kenaf is laborious and costly. Mechanized harvesting is more feasible and efficient for large-scale production. Many types of machines can be used for kenaf cultivation according to the uses of the end product. Furthermore, many modifications have been performed on different types of machines used for harvesting. For instance, a rice header, soybean thresher and some other types of threshers have been modified and successfully implemented in field trials by Malaysian engineers to develop a seed thresher for kenaf (Halimathul Saadiah et al., 2006; Ten et al., 2006; Ten and Wong, 2006; Ghahraei et al., 2011). For fiber production, a pedestrian-type kenaf stem cutter works satisfactorily, but has received very limited practical application in large plantations because of the low stem-cutting capacity of the machine. A sugar-cane tractor was used to harvest kenaf stems and showed good potential for large-scale kenaf plantations (Daud, 2006).

KENAF PROCESSING

After harvesting, kenaf is processed for a variety of uses, such as seed processing, forage and fiber production. For each of these end uses, different methods have been explored and adopted, as discussed below.

Kenaf seed processing and storage

Supply of high-quality seeds is needed for continuous and reliable kenaf production. However, seed production needs a particular climate and harvesting time. About 25% of kenaf seeds lose their viability because of suboptimal storage conditions. Kenaf seeds require drying for storage. It is necessary to clean and dry the seed thoroughly for successful long-term storage. Artificial dryers can be used for this purpose. The seed

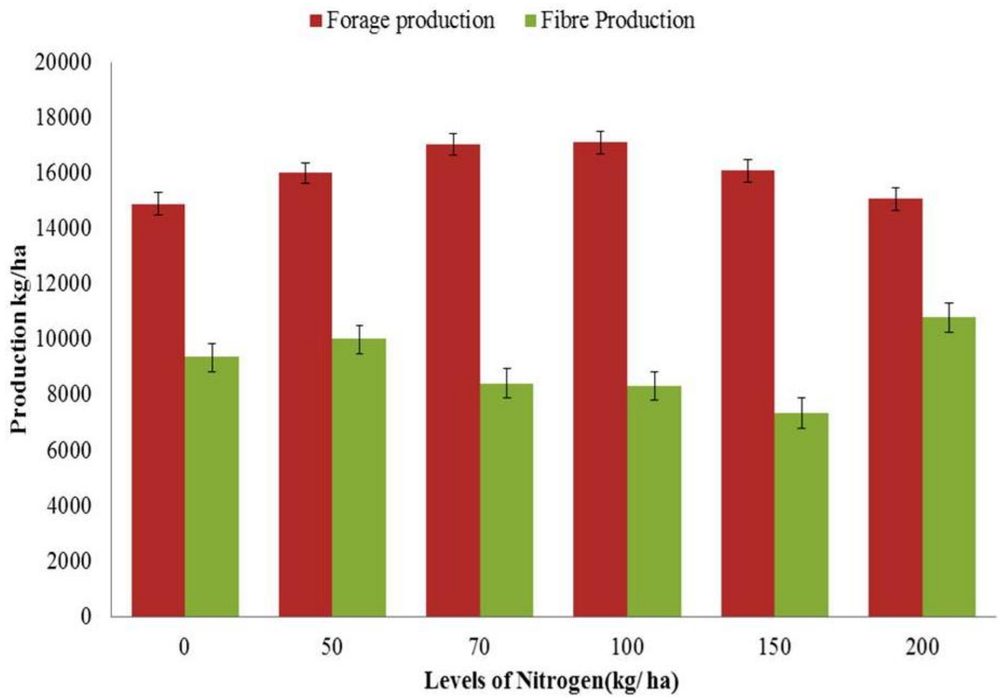

Figure 7. Effects of nitrogen level on forage and fiber production of kenaf (Zainal and Mansur, 2001).

can be stored at 8 to 12% moisture level. Several studies have indicated that seed should be stored at 5°C in a controlled humidity and temperature environment (Halimathul Saadiah, 2001; Bakhtiari et al., 2011).

Kenaf processing for forage use

As a high-protein feed source, kenaf is suggested to be suitable as a protein supplement for livestock feed. The optimum harvest interval for good-quality forage is about seven weeks to obtain the maximum dry yield. It is important to apply minimal doses of chemicals for production of crops to be used as animal feed. A multipurpose disc mill is needed to process kenaf material. The utility of a variety of forms of kenaf feed, such as pellets, silage, cubes, chaffs and meal, as animal feed have been studied (Liang et al., 2003). Kenaf meal is the most favorable for further processing because it can be mixed easily with other feed materials. Processing of kenaf involves a number of stages, such as harvesting, chopping and drying. On the basis of the results from a comprehensive study on forage production, it was recommended that forage kenaf should be harvested between 6 to 8 weeks after planting and chopped into 4-cm-long pieces and dried to less than 15% moisture. Kenaf meal should be stored in proper bags and in a dry environment. A study of bagging techniques revealed that kenaf meal can be stored for up to eight months in a plastic-lined bag at 21°C (Najib et al., 2001).

Kenaf processing for fiber production

As a fiber crop, the kenaf stem must be processed into the bast and core. Retting is the conventional method used to produce high-quality fiber. The traditional method is water retting, but this procedure results in severe environmental pollution and low-grade fiber; therefore it is essential to seek a pollution-free or minimal-pollution retting method. In a study of microbe retting, 91.31% removal of pectin was achieved under the optimal retting conditions. The most effective retting fungus was observed microscopically to be a type of epiphytic filamentous fungus (Yu and Yu, 2007). There is also demand for unprocessed kenaf stems from kenaf board manufacturers as an alternative woody species for paper production.

END PRODUCTS OF KENAF

Edible and cytotoxic oil

The kenaf oil content in kenaf seed varies on average between 16% and 22% (Bakhtiari et al., 2011). Kenaf seed oil is considered edible for human because of the high quantities of monounsaturated and polyunsaturated fatty acids (Coetzee et al., 2008). The seed oil is reported to be cytotoxic (Falusi, 2008) towards leukemia and cancer cells (Foo et al., 2011; Yazan et al., 2011a, b).

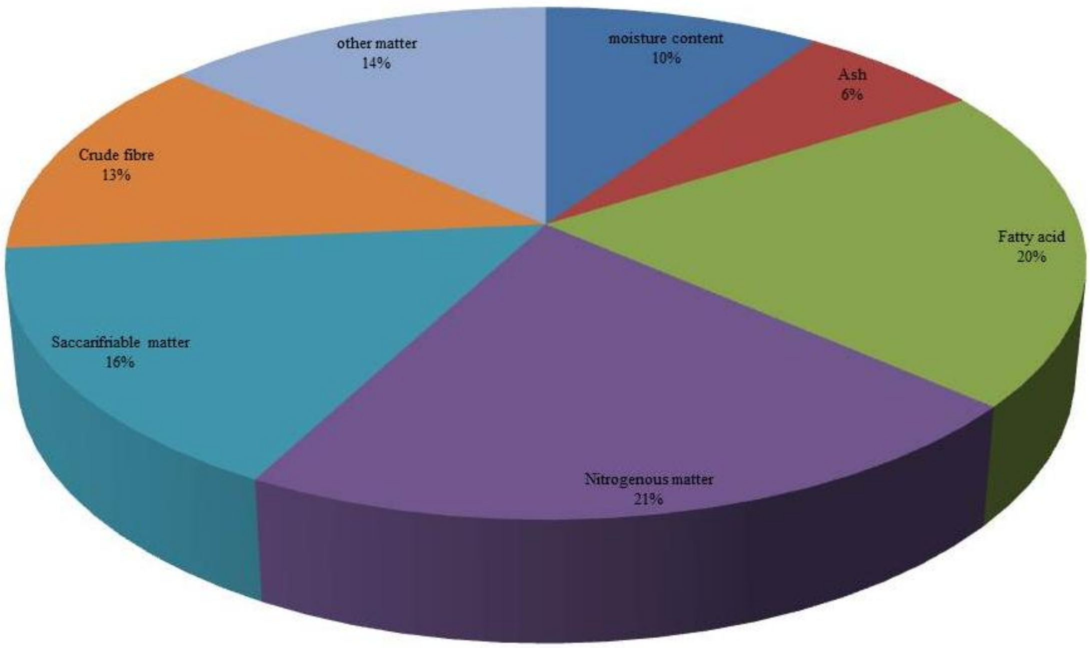

Figure 8. Composition of kenaf seed (Bakhtiari et al., 2011).

Kenaf stem parts were studied to investigate their biomedical value. A survey of pillows filled with kenaf decorticated fiber revealed that they had a positive effect on sleeping problems and reduced pains in 60% of respondents, which were selected on the basis of age, sex, marital status, and level of healthiness (Najib et al., 2006; Bakhtiari et al., 2011) (Figure 8).

Raw material for fiber

Kenaf fiber is a potential raw material for a variety of products such as reinforced composites, fiberboard, fabrics, high-quality paper, and furniture (Najib et al., 2006; Akil et al., 2011). The whole stem of kenaf is an attractive raw material that is suitable for use in high-quality paper production. Kenaf fibers exhibit different behavior during pulping and paper-making because of their different morphological structure (Aji et al., 2009; Akil et al., 2011; Mossello et al., 2010b). Fiber properties directly influence the pulping conditions applied in pulp and paper production. During refining, the core pulp rapidly attains a freeness value that is quite prohibitive for practical purposes. In contrast, bast pulp is refined easily and retains its strength (Mossello et al., 2010c; Harun et al., 2009). Because of differences in the quality of bast and core fibers, researchers have proposed fiber separation and pulping of each fraction separately, and using each pulp alone or blending the refined bast pulp and unrefined core based on the desired final product properties (Mossello et al., 2010d). Generally, selection of the pulping process depends on the function of the end product. Kraft, soda and soda-AQ processes are the most frequently used for kenaf. In comparison to Kraft pulping, the soda-AQ process gives a higher yield and better delignification without causing environmental damage because of restricted sulfur emissions. Soda-AQ pulping with kenaf whole stems requires a lower chemical input and produces a higher pulp yield than the soda process. In addition, the soda-AQ procedure is considered to be suitable for small-scale mills (Mossello et al., 2010, 2010e).

Biodegradable source of composite material

Kenaf has received attention from many researchers as a cheap, renewable, recyclable, and biodegradable alternative to synthetic polymers (Batchiar and Hamdan, 2009; Behjat et al., 2009; Ahmad et al., 2011). Kenaf exhibits a low density and non-abrasiveness during processing. Owing to kenaf's specific mechanical properties and biodegradability, after adequate treatment it can be used in combination with synthetic materials, such as polyester or rubber, which can help to greatly reduce the fiber hydrophilicity for the production of composite material (Ahmad et al., 2005, 2011; Aber et al., 2009; Abu Bakar et al., 2010). A number of studies have been carried out to explore the potential reinforcement of kenaf fiber with polymeric materials. A higher tensile strength of kenaf composite materials can be achieved by using fibers with higher tensile strength filling, but this could reduce the elasticity of kenaf fibers (Ahmad et al., 2005; Edeerozey et al., 2007; Aji et al., 2009, 2011). Different plant growth conditions can affect the length of kenaf fibers, which in turn affects the mechanical strength (Ochi, 2008). Some researchers disagree and state that modification of the fiber always improves the tensile strength of kenaf, but in fact sometimes the tensile strength is reduced (Kalam et al., 2005; Abdul Khalil and Suraya, 2010; Ismail et al., 2011; Thirmizir et al., 2011). The absorbent capacity of kenaf was found to be 10-fold more than the weight of kenaf core material (Najib et al., 2001, 2006; Cao et al., 2011; Jonoobi et al., 2011).

Use of kenaf fiber has shown promising results and requires further exploration to reduce environmental pollution. A number of research experiments have been conducted on the use of kenaf fiber, such as chemical treatment of fibers, matrix combinations, processing techniques, and environmental effects on the composite material. Most of these studies concluded that the problem of wettability of the composites inhibits further increase in fiber stuffing and, consequently, fiber pull-out (Ashori et al., 2005; Aber et al., 2009; Aji et al., 2009, 2011; Abdrahman and Zainudin, 2011).

Kenaf plants with long stems are reported to possess better fiber properties than plants with short stems. Determination of the critical length and tensile strength are important for preparation of a composite because, below this critical length, the mechanical and physical properties will be affected since strength and length of kenaf varies with fiber content (Ashori et al., 2006; Aji et al., 2011; Alavudeen et al., 2011; Anuar and Zuraida, 2011). For example, a composite can be damaged quite easily because of fiber pullouts. The critical fiber length for kenaf-fiber-reinforced biocomposites has been stated to be about 6 mm (Ashori, 2006; Abdul Khalil et al., 2010; Ibrahim et al., 2010; Bai and Yu, 2011). The results of a field experiment on the kenaf cultivar Everglades 71 indicated that the bast fiber contained a high content of holocellulose and alpha-cellulose, which could improve the composite strength and stability (Ashori, 2006; El-Shekeil et al., 2011). Morphological data for the same cultivar showed formation of a strong fiber–fiber hydrogen bond by virtue of easy pulp collapse. The longer length of the bast fibers resulted in flexible fibers that are good for fiber bonding, entanglement, and tear and tensile strength properties that are required in natural-fiber composites (Ashori, 2006; Talib et al., 2011). Similar results were obtained in the downstream sector of ongoing research at the Universiti Putra Malaysia on mechanical properties (Jonoobi et al., 2011; Harun et al., 2009). Many studies have shown considerable promise exists for the commercial viability and enhanced technological application of Malaysian cultivated kenaf for composite material production (Abdul Khalil et al., 2010; Abu Bakar et al., 2010; Abdrahman and Zainudin, 2011).

In a recent study kenaf was evaluated for phytoremediation of heavy-metal-contaminated soil. The results indicated that kenaf has potential to absorb and accumulate nickel and copper from contaminated soils (Hasfalina, 2010; Hasfalina et al., 2010). The detailed research is going on.

Status of kenaf in Malaysia

To develop the Kenaf industry in Malaysia requires an assessment of its overall business environment through a Strength, Weakness, and Opportunity and Threat (SWOT) analysis. There was a need to understand the various components and drivers of the industry in which it is competing. The information gained could then help support key decisions to be made in all areas including business development, Kenaf cultivation, and processing and manufacturing, production technology, human resource development, sales and marketing. It is then possible to make informed strategic choices and plan about the future of the organization. Development of kenaf industry in Malaysia has some considerable weak and strong aspects First of all, the climate of Malaysia is suitable for the kenaf cultivation. It has a high value as an added product and no waste plant utilization. The government and Research Departments of Malaysia are keenly interested in the cultivation of kenaf due to prospective market of its stem fiber in the region. However, unavailability of enough cultivation knowledge, lack of mechanization, high capital investment and low profits are main obstacles in developing kenaf industry in Malaysia.

According to a survey conducted in 2009 by ECER, available opportunities related to kenaf production has been revealed. They reported that there is high demand for Kenaf fibers both locally and internationally which should create opportunity for Kenaf stem cultivation. Kenaf stems market is promising as the demand is increasing. Currently, Kenaf stems have been produced by NKTB, *Everise crimson* and KFI. For example, there is a monthly demand from *Panasonic Electric Work Kenaf (Malaysia) Sdn Bhd* by 900 tonnes through NKTB. There is also a demand on Kenaf fiber and core locally and internationally. Locally, there is a willingness of companies such as *The Armour Factory* to be involved in this procuring of Kenaf fiber to replace their current material to Kenaf hybrid. Internationally, *KEFI Italy* has indicated interest to purchase 12,000 tonnes per year.

There are a number of research institutions (that is, UPM, MARDI and FRIM) who are continuously carrying out research for the development of Kenaf industry. For example, UPM is currently undertaking “Downstream Research and Marketing on Kenaf Based Products” funded by *Economic Planning Unit* (EPU), “Increased Production, Efficiency in Small-Holder Kenaf Production Systems for Specific Industrial Applications”, funded by UNIDO and other research projects which are funded by the university, and MARDI which was directed by NEAC to coordinate R&D on Kenaf as another industrial crop

(Including research on the upstream); and FRIM is developing a product, *Oriented Strand Board* (OSB) by using Kenaf bark. With this condition, there should be an increment in top down R&D funding from the government on selected area according to the Road Map.

It has become a national agenda as the Government supports the promotion of Kenaf as seventh commodity. In 2010, NKTB has received an allocation of more than RM 30 million for developing Kenaf industry in the states of Terengganu, Pahang and Kelantan under seven (7) key programs of Kenaf. This shows a commitment from government in supporting the Kenaf industry, e.g.: Optimization and reproduction of necessary harvesting and fiber processing machines.

FUTURE STRATEGIES

1. Local seed production, cultivation and harvesting of Kenaf and grading of fiber are still ineffective and a there is need to conduct research on these issues.
2. Farmers require effective extension and guides to improve their cultivation agronomy and raise yield. For this to happen, human resource development has to be enhanced to meet farmers' needs.
3. Existence of opportunities is necessary for high value added processing and innovation if fiber supplies arrangement tackled.
4. Government support and participation continue to be an important driver to Kenaf initiative.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Scientific Research and Essays

Numerical solutions for the nonlinear partial fractional Zakharov-Kuznetsov equations with time and space fractional

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In this article, we implement relatively analytical techniques such as the homotopy perturbation method and homotopy analysis method to solve nonlinear partial fractional differential Zakharov-Kuznetsov equations. The fractional derivatives are described in the Caputo sense. We compare between the approximate solutions obtained by the homotopy perturbation method and the approximate solutions obtained by homotopy analysis method. Also we make the figures compare between the approximate solutions. We compare between the approximate solutions and the exact solutions for the partial fractional differential equations when $\alpha,\beta,\gamma \to 1$.

Key words: Zakharov-Kuznetsov equations, the fractional derivatives, the homotopy perturbation method, the homotopy perturbation method, the approximate solutions.

INTRODUCTION

In recent years, fractional differential equations have gained much attention as they are widely used to describe various complex phenomena in many fields such as the fluid flow, signal processing, control theory, systems identification, biology and other areas. Several fields of application of fractional differentiation and fractional integration are already well established, some others have just started. Many applications of fractional calculus can be found in turbulence and fluid dynamics, stochastic dynamical system, plasma physics and controlled thermonuclear fusion, nonlinear control theory, image processing, nonlinear biological systems and astrophysics (Kilbas et al., 2006; Podlubny, 1999; Samko et al., 1993; El-Sayed, 1996; Herzallah et al., 2010, 2011; Magin, 2006; West et al., 2003; Jesus and Machado, 2008; Agrawal and Baleanu, 2007; Tarasov, 2008). Numerical and analytical methods have included the Adomian decomposition method (ADM) (Daftardar-Gejji and Bhalekar, 2008; Herzallah and Gepreel, 2012), the variational iteration method (VIM) (Sweilam et al., 2007), the homotopy perturbation method (Golbabai and Sayevand, 2010), and homotopy analysis method (Gepreel and Mohamed, 2013).

Consider the Zakharov-Kuznetsov ZK (m,n,k) equation:

$$u_t + a(u^m)_x + b(u^n)_{xxx} + c(u^k)_{yyx} = 0, \quad m,n,k \neq 0, \quad (1)$$

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where a,b,c are arbitrary constants and m,n,k are integers. This equation governs the behavior of weakly nonlinear ion-acoustic waves in plasma comprising cold ions and hot isothermal electrons in the presence of a uniform magnetic field (Monro and Parkers, 1999). The Zakharov–Kuznetsov equation supports stable lump solitary waves. This makes the Zakharov–Kuznetsov equation a very attractive model equation for use in the study of vortices in geophysical flows (Molliq and Batiha, 2012; Hammouch and Mekkaoui, 2013; Golbabai and Sayevanda, 2012).

Biazar et al. (2009) applied the homotopy perturbation method to solve the Zakharov-Kuznetsov ZK (m, n, k) equations. Hesam et al. (2012) studied (1) while applying the differential transform method to obtain its approximate solutions.

In this paper, we give a new model of the nonlinear fractional Zakharov-Kuznetsov ZK (2,2,2) equation in the following form:

$$D_t^{\alpha}u + a D_x^{\beta}(u^2) + b D_x^{3\beta}(u^2) + c D_x^{\beta} D_y^{2\gamma}(u^2) = 0, \quad t>0, \quad 0<\alpha,\beta,\gamma \le 1, \tag{2}$$

where $D_t^{\alpha}, D_x^{\beta}, D_y^{\gamma}$ denotes the fractional derivative of order α,β,γ with respect to t,x,y respectively. We will implement HPM and HAM to obtain approximate solutions of the nonlinear fractional Zakharov-Kuznetsov ZK (2,2,2) equation.

PRELIMINARIES AND NOTATION

Here, we give some basic definitions and properties of the fractional calculus theory which will be used further in this work. Podlubny (1999) revealed further details on this. For the finite derivative in [a, b], we define the following fractional integral and derivatives**.**

Definition 1. A real function $f(x), x>0,$ is said to be in the space C_{μ}, $\mu \in R,$ if there exists a real number $(P>\mu)$ such that $f(x) = x^{P} f_1(x),$ where $f_1(x) \in C(0,\infty),$ and it is said to be in the space C_{μ}^{m} if $f^{m} \in C_{\mu}, m \in N$.

Definition 2. The Riemann–Liouville fractional integral operator of order $\alpha \ge 0$ of a function $f \in C_{\mu}, \mu \ge -1,$ is defined as

$$J_t^{\alpha} f(x) = \frac{1}{\Gamma(\alpha)} \int_0^t (t-u)^{\alpha-1} f(u)\,du, \ \alpha>0, t>0, J^0 f(x) = f(x). \tag{3}$$

Properties of the operator J^{α} can be found in Podlubny (1999); we mention only the following:

For $f \in C_{\mu}, \mu \ge -1, \quad \alpha,\beta \ge 0,$ and $\gamma > -1:$

(a) $J^{\alpha} J^{\beta} f(x) = J^{\alpha+\beta} f(x),$

(b) $J^{\alpha} J^{\beta} f(x) = J^{\beta} J^{\alpha} f(x),$

(c) $J^{\alpha} x^{\gamma} = \dfrac{\Gamma(\gamma+1)}{\Gamma(\alpha+\gamma+1)} x^{\alpha+\gamma}.$ (4)

The Riemann–Liouville derivative has certain disadvantages when trying to model real-world phenomena with fractional differential equations. Therefore, we shall introduce a modified fractional differential operator D^{α} proposed by Caputo in his work on the theory of viscoelasticity (Podlubny, 1999).

Definition 3. For $\alpha > 0$ the Caputo fractional derivative of order α on the whole space, denoted by ${}^{C}D_{+}^{\alpha}$, is defined by

$${}^{C}D_{+}^{\alpha} f(x) = \frac{1}{\Gamma(n-\alpha)} \int_{-\infty}^{x} (x-\xi)^{n-\alpha-1} D^{n} f(\xi)\, d(\xi). \tag{5}$$

THE HOMOTOPY PERTURBATION METHOD

To illustrate the basic idea of this method (Golbabai and Sayevand, 2011), we consider the following nonlinear fractional differential equation:

$$D_t^{\alpha} u(\bar{x},t) = f(\bar{x},t) - Lu(\bar{x},t) - Nu(\bar{x},t), \quad m-1<\alpha<m, \quad m \in N, \ t \ge 0, \bar{x} \in R^{n}, \tag{6}$$

subject to the initial and boundary conditions

$$u^{(i)}(\bar{0},0) = c_i, \qquad B\left(u, \frac{\partial u}{\partial x_j}, \frac{\partial u}{\partial t}\right) = 0, \qquad i = 0,1,\dots,m-1, \qquad j = 1,2,\dots,n, \tag{7}$$

where L is a linear operator, while N is a nonlinear operator, f is a known analytical function and D_t^{α} denotes the fractional derivative in the Caputo sense. The solution u is assumed to be a causal function of time, that is, vanishing for $t<0$. Also $u^{(i)}(\bar{x},t)$ is the i^{th} derivative of u , $c_i = 0,1,\dots,m-1$ are the specified initial conditions and B is a boundary operator.

Applying He (2006) homotopy perturbation technique, we can construct the following simple homotopy

$$(1-p) D_t^{\alpha} u(\bar{x},t) + p\,[\,D_t^{\alpha} u(\bar{x},t) + Lu(\bar{x},t) + Nu(\bar{x},t) - f(\bar{x},t)] = 0, \quad p \in [0,1], \tag{8}$$

or

$$D_t^{\alpha} u(\bar{x},t) + p\ [\ Lu(\bar{x},t) + Nu(\bar{x},t) - f\ (\bar{x},t)\ ] = 0, \qquad p \in [0,1]. \tag{9}$$

The homotopy parameter p always changes from zero to unity. In the case $p = 0$, Equation (8) or (9) becomes

$$D_t^{\alpha} u(\bar{x},t) = 0, \tag{10}$$

and when $p = 1$, Equation (8) or (9) turns out to be the original fractional differential equation. Applying the homotopy perturbation method, we use the homotopy parameter p to expand the solution into the following form

$$u(\bar{x},t) = u_0(\bar{x},t) + p\ u_1(\bar{x},t) + p^2\ u_2(\bar{x},t) + p^3\ u_3(\bar{x},t) + ... \tag{11}$$

For nonlinear problems, let us set $Nu(\bar{x},t) = S(\bar{x},t)$. Substituting Equation (11) into (8) or (9) and equating the terms with identical powers of p, we can obtain a series of equations of the form

$$\begin{aligned}
&p^0 : D_t^{\alpha} u(\bar{x},t) = 0,\\
&p^1 : D_t^{\alpha} u_1(\bar{x},t) = -Lu_0(\bar{x},t) - S_0(u_0(\bar{x},t)) + f\ (\bar{x},t)\ ],\\
&p^2 : D_t^{\alpha} u_2(\bar{x},t) = -Lu_1(\bar{x},t) - S_1(u_0(\bar{x},t), u_1(\bar{x},t)),\\
&p^3 : D_t^{\alpha} u_3(\bar{x},t) = -Lu_2(\bar{x},t) - S_2(u_0(\bar{x},t), u_1(\bar{x},t), u_2(\bar{x},t)),\\
&\vdots
\end{aligned} \tag{12}$$

where the functions $S_0, S_1, S_2, ...$ satisfy the following equations

$$\begin{aligned}
S\,(u_0(\bar{x},t) + p\ u_1(\bar{x},t) + p^2 u_2(\bar{x},t) + ...) &= S_0(u_0(\bar{x},t)) + p\,S_1(u_0(\bar{x},t), u_1(\bar{x},t))\\
&\quad + p^2 S_2(u_0(\bar{x},t), u_1(\bar{x},t), u_2(\bar{x},t)) + ...
\end{aligned} \tag{13}$$

Applying the operator I_t^{α} on both sides of Equation (12) and considering the initial and boundary conditions, the terms of the series solution can be given by

$$\begin{aligned}
&u_0(\bar{x},t) = \sum_{i=0}^{n-1} \frac{c_i t^i}{i\,!},\\
&u_1(\bar{x},t) = -J_t^{\alpha}\ [\ Lu_0(\bar{x},t)] - J_t^{\alpha}[\ S_0(u_0(\bar{x},t))\ ] + J_t^{\alpha}[f\ (\bar{x},t)\ ],\\
&u_j(\bar{x},t) = -J_t^{\alpha}\ [\ Lu_{j-1}(\bar{x},t)] - J_t^{\alpha}[\ S_{j-1}(u_0(\bar{x},t), u_1(\bar{x},t), ..., u_{j-1}(\bar{x},t))\ ], \qquad j = 2,3,...
\end{aligned} \tag{14}$$

On setting $p = 1$, we get an accurate approximation solution in the following form

$$u(\bar{x},t) = \sum_{i=0}^{\infty} u_i\,(\bar{x},t). \tag{15}$$

THE HOMOTOPY ANALYSIS METHOD (HAM)

To describe the basic ideas of the HAM, we consider the following differential equation

$$N\,[\ D_t^{\alpha} u(x,y,t)] = 0, \tag{16}$$

where N is a nonlinear operator for this problem, while D_t^{α} stand for the fractional derivative, x, y and t denotes independent variables and $u(x,y,t)$ is an unknown function.

By means of the HAM, one first construct zero-order deformation equation

$$(1-q)\ \ell(\phi(x,y,t;q) - u_0(x,y,t)) = qhH(t)N\,[\phi(x,y,t;q)], \tag{17}$$

where $q \in [0, 1]$ is the embedding parameter, $h \neq 0$ is an auxiliary parameter, $H(t) \neq 0$ is an auxiliary function, ℓ is an auxiliary linear operator and $u_0(x,y,t)$ is an initial guess. Obviously, when $q = 0$ and $q = 1$, it holds

$$\phi(x,y,t;0) = u_0(x,y,t), \qquad \phi(x,y,t;1) = u(x,y,t). \tag{18}$$

Liao (1992, 1995) expanded $\phi(x,y,t;q)$ in Taylor series with respect to the embedding parameter *q*, as follows:

$$\phi(x,y,t;q) = u_0(x,y,t) + \sum_{m=1}^{\infty} u_m(x,y,t)\,q^m, \tag{19}$$

where

$$u_m(x,y,t) = \frac{1}{m\,!} \frac{\partial^m \phi(x,y,t;q)}{\partial q^m}\bigg|_{q=0}. \tag{20}$$

Assume that the auxiliary linear operator, the initial guess, the auxiliary parameter *h* and the auxiliary function $H(t)$ are selected such that the series (19) is convergent at $q = 1$, then we have from (19)

$$u(x,y,t) = u_0(x,y,t) + \sum_{m=1}^{\infty} u_m(x,y,t). \tag{21}$$

Let us define the vector

$$\vec{u}_n(t)=\{u_0(x,y,t),u_1(x,y,t),u_2(x,y,t),...,u_n(x,y,t)\}. \quad (22)$$

Differentiating (17) m times with respect to q, then setting $q=0$ and dividing then by $m!$, we have the mth-order deformation equations

$$\ell(u_m(x,y,t)-\chi_m u_{m-1}(x,y,t))=hH(t)\Re_m(\vec{u}_{m-1}), \quad (23)$$

Where

$$\Re_m(\vec{u}_{m-1})=\frac{1}{(m-1)!}\frac{\partial^{m-1}N[\phi(x,y,t;q)]}{\partial q^{m-1}}\Bigg|_{q=0}, \quad (24)$$

and

$$\chi_m=\begin{cases}0 & m\le 1,\\ 1 & m>1.\end{cases} \quad (25)$$

Applying the Riemann-Liouville integral operator J^α on both side of (23), we have

$$u_m(x,y,t)=\chi_m u_{m-1}(x,y,t)-\chi_m\sum_{i=0}^{n-1}u^i_{m-1}(0^+)\frac{t^i}{i!}+hH(t)J^\alpha\Re_m(\vec{u}_{m-1}). \quad (26)$$

APPLICATIONS

Here, we use the homotopy perturbation and homotopy analysis methods to calculate the approximate solution of the fractional Zakharov-Kuznetsov equation. To calculate fractional derivative to hyperbolic function *sinh* will we use the fractional derivative of the exponential function which defined in Miller and Sugden (2009) as the follows

$$D_x^\mu(e^{\sigma x})=\sigma^\mu e^{\sigma x}, \quad \sigma>0, \qquad D_x^\mu(e^{\sigma x})=(-1)^\mu(-\sigma)^\mu e^{\sigma x}, \quad \sigma<0,$$

so that

$$D_x^\alpha[\sinh(bx)]=D_x^\alpha[\frac{1}{2}(e^{bx}-e^{-bx})]=\frac{1}{2}[b^\alpha e^{bx}-(-1)^\alpha b^\alpha e^{-bx}], \quad b>0.$$

Example 1

Consider the fractional Zakharov-Kuznetsov equation in the following form

$$D_t^\alpha u+D_x^\beta(u^2)+\frac{1}{8}D_x^{3\beta}(u^2)+\frac{1}{8}D_x^\beta D_y^{2\gamma}(u^2)=0, \quad t>0, \quad 0<\alpha,\beta,\gamma\le 1, \quad (27)$$

subject to the following initial conditions

$$u(x,y,0)=\frac{4}{3}\lambda\sinh^2(x+y), \quad (28)$$

where λ is an arbitrary constant.

By the homotopy perturbation technique, we construct a homotopy function $H(V,p)$ which satisfies

$$H(V,p)=(1-p)[D_t^\alpha V-D_t^\alpha V_0]+p[D_t^\alpha V+D_x^\beta(V^2)+\frac{1}{8}D_x^{3\beta}(V^2)+\frac{1}{8}D_x^\beta D_y^{2\gamma}(V^2)]=0. \quad (29)$$

According to the homotopy perturbation method, we can first use the embedding parameter p as a small parameter, and assume that the solution of Equation (29) can be written as a power series in p as follows:

$$V(x,y,t)=V_0(x,y,t)+pV_1(x,y,t)+p^2V_2(x,y,t)+p^3V_3(x,y,t)+... \quad (30)$$

Substituting Equation (30) into (29) and arranging the coefficients of powers of p, after some calculation we obtain

$$p^0:\ D_t^\alpha V_0=0, \qquad V(x,y,0)=\frac{4}{3}\lambda\sinh^2(x+y),$$

$$p^1: D_t^\alpha V_1+D_x^\beta(V_0^2)+\frac{1}{8}D_x^{3\beta}(V_0^2)+\frac{1}{8}D_x^\beta D_y^{2\gamma}(V_0^2)=0,$$

$$p^2: D_t^\alpha V_2+D_x^\beta(2V_0V_1)+\frac{1}{8}D_x^{3\beta}(2V_0V_1)+\frac{1}{8}D_x^\beta D_y^{2\gamma}(2V_0V_1)=0,$$

$$p^3: D_t^\alpha V_3+D_x^\beta(2V_0V_2+V_1^2)+\frac{1}{8}D_x^{3\beta}(2V_0V_2+V_1^2)+\frac{1}{8}D_x^\beta D_y^{2\gamma}(2V_0V_2+V_1^2)=0. \quad (31)$$

After some calculation, we have

$$V_0(x,y,t)=\frac{4}{3}\lambda\sinh^2(x+y), \quad (32)$$

$$V_1(x,y,t)=\frac{-\lambda^2t^\alpha}{9\,\Gamma(\alpha+1)}\Big\{[2^{2\beta}+2^{6\beta-3}+2^{2\beta+4\gamma-3}][e^{4(x+y)}+(-1)^\beta e^{-4(x+y)}]-[2^{\beta+2}+2^{3\beta-1}+2^{\beta+2\gamma-1}][e^{2(x+y)}+(-1)^\beta e^{-2(x+y)}]\Big\}, \quad (33)$$

$$V_2(x,y,t)=\frac{2\lambda^3t^{2\alpha}}{27\Gamma(2\alpha+1)}\Big[2^{-5+2\beta}(8+4^\beta+4^\gamma)(64+2^{3+\beta}+2^{3+2\beta}+2^{3+2\gamma}+2^{\beta+4\gamma}+32^\beta)\cosh(2x+2y)-2^{-4+3\beta}(8+16^\beta+16^\gamma)(16+2^{3+\beta}+2^{1+2\beta}+2^{1+2\gamma}+2^{\beta+4\gamma}+32^\beta)\cosh(4x+4y)+2^{-5+3\beta}3^\beta(8+16^\beta+16^\gamma)(8+32^\beta+32^\gamma)\cosh(6x+6y)\Big], \quad (34)$$

$$V_3(x,y,t)=\frac{-\lambda^4 t^{3\alpha}\,\Gamma(2\alpha+1)}{81\,\Gamma(3\alpha+1)}\Big\{\omega_1[e^{2(x+y)}+(-1)^{\beta}e^{-2(x+y)}]+\omega_2[e^{4(x+y)}+(-1)^{\beta}e^{-4(x+y)}]$$
$$+\omega_3[e^{6(x+y)}+(-1)^{\beta}e^{-6(x+y)}]+\omega_4[e^{8(x+y)}+(-1)^{\beta}e^{-8(x+y)}]\Big\}, \quad (35)$$

and so on, where

$$\omega_1=-8^{-2+\beta}(8+4^{\beta}+4^{\gamma})\Big[\frac{(-2)^{\beta}(8+4^{\beta}+4^{\gamma})(8+16^{\beta}+16^{\gamma})}{\Gamma^2(\alpha+1)}+\frac{2^{\beta}(8+16^{\beta}+16^{\gamma})(16+2^{3+\beta}+2^{1+2\beta}+2^{1+2\gamma}+2^{\beta+4\gamma}+32^{\beta})}{\Gamma(2\alpha+1)}+\frac{(8+4^{\beta}+4^{\gamma})(64+2^{3+\beta}+2^{3+2\beta}+2^{3+2\gamma}+2^{\beta+4\gamma}+32^{\beta})}{\Gamma(2\alpha+1)}\Big], \quad (36)$$

$$\omega_2=2^{-7+4\beta}(8+16^{\beta}+16^{\gamma})\Big[\frac{6^{\beta}(8+16^{\beta}+16^{\gamma})(8+36^{\beta}+36^{\gamma})}{\Gamma(2\alpha+1)}+\frac{4(8+4^{\beta}+4^{\gamma})^2}{\Gamma^2(\alpha+1)}+\frac{(8+4^{\beta}+4^{\gamma})(64+2^{3+\beta}+2^{3+2\beta}+2^{3+2\gamma}+2^{\beta+4\gamma}+32^{\beta})}{\Gamma(2\alpha+1)}+\frac{2^{2+\beta}(8+16^{\beta}+16^{\gamma})(16+2^{3+\beta}+2^{1+2\beta}+2^{1+2\gamma}+2^{\beta+4\gamma}+32^{\beta})}{\Gamma(2\alpha+1)}\Big], \quad (37)$$

$$\omega_3=\frac{-3^{\beta}\;4^{-3+2\beta}(8+16^{\beta}+16^{\gamma})(8+36^{\beta}+36^{\gamma})}{\Gamma^2(\alpha+1)\,\Gamma(2\alpha+1)}\Big[(8+4^{\beta}+4^{\gamma})\Gamma(2\alpha+1)+(16+2^{3+\beta}+2^{1+2\beta}+2^{1+2\gamma}+2^{\beta+4\gamma}+8\times3^{\beta}+3^{\beta+2\gamma}\times4^{\gamma}+32^{\beta}+108^{\beta})\Gamma^2(\alpha+1)\Big], \quad (38)$$

$$\omega_4=8^{-3+2\beta}(8+16^{\beta}+16^{\gamma})(8+64^{\beta}+64^{\gamma})\Big[\frac{2^{\beta}(8+16^{\beta}+16^{\gamma})}{\Gamma^2(\alpha+1)}+\frac{4\times3^{\beta}(8+36^{\beta}+36^{\gamma})}{\Gamma(2\alpha+1)}\Big]. \quad (39)$$

On setting $p=1$, we get an accurate approximation solution by the homotopy perturbation method which takes the following form:

$$u(x,y,t)=\frac{4}{3}\lambda\sinh^2(x+y)-\frac{\lambda^2 t^{\alpha}}{9\,\Gamma(\alpha+1)}\Big\{[2^{2\beta}+2^{6\beta-3}+2^{2\beta+4\gamma-3}][e^{4(x+y)}+(-1)^{\beta}e^{-4(x+y)}]-[2^{\beta+2}+2^{3\beta-1}+2^{\beta+2\gamma-1}][e^{2(x+y)}+(-1)^{\beta}e^{-2(x+y)}]\Big\}$$
$$+\frac{2\lambda^3 t^{2\alpha}}{27\Gamma(2\alpha+1)}\Big[2^{-5+2\beta}(8+4^{\beta}+4^{\gamma})(64+2^{3+\beta}+2^{3+2\beta}+2^{3+2\gamma}+2^{\beta+4\gamma}+32^{\beta})\cosh(2x+2y)-2^{-4+3\beta}(8+16^{\beta}+16^{\gamma})(16+2^{3+\beta}+2^{1+2\beta}+2^{1+2\gamma}+2^{\beta+4\gamma}+32^{\beta})\cosh(4x+4y)+2^{-5+3\beta}3^{\beta}(8+16^{\beta}+16^{\gamma})(8+32^{\beta}+32^{\gamma})\cosh(6x+6y)\Big]$$
$$-\frac{\lambda^4 t^{3\alpha}\,\Gamma(2\alpha+1)}{81\,\Gamma(3\alpha+1)}\Big\{\omega_1[e^{2(x+y)}+(-1)^{\beta}e^{-2(x+y)}]+\omega_2[e^{4(x+y)}+(-1)^{\beta}e^{-4(x+y)}]+\omega_3[e^{6(x+y)}+(-1)^{\beta}e^{-6(x+y)}]+\omega_4[e^{8(x+y)}+(-1)^{\beta}e^{-8(x+y)}]\Big\}+\dots. \quad (40)$$

Equation (40) represented the approximate solution for the fractional Zakharov -Kuznetsov Equation (27) which was obtained by HPM.

By means of the homotopy analysis method, we choose the linear operator

$$\ell[\phi(x,y,t;q)]=\frac{\partial^{\alpha}\phi(x,y,t;q)}{\partial t^{\alpha}}, \quad (41)$$

with property $\ell[c]=0,$ where c is a constant. We define a nonlinear operator as

$$N[\phi(x,y,t;q)]=\frac{\partial^{\alpha}\phi(x,y,t;q)}{\partial t^{\alpha}}+\frac{\partial^{\beta}\phi^2(x,y,t;q)}{\partial x^{\beta}}+\frac{1}{8}\frac{\partial^{3\beta}\phi^2(x,y,t;q)}{\partial x^{3\beta}}+\frac{1}{8}\frac{\partial^{\beta}\partial^{2\gamma}\phi^2(x,y,t;q)}{\partial x^{\beta}\partial y^{2\gamma}}. \quad (42)$$

We consider auxiliary function $H(t)=1.$ So, the zeroth-order deformation equation

$$(1-q)\,\ell[\phi(x,y,t;q)-u_0(x,y,t)]=qhN[\phi(x,y,t;q)]. \quad (43)$$

For $q=0$ and $q=1,$ we can write

$$\phi(x,y,t;0)=u_0(x,y,t), \qquad \phi(x,y,t;1)=u(x,y,t). \quad (44)$$

Thus, we obtain the m^{th} -order deformation equations

$$u_m(x,y,t)=\chi_m u_{m-1}(x,y,t)+J_t^{\alpha}\Big[h\Big(D_t^{\alpha}u_{m-1}+D_x^{\beta}\sum_{n=0}^{m-1}u_n u_{m-1-n}+\frac{1}{8}D_x^{3\beta}\sum_{n=0}^{m-1}u_n u_{m-1-n}+\frac{1}{8}D_x^{\beta}D_y^{2\gamma}\sum_{n=0}^{m-1}u_n u_{m-1-n}\Big)\Big], \quad m\ge 1. \quad (45)$$

By using the Equation (45), and after some calculation we obtain

$$u_1(x,y,t)=\frac{h\,\lambda^2 t^{\alpha}}{9\,\Gamma(\alpha+1)}\Big\{[2^{2\beta}+2^{6\beta-3}+2^{2\beta+4\gamma-3}][e^{4(x+y)}+(-1)^{\beta}e^{-4(x+y)}]-[2^{\beta+2}+2^{3\beta-1}+2^{\beta+2\gamma-1}][e^{2(x+y)}+(-1)^{\beta}e^{-2(x+y)}]\Big\}, \quad (46)$$

$$u_2(x,y,t)=(h+1)u_1(x,y,t)+\frac{2h^2\lambda^3 t^{2\alpha}}{27\Gamma(2\alpha+1)}\Big[2^{-5+2\beta}(8+4^{\beta}+4^{\gamma})(64+2^{3+\beta}+2^{3+2\beta}+2^{3+2\gamma}+2^{\beta+4\gamma}+32^{\beta})\cosh(2x+2y)-2^{-4+3\beta}(8+16^{\beta}+16^{\gamma})(16+2^{3+\beta}+2^{1+2\beta}+2^{1+2\gamma}+2^{\beta+4\gamma}+32^{\beta})\cosh(4x+4y)+2^{-5+3\beta}3^{\beta}(8+16^{\beta}+16^{\gamma})(8+32^{\beta}+32^{\gamma})\cosh(6x+6y)\Big], \quad (47)$$

$$u_3(x,y,t)=(h+1)u_2(x,y,t)+\frac{h^3\lambda^4 t^{3\alpha}\,\Gamma(2\alpha+1)}{81\,\Gamma(3\alpha+1)}\Big\{\omega_1[e^{2(x+y)}+(-1)^{\beta}e^{-2(x+y)}]+\omega_2[e^{4(x+y)}+(-1)^{\beta}e^{-4(x+y)}]+\omega_3[e^{6(x+y)}+(-1)^{\beta}e^{-6(x+y)}]+\omega_4[e^{8(x+y)}+(-1)^{\beta}e^{-8(x+y)}]\Big\}, \quad (48)$$

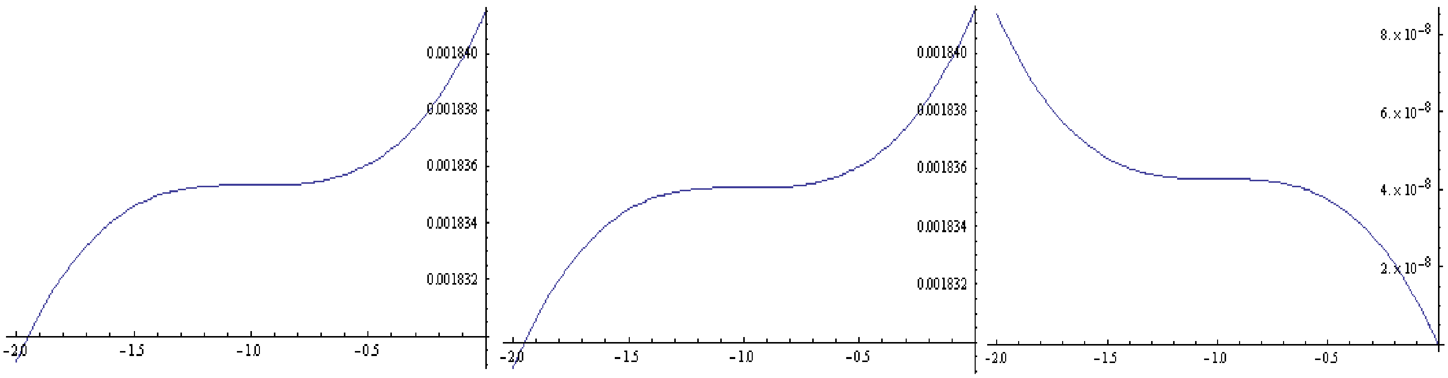


Figure 1. The h-curves of the four-order approximation to Abs $(u(x,y,t))$, Re $(u(x,y,t))$ and Im$(u(x,y,t))$ respectively at $\alpha=\beta=\gamma=0.5,\ \lambda=0.001,\ y=x=0.5,\ t=0.1$.

where $\omega_1,\omega_2,\omega_3,\omega_4$ take the same form (36)…(39) respectively.

In this case, the approximate solution by using the homotopy analysis method of Equation (27) is given by

$$\begin{aligned}
u(x,y,t) &= \frac{4}{3}\lambda\sinh^2(x+y)+\frac{h\lambda^2t^\alpha}{9\,\Gamma(\alpha+1)}\Big\{[\,2^{2\beta}+2^{6\beta-3}+2^{2\beta+4\gamma-3}][\,e^{4(x+y)}+(-1)^\beta e^{-4(x+y)}] \\
&\quad -[\,2^{\beta+2}+2^{3\beta-1}+2^{\beta+2\gamma-1}][\,e^{2(x+y)}+(-1)^\beta e^{-2(x+y)}]\Big\} \\
&\quad +(h+1)u_1(x,y,t)+\frac{2h^2\lambda^3t^{2\alpha}}{27\Gamma(2\alpha+1)}\Big[\,2^{-5+2\beta}(8+4^\beta+4^\gamma) \\
&\quad (64+2^{3+\beta}+2^{3+2\beta}+2^{3+2\gamma}+2^{\beta+4\gamma}+32^\beta)\cosh(2x+2y) \\
&\quad -2^{-4+3\beta}(8+16^\beta+16^\gamma)(16+2^{3+\beta}+2^{1+2\beta}+2^{1+2\gamma}+2^{\beta+4\gamma}+32^\beta)\cosh(4x+4y) \\
&\quad +2^{-5+3\beta}3^\beta(8+16^\beta+16^\gamma)(8+32^\beta+32^\gamma)\cosh(6x+6y)\,\Big] \\
&\quad +(h+1)u_2(x,y,t)+\frac{h^3\lambda^4t^{3\alpha}\,\Gamma(2\alpha+1)}{81\,\Gamma(3\alpha+1)}\Big\{\omega_1[e^{2(x+y)}+(-1)^\beta e^{-2(x+y)}] \\
&\quad +\omega_2[e^{4(x+y)}+(-1)^\beta e^{-4(x+y)}]+\omega_3[e^{6(x+y)}+(-1)^\beta e^{-6(x+y)}] \\
&\quad +\omega_4[e^{8(x+y)}+(-1)^\beta e^{-8(x+y)}]\Big\} \\
&\quad +\ldots
\end{aligned} \tag{49}$$

Equation (49) represented the approximate solution for the fractional Zakharov-Kuznetsov Equation (27) which was obtained by HAM.

Remarks 1

1) The homotopy analysis method determines the interval of convergence from the h-curve (Figure 1). As pointed by Liao (1992, 1995), the valid region of *h* is a horizontal line segment. Therefore, it is straightforward to choose an appropriate range for *h* which ensure the convergence of the solution series. We stretch the h-curve of $u(0.5,0.5,0.1)$ in Figure 1, which shows that the solution series is convergence when $-1.5<h<-0.5$.

2) In special case, when $\alpha,\beta,\gamma\to1$ in Equations (32) to (35), we get

$$\begin{aligned}
V_0(x,y,t) &= \frac{4}{3}\lambda\sinh^2(x+y), \\
V_1(x,y,t) &= \frac{-224}{9}\lambda^2\sinh^3(x+y)\cosh(x+y)t-\frac{32}{3}\lambda^2\sinh(x+y)\cosh^3(x+y)t, \\
V_2(x,y,t) &= \frac{64}{27}\lambda^3(\,1200\cosh^6(x+y)-2080\cosh^4(x+y)+968\cosh^2(x+y)-79)\,t^2, \\
V_3(x,y,t) &= \frac{-4096}{243}\sinh(x+y)\cosh(x+y)\Big[\,23800\cosh^6(x+y) \\
&\quad -42900\cosh^4(x+y)+22665\cosh^2(x+y)-3142\Big]\lambda^4t^3,
\end{aligned} \tag{50}$$

is the same solutions obtained by Biazar et al. (2009).

Table 1 leads to the absolute error between the approximate solutions (40) obtained by HPM and the approximate solutions (49) obtained by HAM. The absolute error is very small so that the approximate solutions has the same behavior.

Approximate solutions obtained by HPM tends to the approximate obtained by HAM when $h\to-1$.

The comparison between the approximate solution of Equation (27) by using the HPM and approximate solution by using HAM are shown in Figure 2.

Example 2

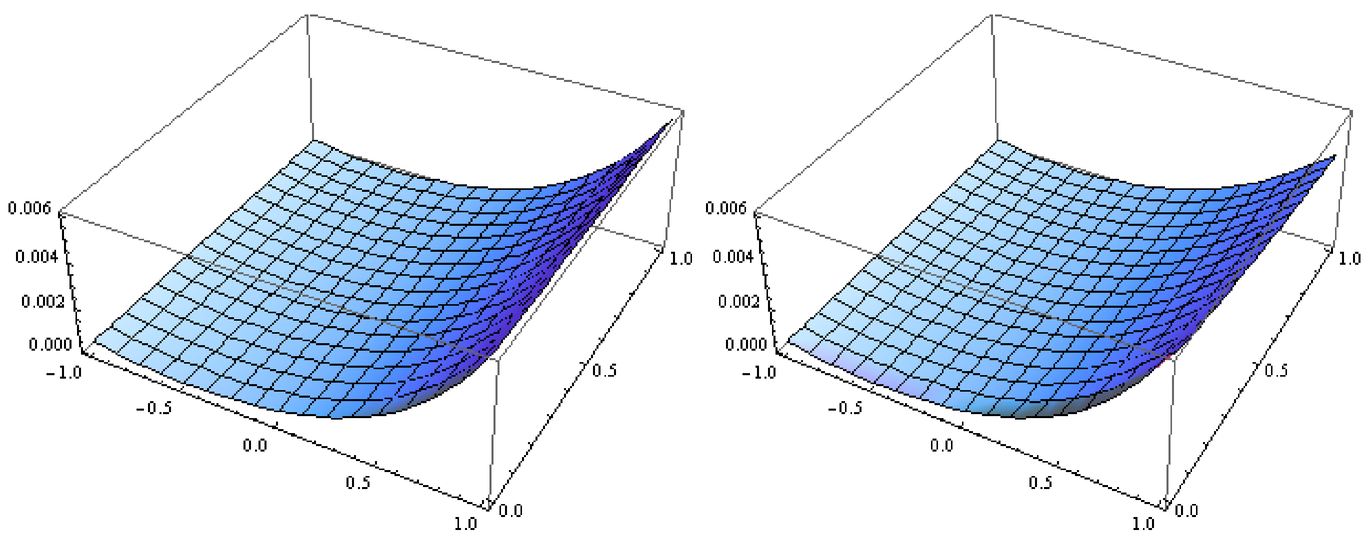
Consider the fractional Zakharov-Kuznetsov equation in the following form

$$D_t^\alpha u-D_x^\beta(u^2)+\frac{1}{8}D_x^{3\beta}(u^2)+\frac{1}{8}D_x^\beta D_y^{2\gamma}(u^2)=0,\qquad t>0,\quad 0<\alpha,\beta,\gamma\le1, \tag{51}$$

subject to the following initial conditions (Hesam et al., 2012):

Table 1. Determine the absolute error between the real part of approximate solutions (40) which obtained by the HPM and the real part of approximate solutions (49) which obtained by the HAM when $y=\alpha=\beta=\gamma=0.1,\ h=-1.1$ and $\lambda=0.001$.

x	t	Re U_{HPM}	Re U_{HAM}	$\lvert u_{HPM}-u_{HAM}\rvert$
	0.1	0.5476301844E-4	0.5476378484E-4	0.76640E-9
0.1	0.5	0.5488796450E-4	0.5488887554E-4	0.91104E-9
	0.9	0.5493885905E-4	0.5493982991E-4	0.97086E-9
	0.1	0.5407093554E-3	0.5407096643E-3	0.3089E-9
0.5	0.5	0.5407569911E-3	0.5407573617E-3	0.3706E-9
	0.9	0.5407763977E-3	0.5407767940E-3	0.3963E-9
	0.1	0.1837593296E-2	0.1837591245E-2	0.2051E-8
0.9	0.5	0.1836921718E-2	0.1836919675E-2	0.2043E-8
	0.9	0.1836648586E-2	0.1836646577E-2	0.2009E-8



(a) (b)

Figure 2. (a) Represents the real part of approximate solution (40) by HPM and (b) represents the real part of approximate solution (49) by HAM at $\alpha=\beta=\gamma=y=0.5,\quad \lambda=0.001,\quad h=-3,\ -1\le x\le 1$ and $0\le t\le 1$.

$$u(x,y,0)=\frac{4}{3}\lambda\sinh^2[\frac{1}{2}(x+y)], \tag{52}$$

where λ is an arbitrary constant.

By the homotopy perturbation technique, we construct a homotopy which satisfies

$$H(V,p)=(1-p)[D_t^\alpha V-D_t^\alpha V_0]+p[D_t^\alpha V-D_x^\beta(V^2)+\frac{1}{8}D_x^{3\beta}(V^2)+\frac{1}{8}D_x^\beta D_y^{2\gamma}(V^2)]=0. \tag{53}$$

According to the homotopy perturbation method, we can first use the embedding parameter p as a small parameter, and assume that the solution of Equation (53) can be written as a power series in p as follows:

$$V(x,y,t)=V_0(x,y,t)+pV_1(x,y,t)+p^2V_2(x,y,t)+p^3V_3(x,y,t)+... \tag{54}$$

Substituting Equation (54) into (53) and arranging the coefficients of powers of p, after some calculation we obtain

$$p^0: D_t^\alpha V_0 = 0, \qquad V(x,y,0) = \frac{4}{3}\lambda \sinh^2[\frac{1}{2}(x+y)],$$

$$p^1: D_t^\alpha V_1 - D_x^\beta (V_0^{\,2}) + \frac{1}{8}D_x^{3\beta}(V_0^{\,2}) + \frac{1}{8}D_x^\beta D_y^{2\gamma}(V_0^{\,2}) = 0,$$

$$p^2: D_t^\alpha V_2 - D_x^\beta (2V_0V_1) + \frac{1}{8}D_x^{3\beta}(2V_0V_1) + \frac{1}{8}D_x^\beta D_y^{2\gamma}(2V_0V_1) = 0,$$

$$p^3: D_t^\alpha V_3 - D_x^\beta (2V_0V_2 + V_1^{\,2}) + \frac{1}{8}D_x^{3\beta}(2V_0V_2 + V_1^{\,2}) + \frac{1}{8}D_x^\beta D_y^{2\gamma}(2V_0V_2 + V_1^{\,2}) = 0. \qquad (55)$$

After some calculation, we have

$$V_0(x,y,t) = \frac{4}{3}\lambda \sinh^2[\frac{1}{2}(x+y)], \qquad (56)$$

$$V_1(x,y,t) = \frac{-\lambda^2 t^\alpha}{9\,\Gamma(\alpha+1)}\Big\{[-2^\beta + 2^{3\beta-3} + 2^{\beta+2\gamma-3}]\,[e^{2(x+y)} + (-1)^\beta\, e^{-2(x+y)}] + 3e^{(x+y)} + 3(-1)^\beta e^{-(x+y)}]\Big\}, \qquad (57)$$

$$V_2(x,y,t) = \frac{2\,\lambda^3 t^{2\alpha}}{27\,\Gamma(2\alpha+1)}\,[\; 2^{-5+\beta}3^\beta(-8+4^\beta+4^\gamma)(-8+9^\beta+9^\gamma)\cosh(3x+3y) - 2^{-4+\beta}(-8+4^\beta+4^\gamma)(-12-2^{3+\beta}+2^{\beta+2\gamma}+8^\beta)\cosh(2x+2y) - \frac{3}{16}(-48-2^{3+\beta}+2^{\beta+2\gamma}+8^\beta)\cosh(x+y)\;], \qquad (58)$$

$$V_3(x,y,t) = \frac{-\lambda^4 t^{3\alpha}\,\Gamma(2\alpha+1)}{81\,\Gamma(3\alpha+1)}\Big\{\rho_1[e^{4(x+y)} + (-1)^\beta e^{-4(x+y)}] + \rho_2[\,e^{3(x+y)} + (-1)^\beta e^{-3(x+y)}] + \rho_3[e^{2(x+y)} + (-1)^\beta e^{-2(x+y)}] + \rho_4[e^{(x+y)} + (-1)^\beta e^{-(x+y)}]\Big\}, \qquad (59)$$

and so on, where

$$\rho_1 = (-2^{2+\beta} + 2^{-3+6\beta} + 2^{-3+2\beta+4\gamma})\;\Big[\;\frac{4(-2^\beta + 2^{3\beta-3} + 2^{\beta+2\gamma-3})(-3^\beta + \frac{3^{3\beta}}{8} + \frac{3^{\beta+2\gamma}}{8})}{\Gamma(2\alpha+1)} + \frac{(-2^\beta + 2^{3\beta-3} + 2^{\beta+2\gamma-3})^2}{\Gamma^2(\alpha+1)}\Big], \qquad (60)$$

$$\rho_2 = \frac{2^{-6+\beta}3^\beta(-8+4^\beta+4^\gamma)(-8+9^\beta+9^\gamma)}{\Gamma(2\alpha+1)\;\;\Gamma^2(\alpha+1)}\;[\;6\,\Gamma(2\alpha+1) - (-12-2^{3+\beta}+2^{\beta+2\gamma}-8\times 3^\beta+3^{\beta+2\gamma}+8^\beta+27^\beta)\Gamma^2(\alpha+1)\;], \qquad (61)$$

$$\rho_3 = 2^{-3+\beta}(-8+4^\beta+4^\gamma)\Big[\frac{9}{\Gamma^2(\alpha+1)} + \frac{4}{\Gamma(2\alpha+1)}(\frac{9}{2} + 27\times 2^{-2+\beta} - 27\times 2^{-5+3\beta} - 27\times 2^{-5+\beta+2\gamma} + 4^{-2+\beta}(-8+4^\beta+4^\gamma)^2 + 2^{-6+\beta}\times 3^\beta(-8+4^\beta+4^\gamma)(-8+9^\beta+9^\gamma)\Big], \qquad (62)$$

$$\rho_4 = -\frac{3}{4}\Big[\frac{-288-9\times 2^{4+\beta}+9\times 2^{1+3\beta}-4^{3+\beta}-4^{\beta+2\gamma}+16^{1+\beta}-64^\beta+2^{1+\beta+2\gamma}(9+2^{3+\beta}-8^\beta)}{8\,\Gamma(2\alpha+1)} + \frac{6(-1)^\beta(-2^\beta+2^{-3+3\beta}+2^{-3+\beta+2\gamma})}{\Gamma^2(\alpha+1)}\Big]. \qquad (63)$$

On setting $p=1$, we get an accurate approximation solution by the homotopy perturbation method which takes the following form:

$$u(x,y,t) = \frac{4}{3}\lambda \sinh^2[\frac{1}{2}(x+y)] - \frac{\lambda^2 t^\alpha}{9\,\Gamma(\alpha+1)}\Big\{[-2^\beta + 2^{3\beta-3} + 2^{\beta+2\gamma-3}]\,[e^{2(x+y)} + (-1)^\beta\, e^{-2(x+y)}] + 3e^{(x+y)} + 3(-1)^\beta e^{-(x+y)}]\Big\}$$
$$+ \frac{2\,\lambda^3 t^{2\alpha}}{27\Gamma(2\alpha+1)}\,\{\; 2^{-5+\beta}3^\beta(-8+4^\beta+4^\gamma)(-8+9^\beta+9^\gamma)\cosh(3x+3y) - 2^{-4+\beta}(-8+4^\beta+4^\gamma)(-12-2^{3+\beta}+2^{\beta+2\gamma}+8^\beta)\cosh(2x+2y) - \frac{3}{16}(-48-2^{3+\beta}+2^{\beta+2\gamma}+8^\beta)\cosh(x+y)\;\}$$
$$- \frac{\lambda^4 t^{3\alpha}\,\Gamma(2\alpha+1)}{81\,\Gamma(3\alpha+1)}\Big\{\rho_1[e^{4(x+y)} + (-1)^\beta e^{-4(x+y)}] + \rho_2[e^{3(x+y)} + (-1)^\beta e^{-3(x+y)}] + \rho_3[e^{2(x+y)} + (-1)^\beta e^{-2(x+y)}] + \rho_4[e^{(x+y)} + (-1)^\beta e^{-(x+y)}]\Big\} + \ldots \qquad (64)$$

Equation (64) represented the approximate solution for the fractional Zakharov -Kuznetsov Equation (51 obtained by HPM.

By means of the homotopy analysis method, we choose the linear operator

$$\ell[\phi(x,y,t;q)] = \frac{\partial^\alpha \phi(x,y,t;q)}{\partial t^\alpha}, \qquad (65)$$

with property $\ell[c]=0,$ where c is a constant. We define a nonlinear operator as

$$N[\phi(x,y,t;q)] = \frac{\partial^\alpha \phi(x,y,t;q)}{\partial t^\alpha} - \frac{\partial^\beta \phi^2(x,y,t;q)}{\partial x^\beta} + \frac{1}{8}\frac{\partial^{3\beta}\phi^2(x,y,t;q)}{\partial x^{3\beta}} + \frac{1}{8}\frac{\partial^\beta\partial^{2\gamma}\phi^2(x,y,t;q)}{\partial x^\beta \partial y^{2\gamma}}. \qquad (66)$$

We consider auxiliary function $H(t)=1.$ So, the zeroth-order deformation equation

$$(1-q)\;\ell[\;\phi(x,y,t;q) - u_0(x,y,t)\;] = qhN[\phi(x,y,t;q)]. \qquad (67)$$

For $q=0$ and $q=1,$ we can write

$$\phi(x,y,t;0) = u_0(x,y,t), \qquad \phi(x,y,t;1) = u(x,y,t). \qquad (68)$$

Thus, we obtain the *m*th-order deformation equations

$$u_m(x,y,t) = \chi_m u_{m-1}(x,y,t) + J_t^\alpha\Big[h\,\Big(D_t^\alpha u_{m-1} - D_x^\beta\sum_{n=0}^{m-1}u_n u_{m-1-n} + \frac{1}{8}D_x^{3\beta}\sum_{n=0}^{m-1}u_n u_{m-1-n} + \frac{1}{8}D_x^\beta D_y^{2\gamma}\sum_{n=0}^{m-1}u_n u_{m-1-n}\Big)\Big], \quad m\ge 1. \qquad (69)$$

Table 2. Determine the absolute error between the real part of approximate solutions (64) obtained by the HPM and the real part of approximate solutions (73) obtained by the HAM when $y = \alpha = \beta = \gamma = 0.1,\ h = -1.1$ and $\lambda = 0.001$.

x	t	Re U HPM	Re U HAM	$\lvert u_{HPM} - u_{HAM} \rvert$
0.1	0.1	0.1297232493E-4	0.1297193845E-4	0.38648E-9
	0.5	0.1290155925E-4	0.1290110921E-4	0.45004E-9
	0.9	0.1287274434E-4	0.1287226875E-4	0.47559E-9
0.5	0.1	0.1232468684E-3	0.1232464860E-3	0.3824E-9
	0.5	0.1231776456E-3	0.1231771992E-3	0.4464E-9
	0.9	0.1231494580E-3	0.1231489857E-3	0.4723E-9
0.9	0.1	0.3617327474E-3	0.3617324328E-3	0.3146E-9
	0.5	0.3616767081E-3	0.3616763399E-3	0.3682E-9
	0.9	0.3616538879E-3	0.3616534979E-3	0.3900E-9

By using the Equation (69), and after some calculation we obtain

$$u_1(x,y,t) = \frac{h\,\lambda^2 t^\alpha}{9\,\Gamma(\alpha+1)}\Big\{[-2^\beta + 2^{3\beta-3} + 2^{\beta+2\gamma-3}]\,[e^{2(x+y)} + (-1)^\beta\, e^{-2(x+y)}] + 3e^{(x+y)} + 3(-1)^\beta e^{-(x+y)}]\Big\}, \quad (70)$$

$$u_2(x,y,t) = (h+1)u_1(x,y,t) + \frac{2h^2\lambda^3 t^{2\alpha}}{27\Gamma(2\alpha+1)}\Big[\,2^{-5+\beta}3^\beta(-8+4^\beta+4^\gamma)(-8+9^\beta+9^\gamma)\cosh(3x+3y) - 2^{-4+\beta}(-8+4^\beta+4^\gamma)(-12-2^{3+\beta}+2^{\beta+2\gamma}+8^\beta)\cosh(2x+2y) - \frac{3}{16}(-48-2^{3+\beta}+2^{\beta+2\gamma}+8^\beta)\cosh(x+y)\,\Big], \quad (71)$$

$$u_3(x,y,t) = (h+1)u_2(x,y,t) + \frac{h^3\lambda^4 t^{3\alpha}\,\Gamma(2\alpha+1)}{81\,\Gamma(3\alpha+1)}\Big\{\rho_1[e^{4(x+y)} + (-1)^\beta e^{-4(x+y)}] + \rho_2[e^{3(x+y)} + (-1)^\beta e^{-3(x+y)}] + \rho_3[e^{2(x+y)} + (-1)^\beta e^{-2(x+y)}] + \rho_4[e^{(x+y)} + (-1)^\beta e^{-(x+y)}]\Big\}, \quad (72)$$

$$\vdots$$

where $\rho_1, \rho_2, \rho_3, \rho_4$ take the same form (60)…(63) respectively. In this case, the approximate solution by using HAM of Equation (51) is given by

$$\begin{aligned} u(x,y,t) &= \frac{4}{3}\lambda\sinh^2[\frac{1}{2}(x+y)] + \frac{h\lambda^2 t^\alpha}{9\,\Gamma(\alpha+1)}\Big\{[-2^\beta + 2^{3\beta-3} + 2^{\beta+2\gamma-3}]\,[e^{2(x+y)} + (-1)^\beta\, e^{-2(x+y)}] + 3e^{(x+y)} + 3(-1)^\beta e^{-(x+y)}]\Big\} \\ &+ (h+1)u_1(x,y,t) + \frac{2h^2\lambda^3 t^{2\alpha}}{27\Gamma(2\alpha+1)}\Big[\,2^{-5+\beta}3^\beta(-8+4^\beta+4^\gamma)(-8+9^\beta+9^\gamma)\cosh(3x+3y) \\ &- 2^{-4+\beta}(-8+4^\beta+4^\gamma)(-12-2^{3+\beta}+2^{\beta+2\gamma}+8^\beta)\cosh(2x+2y) - \frac{3}{16}(-48-2^{3+\beta}+2^{\beta+2\gamma}+8^\beta)\cosh(x+y)\,\Big] \\ &+ (h+1)u_2(x,y,t) + \frac{h^3\lambda^4 t^{3\alpha}\,\Gamma(2\alpha+1)}{81\,\Gamma(3\alpha+1)}\Big\{\rho_1[e^{4(x+y)} + (-1)^\beta e^{-4(x+y)}] + \rho_2[e^{3(x+y)} + (-1)^\beta e^{-3(x+y)}] + \rho_3[e^{2(x+y)} + (-1)^\beta e^{-2(x+y)}] + \rho_4[e^{(x+y)} + (-1)^\beta e^{-(x+y)}]\Big\} \\ &+ \ldots \end{aligned} \quad (73)$$

Equation (73) represented the approximate solution for the fractional Zakharov-Kuznetsov Equation (51) obtained by HAM.

Remarks 2

1) The homotopy analysis method determines the interval of convergence from the h-curve (Figure 5). As pointed by Liao (1992), the valid region of *h* is a horizontal line segment. Therefore, it is straightforward to choose an appropriate range for *h* which ensures the convergence of the solution series. We stretch the h-curve of $u(0.1, 0.1, 0.2)$ in Figure 5, which shows that the solution series is convergence when $-1.5 < h < -0.5$.

2) In special case, when $\alpha, \beta, \gamma \to 1$, the approximate solution (64) takes the following form

$$u_{app}(x,y,t) = \frac{4}{3}\lambda\sinh^2[\frac{1}{2}(x+y)] - \frac{2}{3}\lambda^2 t\,\sinh(x+y) + \frac{1}{3}\lambda^3 t^2\cosh(x+y) - \frac{1}{9}\lambda^4 t^3\sinh(x+y) + \ldots. \quad (74)$$

Using Taylor series expansion near $t = 0,$ we get

$$u_{ex}(x,y,t) = \frac{4}{3}\lambda\sinh^2[\frac{1}{2}(x+y-\lambda t)]. \quad (75)$$

This solution (75) is exactly the same solution obtained in (Hesam et al., 2012).

Table 2 leads to the absolute error between the approximate solutions (64) obtained by HPM and the approximate solutions (73) obtained by HAM. The absolute error is very small so that the approximate solutions have the same behavior.

The comparison between the approximate solution of Equation (51) by using the HPM and approximate solution by using HAM are shown in Figure 3, 4, 6, 7, 8.

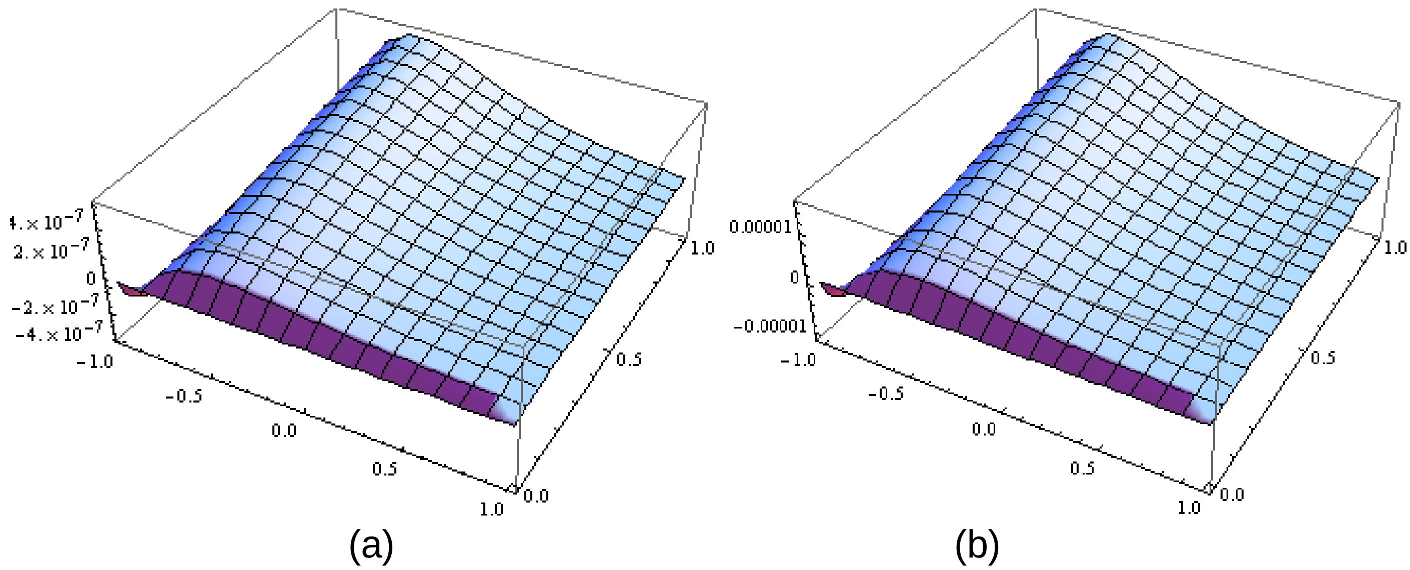


Figure 3. (a) Represents the imaginary part of approximate solution (40) by HPM and (b) represents the imaginary part of approximate solution (49) by HAM at $\alpha = \beta = \gamma = y = 0.5, \quad \lambda = 0.001, \quad h = -3, \ -1 \le x \le 1$ and $0 \le t \le 1$.

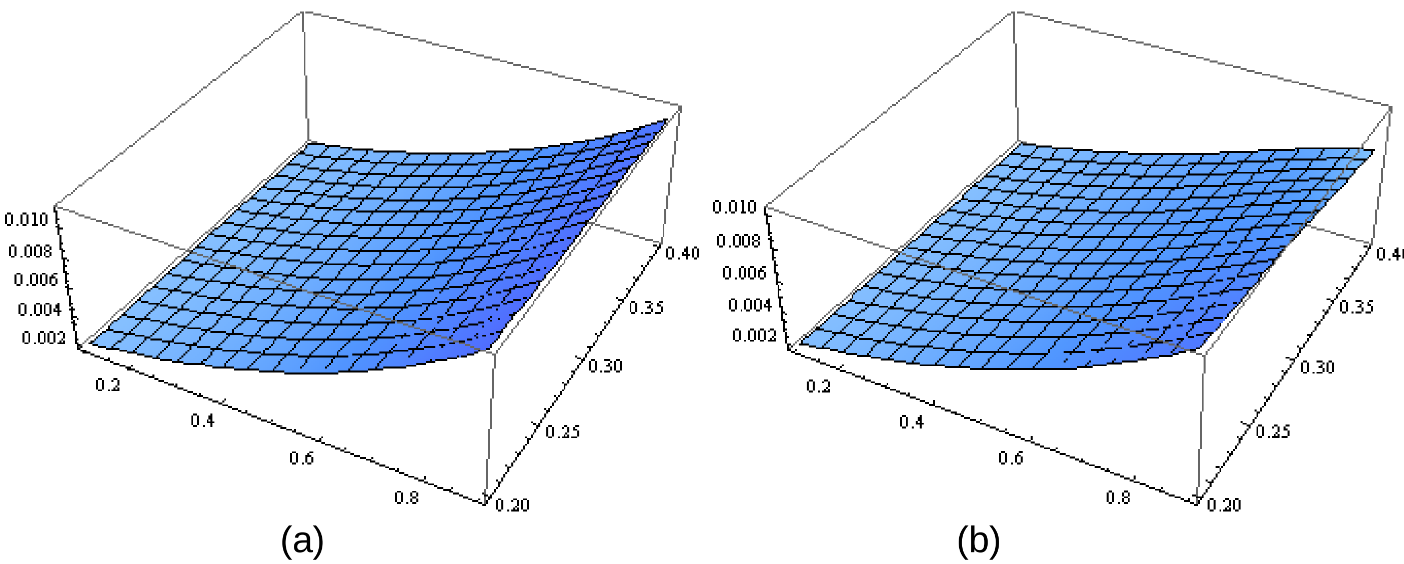


Figure 4. (a) Represents approximate solution (40) by HPM and (b) represents approximate solution (49) by HAM at $\alpha = \beta = \gamma = 1, \quad \lambda = 0.001, \quad y = 0.9, \quad h = -2, \ 0.1 \le x \le 0.9$ and $0.2 \le t \le 0.4$.

Conclusion

In this paper, we used the two different methods such as homotopy perturbation method and homotopy analysis method to obtain analytic approximate solutions for the fractional Zakharov-Kuznetsov equations which are very important in mathematical physics especially in nonlinear dynamics and plasma physics. We compared between the approximate solutions obtained by using the homotopy perturbation method and the approximate solutions obtained by using the homotopy analysis method. The homotopy analysis method investigates the influence of *h* on the convergence of the approximate solution. Note that the solution series contains the auxiliary parameter *h* which provides us with a simple way to adjust and control the convergence of the solution series. Also we compared between the approximate solutions obtained by these methods and the exact solutions when $\alpha, \beta, \gamma \to 1$. These methods are effective and allows us to solve nonlinear partial fractional

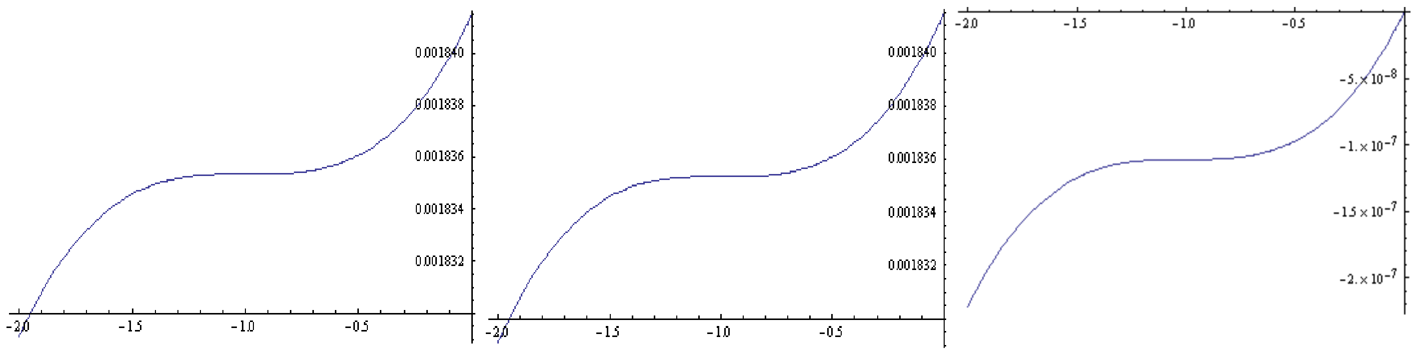
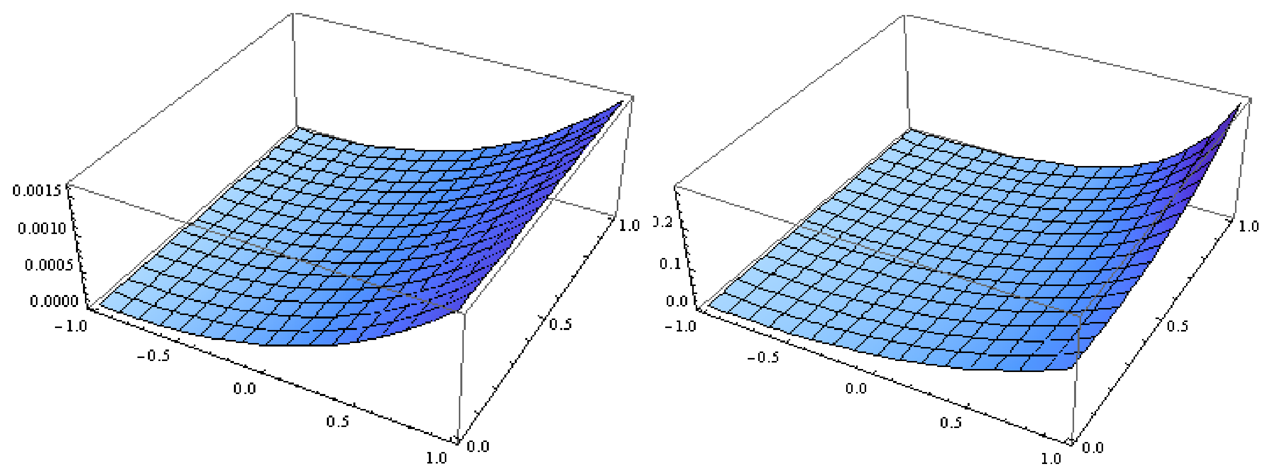
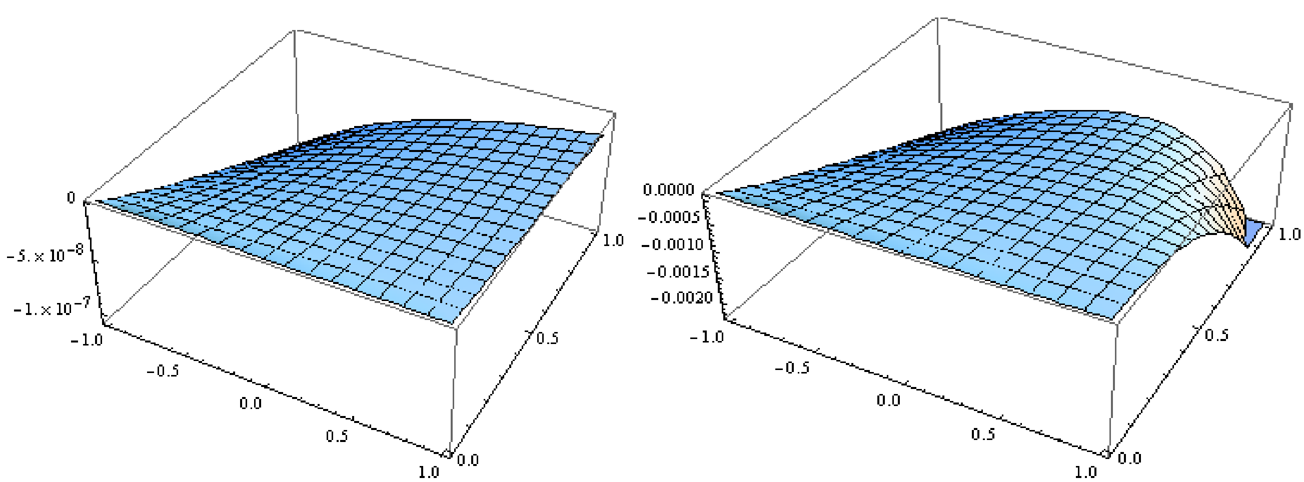


Figure 5. The h-curves of the four-order approximation to Abs $(u(x,y,t))$, Re$(u(x,y,t))$ and Im$(u(x,y,t))$ respectively at $\alpha=\beta=\gamma=0.5,\ \lambda=0.001,\ y=x=0.1,\ t=0.2$.



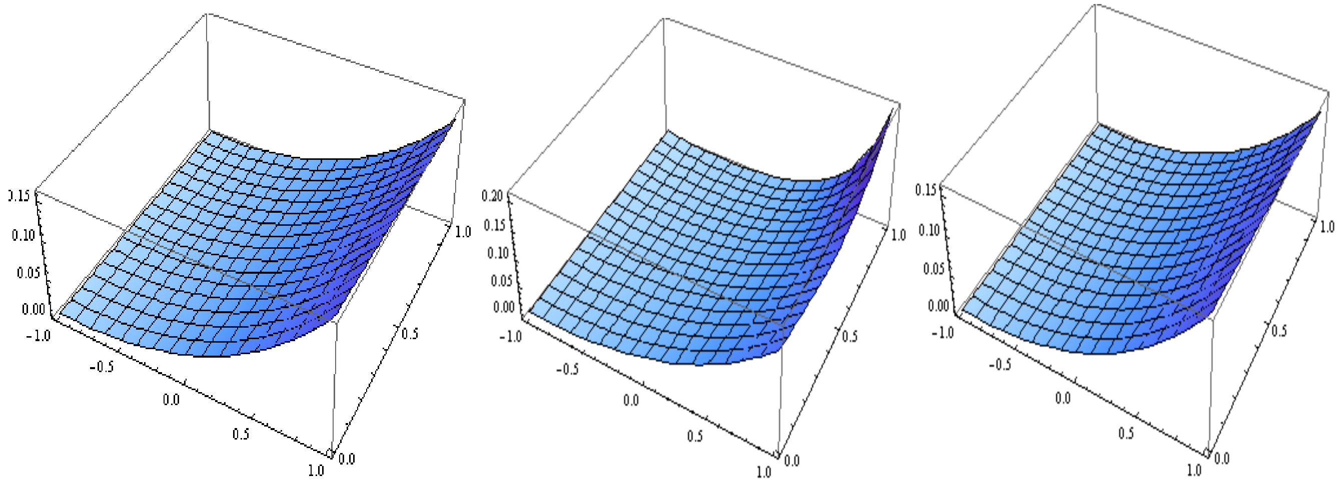
(a) (b)

Figure 6. (a) Represents the real part of approximate solution (64) by HPM and (b) represents the real part of approximate solution (73) by HAM at $\alpha=\beta=\gamma=0.9,\quad y=0.1,\quad \lambda=0.1,\quad -1\le x\le 1$ and $0\le t\le 1$.



(a) (b)

Figure 7. (a) Represents the imaginary part of approximate solution (64) by HPM and (b) represents the imaginary part of approximate solution (73) by HAM at $\alpha=\beta=\gamma=0.9,\quad y=0.1,\quad \lambda=0.1,\ h=-2,\quad -1\le x\le 1$ and $0\le t\le 1$.



(a) (b) (c)

Figure 8. (a) Represents approximate solution (64) by HPM, (b) represents approximate solution (73) by HAM and (c) represents the exact solution (75) at $\alpha=\beta=\gamma=1,\ \lambda=0.1,\ y=0.9,\ h=-2.5,\ -1\leq x\leq 1$ and $0\leq t\leq 1$.

differential equations.

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Scientific Research and Essays

Full Length Research Paper

Flow-induced Noise Prediction for 90˚Bend Pipeby LES and FW-H Hybrid Method

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This paper focuses on an aerodynamic noise study of outlet elbow of Continuous Positive Airway Pressure (CPAP) machine by analyzing the wall pressure fluctuations and predicting the far filed sound generated by turbulent flow. A hybrid approach combing the Larger-Eddy Simulation (LES) and Ffcowcs Williams-Hawkings (FW-H) acoustic analogy was used to simulate the flow distribution as well as calculate the flow-induced noise for a three-dimensional elbow pipe. Then, a different elbow structure was designed to form the appropriate structure for the air outlet via considering the sound pressure level of each model. As a result, elbow with guiding plate was demonstrated to be an effective method to reduce the aerodynamic noise strength since this design could weaken the wall pressure fluctuation and vortex magnitude. Furthermore, the decreased magnitude could reach more than 1dB when velocity increased from 5m/s to 9m/s. The results of simulation were a little higher than experimental results since the background noise, elbow vibration and the defect of FW-H equation which couldn't be eliminated thoroughly.

Key words: Exhaust elbow, aerodynamic noise, Large-Eddy simulation, guiding plate, FW-H Acoustic Analogy

INTRODUCTION

Clinical practice has shown that Continuous Positive Airway Pressure (CPAP) is a far more effective therapy for Obstructive Sleep Apnea Syndrome (OSAS) than traditional surgery Since the devices used in CPAP therapy inevitably creates noise, evaluating the impact of noise on sleeping was given a fair amount of attention in the past decades (Mcdaid et al., 2009; Katrien and Bauters, 2010). It is known from previous research that major sources of noise from a ventilator are vibration, the centrifugal fan and aerodynamic noise caused by air turbulence (Pavić, 2003; Park et al., 2010). Noise caused by pipe vibration had been studied systematically in recent years and some effective ways have developed to reduce the vibration noise (Kolesnikov et al., 2012; Dai et al., 2013). However, aerodynamic noise related of elbow pipe has been the less researched one so far, as well as lacking effect ways to eliminate the noise generated by turbulent fluid in the elbows.

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In recent years, the Large-Eddy Simulation (LES) has been widely applied on flow filed analysis of elbow because it resolves large scales of the flow field solution allowing better fidelity than Reynolds-averaged Navier–Stokes (RANS) methods, as well as models the small scales of the solution with low cost of computing resources than direct numerical simulation(DNS). Later, Rütten et al. (2005) studied the oscillation caused by vortex shedding at the inner side of the bend and shear layer instability based on LES. Research work showed that the cause of the measurable low frequency oscillation was the shedding of dean vortices and that the oscillation and its effect on the flow field varied in strength over time. Liu et al. (2010) used k-ε and Large-Eddy Simulation (LES) model to calculate the flow field of the transition zone at specific Reynolds numbers, respectively. The simulation results indicated that the LES model was more effective than the k-ε model. Eguchi et al. (2011) proved that flow separation played an important role in determining pressure fluctuation by simulating flow pressure distributions of a short elbow pipe which was critical in Sodium-cooled Fast Reactor (JSFR) with a Large-Eddy Simulation for a high Reynolds number flow. Tan et al. (2014) applied a hybrid numerical method of LES combing with characteristic-based split scheme (CBS) to analyze the flow filed and vortex shedding phenomenon. However, these research works mainly focused on the study of flow distribution. Limitation information on has been reported aerodynamic noise generated by flow.

When it comes to aerodynamic noise simulation, many researchers have done tremendous work on the theory and numerical simulation algorithms. Lighthill (1951) was the first to develop the aerodynamic theory by reformulating the Navier-Stokes equation into an exact, inhomogeneous wave equation. Later, Curle (1955) developed the acoustic equation for the flow field with boundary based on the work of Lighthill. In the case of stationary walls, Curle demonstrated that pressure fluctuations on walls could also become a significant noise source which was regarded as dipole source. Furthermore, Williams and Hawkings (1969) extended the circumstance to moving walls by taking moving effect into consideration. If only stationary walls existed, the FW-H equation degenerated into Curle equation.

Entering new century, many researchers started to focus on the aerodynamics noise generated by flow as the development of the computational ability.

Lafon et al. (2003) shed light on the mechanism of the flow acoustic coupling in the cavity and in the duct through an aeroacoustical analysis and also proposed the way of energy transfer from the fluid to the main pipe through a vibro-acoustical analysis. Adam et al. (2008) used low dissipative Lattice Blotzmann theory to calculate the aeroacoustic sources that could generate turbulent fluctuations. They also depicted sound propagation as well as flow field with CFD software PowerFLOW.

Ji and Wang (2010) used LES simulation and Lighthill's theory to analyze the aeroacoustics of low-Mach-number flow over backward steps by comparing the calculated pressure fluctuations with experimental results.

Moon et al (2010) proposed a hybrid method to predict the low-subsonic, turbulent noise. LES was employed to compute the noise source in the near wall or in the wake, while the characteristics of wall pressure fluctuations also were analyzed further to quantify the sizes of the noise sources.

Later, Zhang et al. (2010) simulated the wall pressure fluctuations by large eddy simulation and the flow induced noises calculated by FW-H acoustic analogy were compared to experimental data.

For the similar case, Wang et al. (2011) investigated the hydrodynamic noise induced by mechanic cavities with different shapes with a hybrid method in which LES was used to simulate the noise source in near wall turbulences or in the wake and FW-H acoustic analogy was adopted to calculate the propagation.

Zhu et al. (2013) investigated the transient flow field in the aerostatic bearing based on LES, and relationship between pressure fluctuations and bearing vibration was studied as well.

Zhang et al. (2014) linked the LES with the Lighthill’s acoustic theory to simulate the flow-induced noise for a three-dimensional pipeline. They mainly focused on the hydrodynamic noise (dipole source) of flow through the pipe with different types of trash racks which was used to determine the best form of trash rack. In summary, pressure fluctuations which were obtained by numerical and experimental in previous studies were used to be an evaluating index in sound source,

From the above overview of literatures, it is apparent that past researches were mainly focused on the sound propagation in an elbow or how pressure fluctuations played a critical role in determine the sound source in other models. However, how pressure fluctuation affects the acoustic in the elbow has yet to be fully investigated. This paper employed the LES model to present the detailed flow field analysis and wall pressure fluctuations of an elbow with a guiding plate, which could be used as the exhaust onSleep Portable Ventilators and other portable air exhausting devices. Velocity distribution, wall pressure fluctuations as well as sound pressure level (SPL) was computed based on the LES and FW-H hybrid method which regards wall pressure fluctuations as a noise source. Finally, experiments were also carried out to investigate how the guiding plate reduces the pressure difference and overall (SPL).

THEORY AND EXPERIMENTAL PROCEDURES

Large-Eddy simulation

For incompressible air, Navier-Stokes equations in the Cartesian coordinates can be described as the following when gravity is neglected.

$$\frac{\partial \bar{u}_i}{\partial x_i} = 0$$

$$\frac{\partial \bar{u}_i}{\partial t} + \frac{\partial}{\partial x_j}\left(\bar{u}_i\bar{u}_j + \tau_{ij}\right) = -\frac{1}{\rho}\frac{\partial \bar{p}}{\partial x_i} + \frac{\partial}{\partial x_j}\left\{\nu\left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right)\right\} + P_i$$

where, $\bar{u}_i$ (i=1,2,3) is the grid scale velocity component in the x, y, and z directions. $\bar{p}$ is the grid-scale static pressure. ρ is air density, ν is the kinematic viscosity. And P_i is the inertial force associated with the motion of the frames of reference and in this paper, $P_i=0$ (Tan et al., 2014). τ_{ij} is called the subgrid-scale (SGS) stress tensor which is expressed using Leonard decomposition. Thus, τ_{ij} is defined as $\tau_{ij} = \overline{u_i u_j} - \bar{u}_i\bar{u}_j$. $\bar{S}_{ij}$ is filtering strain tensor.

In this research, the complex interactions between the resolved and unresolved scales are modeled using a turbulent eddy viscosity assumption (Kuhn et al., 2010). Then anisotropic part of the sub-grid scale stress τ_{ij} is connected to the eddy viscosity v_τ by the following formulations:

$$\tau_{ij} - \frac{\delta_{ij}}{3}\tau_{kk} = -2\nu_\tau \bar{S}_{ij}$$

$$\nu_\tau = (C\Delta)^2 \left|\bar{S}\right|$$

$$\left|\bar{S}\right| = (2\bar{S}_{ij}\bar{S}_{ij})^{1/2}$$

$$S_{ij} = \frac{1}{2}\left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right)$$

where, C is the dimensionless model coefficient, $\Delta = (\Delta_x\Delta_y\Delta_z)^{1/3}$ is LES grid filter width, S_{ij} is known as strain rate tensor and $\left|\bar{S}\right|$ is the magnitude of the filtered strain-rate tensor.

The Smagorinsky is the first to employ the v_τ and still includes it more often than others. The constant C is depended on specific circumstance and other various values have been proposed in past literatures. However, Smagorinsky Model does not allow for possible sub-grid scale energy backscatter to the resolved scales since it is too dissipative, and predicts unrealistic asymptotic behaviors near a wall or in laminar zones. It also over-predicts the length of the potential core. Later, Lilly (1992) modified the model to allow for possible energy backscatter and the modified model exhibits more plausible asymptotic behaviors near the walls and in laminar regions. The coefficient C_d, which depends on the local structure of the flow, is dynamically calculated, and it is used to replace C_s^2. C_d is computed with a least-squares error approach according to:

$$C_d = -\frac{1}{2}\frac{[(L_{ij} - L_{kk}\delta_{ij}/3)M_{ij}]}{M_{ij}M_{ij}}$$

$$L_{ij} = \widehat{\bar{u}_i\bar{u}_j} - \hat{\bar{u}}_i\hat{\bar{u}}_j$$

$$M_{ij} = \widehat{\Delta^2}|\hat{\bar{S}}|\hat{\bar{S}}_{ij} - \Delta^2\widehat{|\bar{S}|\bar{S}_{ij}}$$

The model constant C_d in above equation which is dynamically calculated is a local and instantaneous quantity and thus can vary widely in time and space. As a result, to avoid numerical instability resulting from negative values of C_d, the numerator and denominator are averaged in the homogeneous directions. The constant C_d is manually set to be zero for the few instances when it is still negative. Therefore, this paper adopts the dynamic Smagorinsky-Lilly (DSL) to avoid the instability as mentioned above (Wang et al., 2011; Zhang et al. 2010).

FW-H analogy theory

This paper focused on flow analysis when normal air flows through elbow at low Mach number as well as the noise level generated by the air flow. As aforementioned, Lighthill was the first to use the acoustic analogy method to separate the acoustic equation from the Navier-Stokes equations (Lighthill, 1952) and the equations are the following:

$$\frac{\partial^2 \rho'}{\partial t^2} - c_0^2\nabla^2\rho' = \frac{\partial^2 T_{ij}}{\partial y_i \partial y_j}$$

$$T_{ij} = \rho u_i u_j - e_{ij} + \delta_{ij}[(\mathrm{p} - p_0) - c_0^2(\rho - \rho_0)]$$

where, T_{ij} is Lighthill stress tensor, e_{ij} is viscous stress tensor, $\rho' = \rho - \rho_0$ is the density fluctuation defined with respect to a reference density ρ_0. c_0 is sound speed in the air, and p, ρ and p_0, ρ_0 are the air pressure and density before and after perturbation, respectively.

If the right side of the first equation is seen as a sound source term, it can be regarded as a typical acoustic wave equation, which can be solved by the classical acoustic approach. Lighthill stress tensor can be obtained by experiments or other methods according to the literatures. Curle took the wall boundary into consideration. However, our work focused on problems involving solid surfaces and FW-H equation is more suitable for stationary surfaces (Wang et al., 2012). For the FW-H equation below, pressure fluctuation is substituted into the sound source term to compute SPL (Zhang et al., 2014).

$$\frac{1}{c_0^2}\frac{\partial^2 p'}{\partial t^2} - \nabla^2 p' = L_M + L_D + L_Q$$

$$L_M = \frac{\partial}{\partial t}\{[(\rho_0 - \rho)v_n + \rho u_n]\delta(f)\}$$

$$L_D = -\frac{\partial}{\partial x_i}\{[P_{ij}n_j + \rho u_i(u_n - v_n)]\delta(f)\}$$

$$L_Q = \frac{\partial^2}{\partial x_i \partial x_j}[T_{ij}H(f)]$$

where, u_i, u_n, v_i, v_n are the tangential and normal velocity of flow and solid wall, respectively. $\delta(f)$ is Dirac Delta function, $H(f)$ is Heaviside function, L_M, L_D, L_Q are monopole, dipole, quadrupole sound source, respectively. Flow field must be obtained in order to apply the FW-H equation. According to the acoustic analogy theory, there are two major steps in the analysis of hydrodynamic noise.

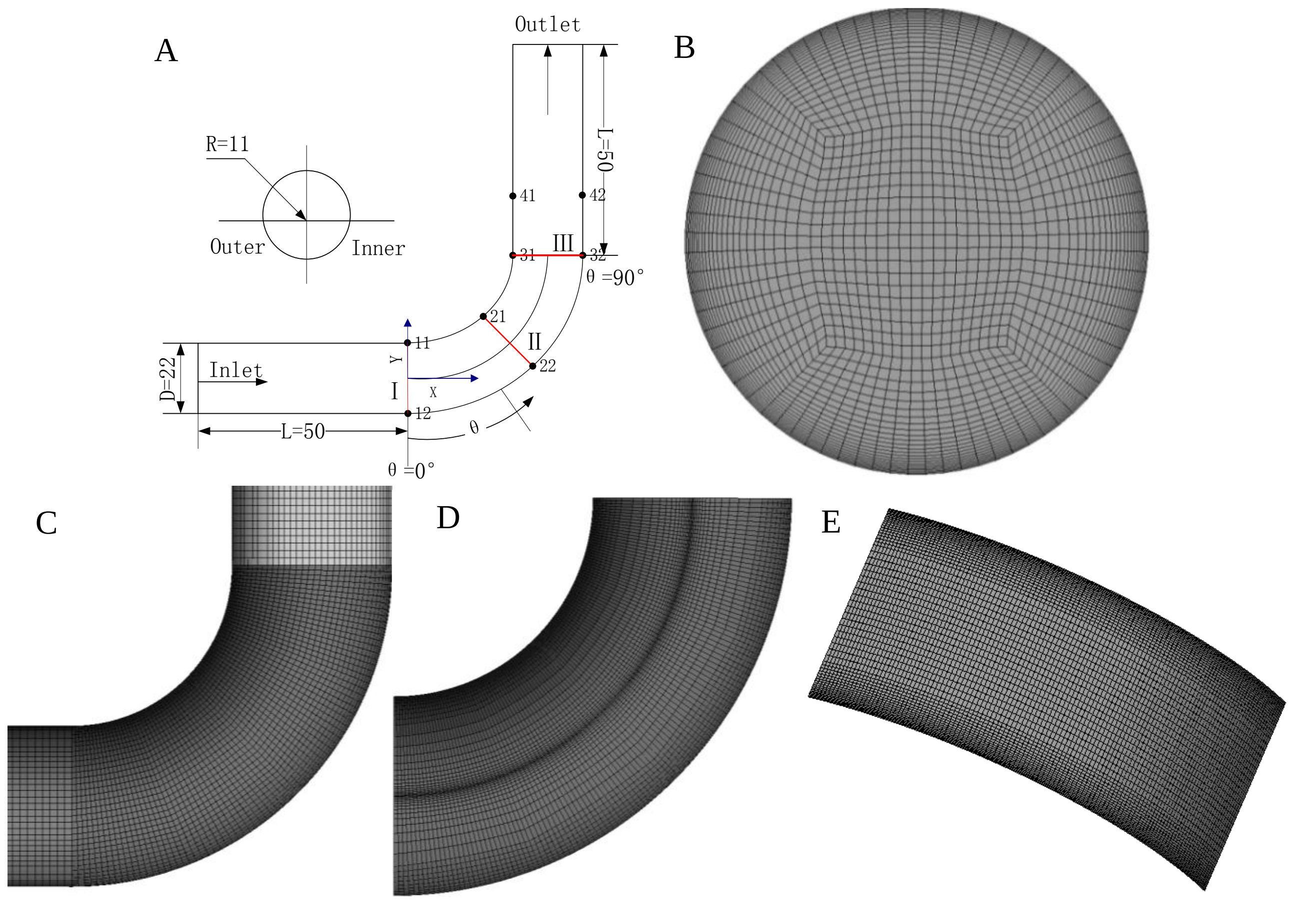

Figure 1. Schematic of the elbow and computational mesh (unit: mm). A: Detailed dimensions, three probe lines (I, II, III) and eight observation points, B: inlet cross section mesh, C: curved section mesh without plate, D: curved section mesh with plate, E: mesh of plate.

Firstly, the sound source region is computed by unsteady flow in the elbow pipe. Secondly, sound propagation is calculated by the FW-H equation in the fluid medium (Zhang et al., 2014).

MODEL SETUP AND MESHING

Figure 1 showed the schematic of a stainless steel elbow and computational mesh of two different models. The pipe diameter D was 22 mm, the straight part of the inlet and the outlet measured 50 mm each, inner and outer diameters of the bend part can be seen in the figure and the center radius of bend part to the pipe diameter ratio (R/D) was 1.5. A guiding plate was located at the center of the bend part of the pipe. Besides, the plate had the same curvature radius with the bend pipe. After completing the model design, ICEM mesh software was used to mesh the model. Special attention was paid to the wall mesh processing. According to reported literatures, all three approaches used logarithmic law of the wall based functions to solve a separate set of equations in the near-wall region, and simulate this region in Reynolds-averaged sense. Cavar and Meyer (2011) demonstrated that the computational mesh chosen for modeling of subgrid scale stresses in the conducted LES simulation was of high importance, and they pointed out that LES seem to be fully capable of explain the fundamental properties of the complex no-equilibrium boundary layer flow over a surface with discontinuity Since the near-wall mesh resolution was of critical importance in LES, the thickness of the first layer of cells near a wall must satisfy the requirement $y^+{\sim}1$ (Cavar and Meyer 2011). Pressure implicit with splitting of operator (PISO) method was employed to solve the pressure-velocity coupling equation for both steady and unsteady cases, while Pressure Staggering Option (PRESTO) method was adopted to discretize the continuity equation and the spatial discretization for momentum was Bounded Central Differencing. In addition, steady simulation was first processed in order to accelerate the convergence. The inlet velocities were chosen from 5 to 7 m/s according to the CPAP application. The wall of elbow and guiding plate were regarded as stationary and non-rough ones. The outlet was set as pressure-outlet and pressure was the same as atmosphere pressure. As sound boundary condition of acoustic simulation, the same mesh was used and we assumed that sound can penetrate the pipe wall and propagated in the free-space. In order to capture the wall pressure fluctuation, the step time was selected as $\Delta t=10^{-4}$s. Moreover, we adopted proper CFL number (CFL was set as 0.2 by considering the max velocity, cell size and time step size) to ensure the convergence of our cases. In the paper, we presumed that flow-induced sound can penetrate the pipe wall without attenuation as well as sound can propagate in an infinite free space (Kim et al., 2002; Jung and Chung, 2012).

Experimental procedures

Figure 2 showed the schematic of the noise test setup. The

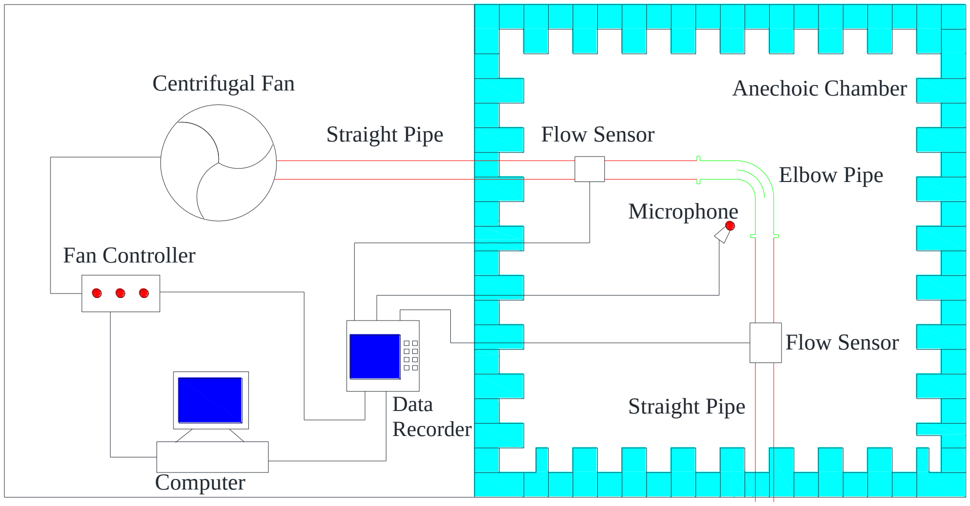

Figure 2. Schematic of the noise test setup.

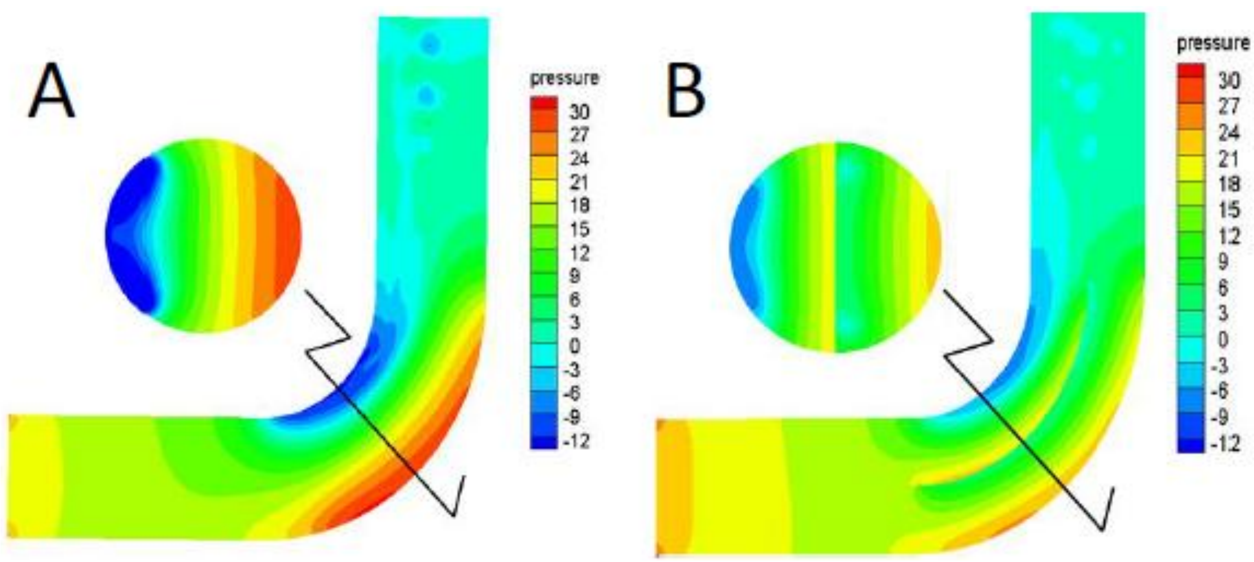

Figure 3. Pressure Distribution in the Elbow Pipe (Unit: Pa). A, Without Plate; B, With Plate.

background sound pressure of anechoic chamber on the right hand of the figure was 19±1 dB. The air generated by a centrifugal fan which was controlled by the computer flowed into the inlet and then it passed the long straight pipe and developed fully before it reached the elbow. In addition, there were two flow sensors (160PC serials: provided by Honeywell company) to monitoring the flow rate to determine the inlet flow rate and the outlet velocity flow rate. The flow rates monitored by two flow sensors were the same value and it indicated that there was no air leakage at the joints between elbow and flow sensors. The elbow was manufactured in stainless materials so that sound can penetrate the pipe wall without substantial attenuation. Furthermore, the guide plate should be as thin as possible so that the vortex shedding's effect can be avoided on sound calculation. The thickness and radius were 0.9 and 33 mm, respectively. The elbow was fixed on a platform to avoid it vibrating. A multifunctional sound level meter provided by Hangzhou Aihua Instruments Co. Ltd. was used to monitored the SPL whose microphone was 1/2" Prepolarized Condenser Mic. Model AWA14425. Then, the sound level meter was located at the center of the plate in z=0 plane. All data was recorded by the data record and processed by a computer.

RESULTS

Figure 3 showed the pressure distributions of the elbow pipe of two different models. The circle displayed the pressure distribution of θ (45º) cross section of the elbow. Obviously, we can tell that pressure of the outer wall (the red area) was larger than the inner wall (the blue area). Figure 4 showed the velocity on the three probe lines I~III which were shown in Figure 1 in the curved section of

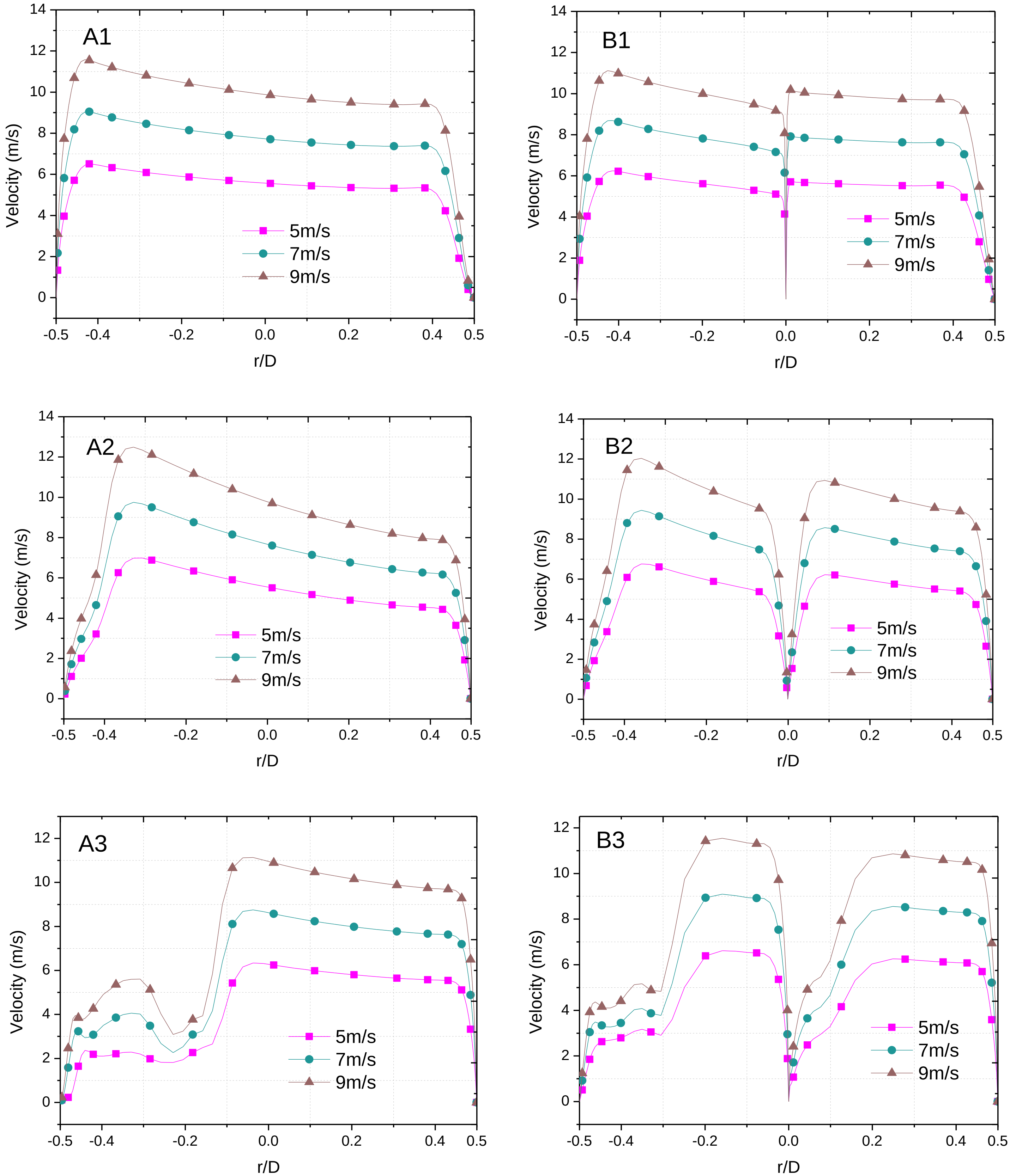

Figure 4. Velocity at probe line I~III of two models. A1~A3: cases without plate. B1~B3: cases with plate. (Negative means inner side, Positive means outer side).

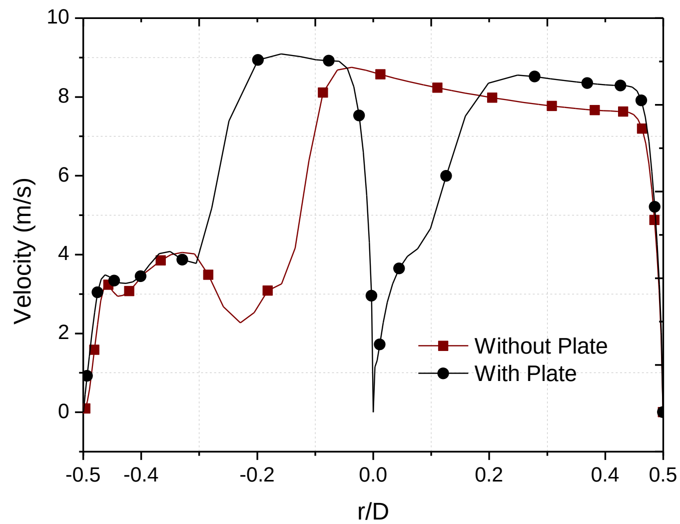

Figure 5. Comparison of velocity at probe line 3 of two models (inlet velocity 7 m/s).

two models on the symmetric plane (z=0). In the cases without plate, the flow pattern was symmetric in the straight part before flow reached the bend part. However, this pattern was disrupted when air flow passes through the elbow part as Figure 4-A1 and 4-B1 (Tan et al., 2014). Then, velocity at the outside region decreased, the majority of the flow trended to the inner side as Figure 4-A2 and 4-B2 at the θ=45º (Adam et al., 2008). At rear half of curved section of the elbow, the velocity happened to deflect to the outside. Therefore, the curved section of elbow can affect the flow distribution to a great degree. The velocity on the probe line happened to deflect to the outside greatly and has a trough nearly at the non-dimensional radius -0.2 as Figure 4-A3 as well as at -0.1 as Figure 4-B3. Another conclusion was that the velocity curves nearly are symmetric to the zero at θ=45º and 60 º except last one as Figure B1 and B2. It also can be found that when a plate was inserted in elbow, the trough of the curve at θ=90º was not that clear as Figure 5.

The wall pressure fluctuation at eight observation points of two models was presented in Figure 6 in which pressure fluctuations were average values (twenty time steps) between 0.07 and 0.08 s, respectively. In addition, these computations were used to verify the performance of the LES in predicting the unsteady features of turbulent flow and all the eight figures demonstrated that the LES was stable to simulate the turbulent flow in elbow pipes as the fluctuations were stable in time domain. According to the figures of cases without guiding plate, it can be observed that pressure fluctuation amplitudes at all points were periodic in nature and their cycles were the same. Similarly, fluctuation curves in cases with plate were periodic except delayed a little comparing to the other model.

Numerical vorticity distributions on pipe wall as well as cross section of two models were shown in Figure 7. The vorticity distribution shown in the figure indicated that, when a guiding plate inserted into the elbow pipe, the magnitude of the vorticity on both the pipe wall and cross section decreased obviously according to the vorticity contour.

Figure 8 presented the calculated SPL spectrum of two models. It can be observed that the overall trend was similar and both curves decreased as frequency increased. Moreover, both curves had a peak at ~800 Hz and another peak at ~1500 kHz. However, the peak of SPL spectrum of model with guiding plate appeared a little earlier than that without plate.

Figure 9 was A-weighted sound pressure level of the monitoring point recorded by the data receiver. According to the figure, for the cases with the guiding plate or not, both the simulation and experimental results increased as inlet velocity increased from 5 to 9 m/s, respectively. It can be observed that, the calculated result was 2 dB smaller than the experimental result when inlet velocity was 5 m/s for both two models. However, the difference between the experiment and simulation values decreased to 1 dB when velocity is 9 m/s.

DISCUSSION

The pressure difference between inner and outer wall results from a contraction effect on the concave side of the elbow and the increasing flow velocity (Tan et al., 2014). When the air has just passed by the bend part, the centrifugal effect, though not material, still has an effect on the straight pipe. Then, fluid velocity and pressure field become uniformly distributed gradually. By comparing the two pictures of Figure 3, we see a more

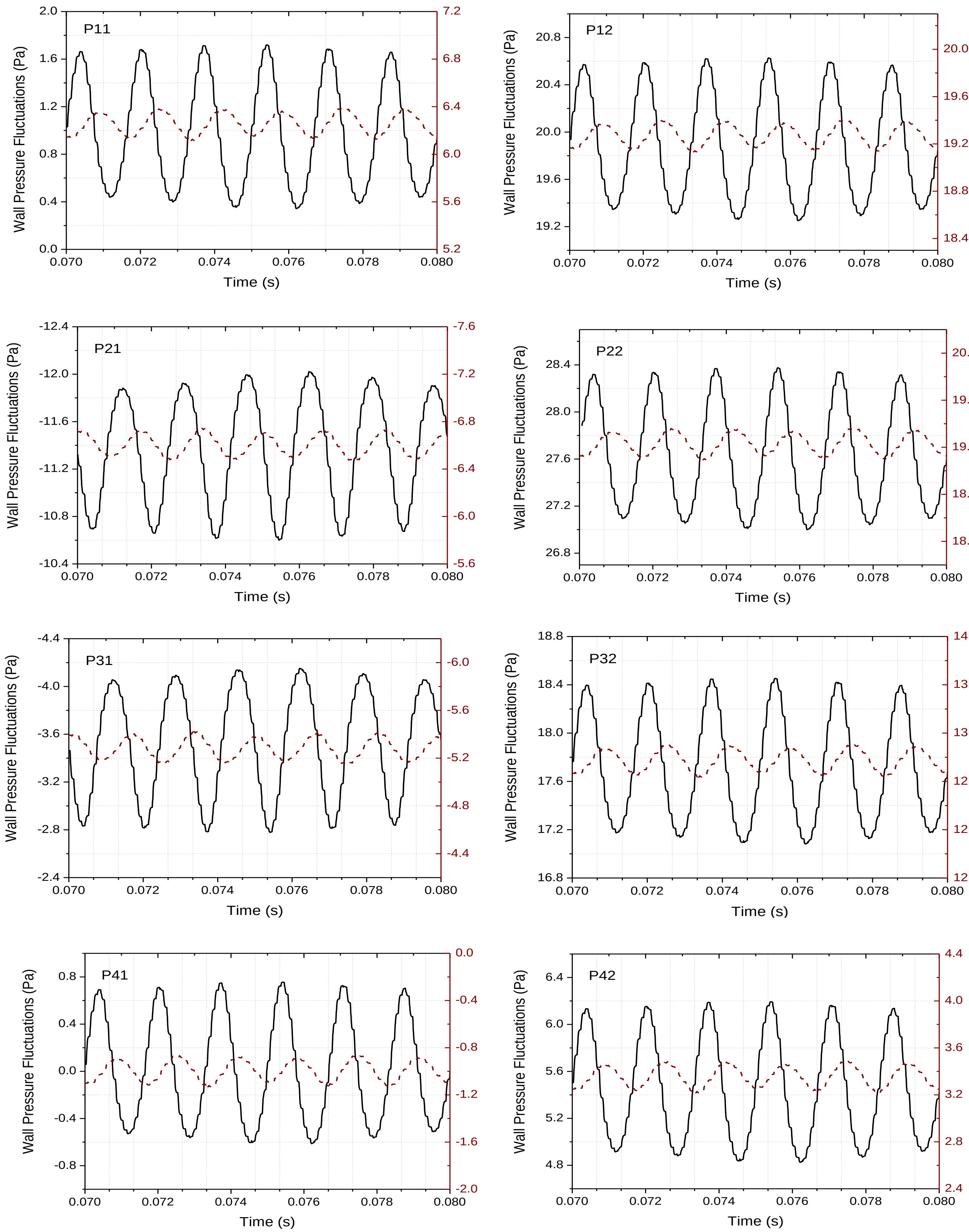

Figure 6. Pressure fluctuations in time domain at eight observation points at inlet velocity 7 m/s of two models (Solid line for without plate and dot line for with plate).

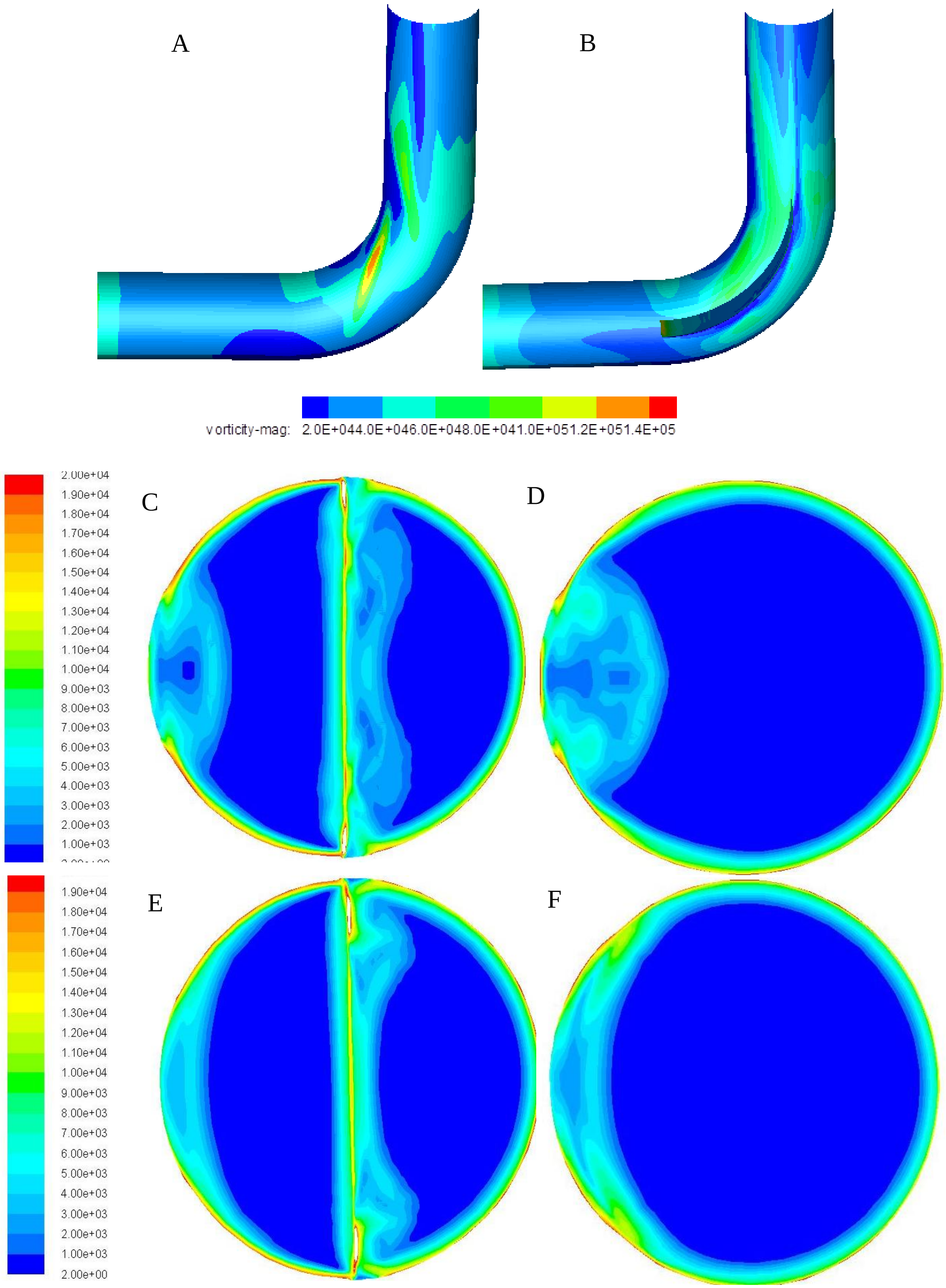

Figure 7. Figure 7. Vorticitydistributions on the pipe wall and cross section wall of two modelsat 7 m/s (Unit: s-1); A: without plate; B: with plate; C and D: θ=45˚; E and F: θ=90˚

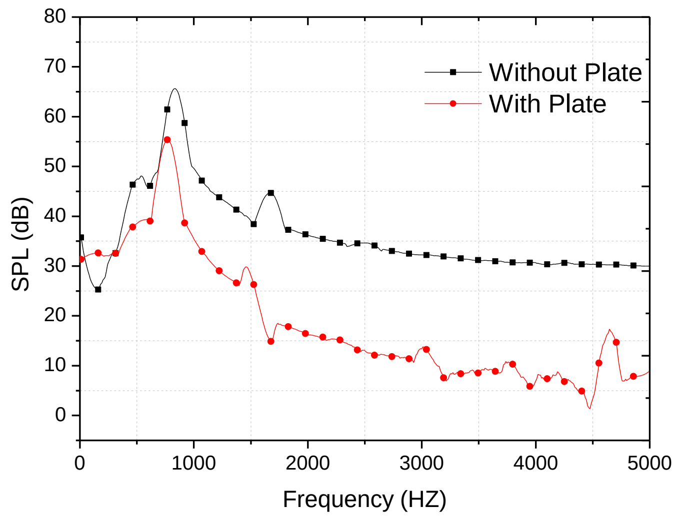

Figure 8. Calculated SPL spectrum of two models.

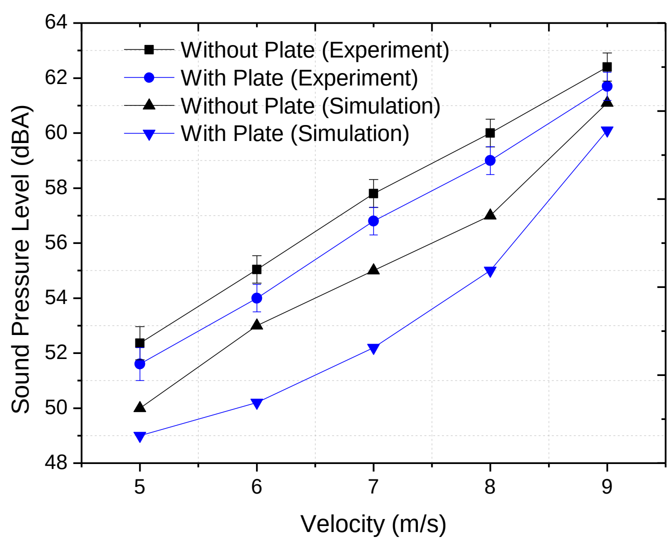

Figure 9. A-weighted sound pressure level at monitoring point.

even pressure distribution between the inner and outer wall when a guiding plate was inserted in the middle of elbow. Evidently, this design reduced the pressure difference between the inner and outer walls. By comparing the two models, the velocity tendency on three probe lines is similar if we regard the elbow with guiding plate as two elbows without plate whose radius is half length of the big one. Speaking of difference, the most obvious one is that the velocity at the guiding plate is zero as figure series B. Furthermore, the differences of velocity profile in two models are mainly caused by curved section since centrifugal force exerted on the flow (Adam et al., 2008).

The wall pressure fluctuations are important characteristics of turbulence and also play an important role to assess the aerodynamic sound source in calculating the far filed sound pressure level (Zhang et al., 2010). Due to the low Mach number, the contribution of quadrupole sources is so slight that it can be ignored. Therefore, most of the sound is generated on wall surfaces (dipole and monopole sources). As the numerical simulation method makes it possible to compute the unsteady pressure fluctuations of the model, it is flexible to evaluate the aerodynamic noise by regarding the pressure fluctuations as sound source. Evidently, pressure fluctuation values of cases without guiding plate are much larger than cases with plate and the difference varies from 1.2 to 9 Pa. It is because the flow disturbance can be decreased when a guiding plate is inserted in the elbow. Speaking of amplitudes of the waves, all pressure fluctuation amplitudes of models with guiding plate are smaller than that without plate to some extent and pressure fluctuation waveform at each point is similar according to the figures (Zhu et al., 2013). Actually, all fluctuation amplitudes approximate to each other as seen in Table 1. This is because that all pressure fluctuations vary synchronously as guiding plate is inserted into the elbow. In summary, the results of simulation demonstrate that predominant component of the pressure fluctuation as flow passes through the elbow is correlated with flow separation characteristics (Tan et al., 2014). From analysis of above figures, pressure fluctuations are mainly generated by oscillation of the vortices excited by the flow separation and it is unsteady according to the curves (Eguchi et al., 2011). Simultaneously, magnitude of vorticity decreases when a guide plate is inserted into elbow since both the velocity and amplitude decrease to some degree. This also can demonstrate that intensity of sound source weakens slightly as rapid changes of vortexes which are adjacent to walls in the flow are the primary sources to generate sound (Zhang et al., 2010; Wang et al., 2011). To mention the sound spectrum, the reason why peaks of SPL spectrum of model with guiding plate appears a little earlier is that, we speculate, the pressure fluctuations have prolonged when a plate is inserted in the elbow based on the analysis of pressure fluctuation figures as mentioned above (Zhang et al., 2010; Shi et al., 2012). In addition, the spectrum of model with plate has another peak at frequency ~4.7 kHz and this may be induced by vortex frequency change.

The reason why SPL of simulation is smaller than experimental results is that this work didn't take pipe vibration into consideration since we haven't found an effective way to quantify the vibration noise yet, and background noise is another possible factor for the variation (Lin and Tsai, 2012). Since FW-H equation is applicable only in predicting the propagation of sound toward the free space according to the reported literatures. It doesn't take into account wave reflection or

Table 1. Pressure Fluctuation amplitude at each observation point (Unit: Pa).

Pressure fluctuation amplitude	11	12	21	22	31	32	41	42
Without Plate	1.3776	1.3777	1.3761	1.3765	1.3729	1.3720	1.3696	1.3690
With Plate	0.2734	0.2709	0.2753	0.2701	0.2734	0.2713	0.2697	0.2731

scattering due to any existing solid surface between the sound flow-field source and the observer. In aggregation, these factors translate into a lower SPL computed by simulation than SPL from experiments (Martínez-Lera et al., 2015).

Furthermore, the results obtained by experiment are approximately linear, while the calculated results deviate slightly from linearity. When the cases with and without the guiding plate are compared, large consistent differences could be easily observed. The experiments show that the sound pressure level values of cases with a flow guiding plate is approximate 1 dB less than cases without a plate, regardless of the inlet velocity. This is because the wall pressure fluctuation attenuated as well as vorticity magnitude decreased when guiding plate is inserted into the pipe as mentioned in previous part, and the intensity of sound source diminishes to some extent so that SPL at the receiver decreases accordingly (Zhang et al., 2010; Shi et al., 2012). In summary, results of simulation agree well with experimental data and it proves that the hybrid combing LES and FW-H theory is flexible to evaluate the aerodynamic noise generated by flow.

Conclusion

Firstly, this paper adopted large-eddy simulation which has been widely used on engineering application to simulate the flow distribution of a creative elbow structure with a guiding plate inserted in the pipe. Compared to other turbulent models, LES is more advantageous for its stable to depict a more accurate flow field. Subsequently, sound level pressures (SPL) were calculated by FW-H acoustic theory from the flow field simulated by LES.

Then, results of the simulations were analyzed. It is demonstrated that the curved section of elbow influences the velocity distribution to a great extent, and velocity profile altered much when a guiding plate was inserted in the elbow. More importantly, pressure fluctuation values of cases without guiding plate are much larger than cases with plate and the difference varies from 1.2 to 9 Pa and all fluctuation amplitudes approximate to each other. Finally, aerodynamic noise value of monitored point was measured to provide empirical evidence for the simulated decreasing in noise level by inserting the plate. Sound pressure level of different cases had similar linear trends when inlet velocity increased from 5 to 9 m/s. The SPL values observed in experiments were slightly greater than which of the simulation due to uncontrollable factors such as elbow vibration, background noise and the defect of the FW-H equation. The results show that, SPL decreased significantly when inserted a plate in the elbow as wall pressure fluctuations weakened when a guiding plate existed and the biggest difference could reach 1 dB.

These results provide a theoretical explanation and a simple method to reduce aerodynamic noise as outlet in airflow devices. Therefore, this paper promises wide applications in industrial fields, such as some medical device design, air exhaust setup and so forth.

Conflict of Interests

The authors declared that they have no conflicts of interest to this work.

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Scientific Research and Essays

Full Length Research Paper

Effect of ultra-short wave on hormone-induced ischemic necrosis of femoral head in early stage

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This study aims to investigate the effect of ultra-short wave on hormone-induced ischemic necrosis of femoral head in early stage by using an Avascular necrosis of the femoral head (ANFH) rabbit model. Horse serum was administered to male rabbits via the marginal ear vein, whereas control rabbits received saline. After five weeks, the rabbits with horse serum were injected with methylprednisolone. Blood-lipoids and hemodynamic parameters were analyzed. Collagen type I was analyzed by using immunohistochemistry. Pathological examination of femoral head was analyzed by hematoxylin-eosin (HE) staining; Expression of vascular endothelial growth factor (VEGF) and BMP-2 mRNA was analyzed by RT-PCR. Results revealed that when compared with control group, the difference in model group was significant ($P<0.05$ or $P<0.01$), with regard to TXB2, 6-keto-PGF1α, blood fat level, T/P, and hemodynamic parameters, while compared with model group, the difference of USW group was significant ($P<0.05$ or $P<0.01$). The expression of collagen type I was significantly lower in the model animals than that in the controls, while that of the USW diathermy group was significantly higher than the control group ($P<0.05$). Pathology index was significantly different in the USW diathermy animals than that in the controls ($P<0.05$). Real-time PCR showed that VEGF mRNA and BMP-2 mRNA levels in the model group were higher significantly as compared to those in the control group ($P<0.01$), while that in the diathermy group were significantly higher than those in the model group ($P<0.01$). The study thus revealed that ultra-short wave has a positive curative effect on ANFH.

Key words: Ultra-short wave, Avascular necrosis of the femoral head (ANFH), Collagen Type I, VEGF mRNA, BMP-2 mRNA.

INTRODUCTION

Avascular necrosis of the femoral head (ANFH) is a pathologic process that results from interruption of blood supply to the bone which might lead to eventual collapse of bone structure if there is no immediate intervention (Shi et al., 2010). Femoral head osteonecrosis is common in China (Zhao and Wang, 2007). The etiology of femoral head osteonecrosis involves trauma and non-traumatic factors such as corticosteroid use, high alcohol

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intake, genetic predisposition, Gaucher's disease, radiation, chronic pancreatitis, HIV as well as idiopathic causes (Miller et al., 2002). Hormone therapy is the most common cause of non-traumatic ANFH (Assouline-Dayan et al., 2002).

Hormone, especially corticosteroid, has been widely used in clinic. Although corticosteroid can provide striking effects on various diseases, it also could have adverse effects including growth retardation, obesity, osteoporosis hyperglycemia, osteonecrosis, cataract, and Cushing syndrome, (Ahmed et al., 2012) particularly after high dosages and long-term use (Gulati et al., 2003; Hougardy et al., 2000). Recently, more cases of ANFH induced by corticosteroid have been reported. The therapeutic effect of ANFN is often not satisfactory, while patients with ANFH usually end up with hip arthroplasty. So it is worthwhile to prevent and cure ANFH before the lesion reaches the stage when arthroplasty becomes an inevitable option. In the early stage, there are several options, such as anti-lipid drugs and Chinese medicine, but the effect is often not satisfactory (Dotti et al., 2002).

The application of ultra-short wave (USW) therapy in rehabilitation medicine has become more and more extensive, especially in peripheral circulatory system (Zhang et al., 2008). USW therapy can resolve inflammatory states, reduce swelling, promote vasodilation, and ameliorate blood circulation (Pang et al., 2013). Thus, USW was widely used in acute or chronic inflammatory disease, and have a positive effect. However, the effect of ultra-short wave on ANFN femoral head injury was not completely understood. In this study, we used horse serum and hormone to establish ANFN rabbit model. Then, we evaluated the effects of USW on ANFN femoral head injury in early stage. In addition, the potential mechanism was also investigated.

MATERIALS AND METHODS

Animal experiments were conducted in accordance to the Principles of Laboratory Animal Care (NIH Publication No. 86-23, revised 1985) and the Regulations of the Committee on the Use and Care of Animals of Shandong University in Jinan, China. This study was approved by the Ethics Committee of the Second Hospital of Shandong University in Jinan, China.

Chemicals and reagents

Methylprednisolone was purchased from US (Chinese Drug Approval Number: H20040338). Horse serum was purchased from US. Immunohistochemical kit of streptavidin biotin-peroxidase complex (SABC) and collagen Type I polyclonal antibody of rabbit were both purchased from Tianlai Biotechnology Co. Ltd (Beijing, PRC)

Animals and experimental proceeding

Male New Zealand rabbits aging 24 weeks and weighing 2.5 to 3.0 kg were provided by the Laboratory Animal Center of Shandong University (Jinan, Shandong, China). Prior to the experiments, animals were adapted to new environment for one week. In the present study, animals were housed in separate cages under diurnal lightning conditions with free access to food and water.

After acclimatization, the animals were randomly divided into 3 groups: blank control group (group A), model group (group B) and experiment group (group C) (n =10 in each group). Rabbits in model and experiment group were injected with horse serum (15 ml/kg) via the ear vein in the first and third week. Meanwhile, the control rabbits received saline. After five weeks, the rabbits receiving horse serum were injected with methylprednisolone (40 mg/kg) intraperitoneally daily for three days. Rabbits in control group received the same dose of saline. The rabbits in experiment group were treated with USW diathermy treatment from the sixth week. The USW therapy apparatus is floor-type LDT-CD31 electrotherapy machine (Shanghai, China). It has a frequency of 40.68 MHz, the wavelength of 7.3 m, the utmost output power of 200w and two electrodes of 20 cm multiplied by 15 cm. The electrodes are put both sides of the hip of a controlled rabbit with a gap of 2 to 3 cm between the electrode and the skin. Tiny quantity of heat is needed. Continuous treatment lasts 3 weeks, 15 min once per day, to an end in the 9th week.

Observation of general condition

The weight changes, color and luster of hair and tail, and activity of all the rabbits were recorded.

Blood-lipoids and hemodynamic parameters

In the 10th week, 3 ml venous blood was obtained from marginal ear vein of each rabbit. Then blood was centrifuged at 3000 rpm for 10 min to collect serum. Total cholesterol (TCH) and triglyceride (TG) were detected by the blood cell analyzer using partial serum, and the rest was reserved at -20°C. Serum thromboxane B2 (TXB2, the stable metabolites of TXA2) and 6-Keto prostaglandin F1 alpha (6-keto-PGF1α, the stable metabolites of PGI2) were detected with the EIA kit (Cayman co. Ltd). TXB2/6-keto-PGF1α (T/P) representing balance of TXA2-PGI2 was calculated. Venous blood (4 ml) was obtained from the opposite side of marginal ear vein, mixed with heparin to prevent blood coagulation. Hemodynamic parameters were detected using fully automatic blood rheometer (FASCO-3010A).

Immunohistochemistry for collagen Type I

At the end of the 12^{th} week, the rabbits were sacrificed through air embolism. Then bilateral femoral head of rabbit tissue was taken immediately. Femoral head tissues were stored in 10% formalin, fixed at room temperature for 36 ~ 72 h. The fixed tissue was decalcified with 20% EDTA (ethylene diamine tetraacetic acid) for preparation of paraffin section. The section was dewaxed and washed with phosphate buffer solution (PBS) flushing to repair tissue antigen. The first antibody, biotinylated sheep-anti-rabbit horseradish peroxidase (HRP) polymer and avidin-biotinylated-enzyme complex (ABC) were added, and colored using hydrogen peroxide after PBS flushing. The reaction was terminated until the orange-yellow granules occurred under microscope. The sections were stained with hematoxylin, dehydrated with alcohol, and sealed with neutral resins. We observed the immune complex deposition area and strength of immune response. The orange-yellow flake or granular staining was considered as standard positive reaction. The collagen Type I level was positively related to the intensity of immunohistochemical staining grading five levels.

Table 1. Oligonucleotide sequences of primers.

Gene	Sequence	
VEGF	Forward primer	5'-AATGATGAAAGCCTGGAGTGTG-3'
	Reverse primer	5'-TCACATTTGTTGTGCTGTAGGAAG-3'
BMP-2	Forward primer	5'-TTTGGTCAACTCCGTGAACTCTAA-3'
	Reverse primer	5'-ACACCCACAACCCTCCACA-3'
β-actin	Forward primer	5'-TGCGGGACATCAAGGAGAA-3'
	Reverse primer	5'-AGGAAGGAGGGCTGGAACA-3'

Pathological examination of femoral head

The fixed tissue was decalcified in 5% salpeter solution for one week, dehydrated using graded ethanol, wrap with wax immersion, and embedded in paraffin. Then it was sliced into sections up to about 5 μm thick using a microtome, and the sections were dewaxed, stained by routine HE staining. Morphological changes of osteoblast and osteoclast, the empty cartilage cell lacunae, and the density of blood vessels under the cartilage were observed. Meanwhile, the thickness of femoral head cartilage, the width of bone trabeculae, the diameters of fat cells and the adipocyte area rates were analyzed using image analysis system.

Real-time PCR analysis of the femoral head tissues

Femoral head was frozen quickly through liquid nitrogen and reserved in cryogenic refrigerator. The expression of VEGF and BMP-2 mRNA in the femoral head was detected by quantitative real-time PCR. The oligonucleotide sequences of the primers were synthesized by TaKaRa Bio (China) (Table. 1). And all the reagent kits used bellow were provided by TaKaRa Bio (China). Total RNA was extracted with Trizol reagent (Invitrogen, USA). Then the purified RNA was diluted up to 500 ng μl^{-1} and 3 μl RNA was utilized to synthesize cDNA with Prime-Script RT reagent kit. Following manufacturer's instruction, the mixture was incubated at 37°C for 45 min, 85°C for 5 s and 4°C for 7 min. Real-time PCR was performed with SYBR1Premix Ex Taq TM kit and qPCR system. The cycling parameters were set as follows: initial denaturation at 95°C for 30 s, followed by 40 cycles at 95°C for 5 s and 60°C for 30 s, and final melting curve analysis for distinguishing main PCR products from primer dimers. The cycle number where the amplification curve crossed the threshold line was noted as the critical threshold (CT) and the gene expression was calculated by the comparative C_T ($2^{-\Delta\Delta CT}$) method, using β-actin as the control housekeeping gene for normalization.

Statistical analysis

All data were presented as means ± SD and analyzed with one-way analysis of variance (ANOVA) and Student's t-test. P value < 0.05 was considered statistically significant.

RESULTS

General condition

After induction of ANFN, all ANFN groups showed less weight growth as compared with control group. After USW therapy, weight of rabbits grew more as compared with the model group (Figure 1). Rabbits of model group were depressed, and had fluffy lackluster fur, awkward hind limbs, short bounce distance and height. In contrast, the rabbits after treatment, which had glossy fur, sensitive activity, and long bounce distance and height, were active. The USW therapy significantly improved the weight and motility.

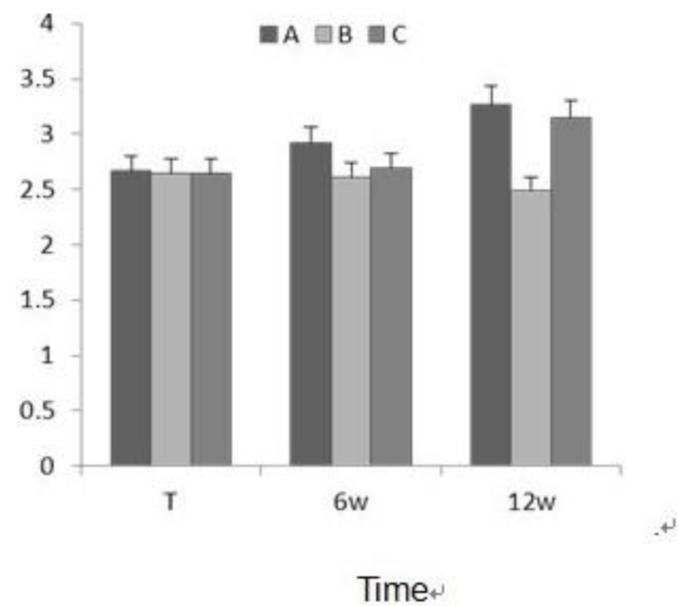

Figure 1. The ultra-short wave improved the weight following ANFN. The weight was measured as described in "Materials and Methods". The aggregate score represents the average weight per animal (n=20 for each group). *P < 0.01 vs. Group A, ΔP < 0.05 vs. Group B. Group A: control; Group B: vehicle treated ANFN; Group C: ultra-short wave treated ANFN.

Effect of USW on blood-lipoids and hemodynamic parameters

When compared with control group, the difference of

Table 2. TXB2, 6-keto-PGF1α, T/P, blood fat level analysis (mean±SD).

Group	TXB2(pg/ml)	6-keto-PGF1α(pg/ml)	T/P	TG(mmol/L)	TCH(mmol/L)
A	170.5±39.8	241.6±52.3	0.6±0.2	0.7±0.2	1.5±0.5
B	450.1±108.6*	140.3±25.2*	3.2±0.5*	3.0±0.8*	4.1±0.4*
C	227.1±52.5*∆	235.6±71.8*∆	0.9±0.2*∆	1.3±0.4*∆	2.6±0.6*∆

*P < 0.05 vs. Group A; ∆P < 0.05 vs. Group B. Group A: control; Group B: vehicle treated ANFN; Group C: ultra-short wave treated ANFN.

Table 3. Hemodynamics analysis (mean±SD).

Group	WBLSV (mPa.s)	WBHSV (mPa.s)	PV (mPa.s)	Equation K value	EDI
A	6.33±0.58	4.21±0.32	1.56±0.21	13.91±4.18	0.79±0.09
B	11.27±0.75*	6.98±0.50*	2.02±0.46*	38.16±1.79*	0.90±0.03
C	8.70±0.71*∆	5.03±0.38*∆	1.70±0.32	30.12±2.01*∆	0.93±0.11

*P < 0.05 vs. Group A; ∆P < 0.05 vs. Group B. Group A: control; Group B: vehicle treated ANFN; Group C: ultra-short wave treated ANFN. WBLSV: whole blood low sheathed viscosity; WBHSV: whole blood high sheathed viscosity; PV: plasma viscosity; EDI:erythrocyte deformability index

Table 4. Immunohistochemistry staining analysis (number).

Group	Number	immunohistochemistry staining intensity				
		++++	+++	++	+	-
A	20	0	3	17	0	0
B	20	0	0	2	18	0
C	20	2	15	3	0	0
Total	60	2	18	22	18	0

Comparison between groups was statistically significant (P<0.05).++++: super strong positive reaction; +++: strong positive reaction; ++: moderate positive reaction; +: weakly positive reaction; -: negative reaction.

model group was significant (P<0.05 or P<0.01), with regard to TXB2, 6-keto-PGF1α, blood fat level, T/P, and hemodynamic parameters. Compared with model group, the difference of USW group was significant (P<0.05 or P<0.01). They improved the 6-keto-PGF1α of cases, and decreased TXB2, blood fat level, T/P, (Table 2) and hemodynamic parameters (Table 3) respectively. The animals in the model group were found with ANFN manifesting avascular necrosis of femoral head bone cells, decrease of bone marrow cells, high blood viscosity and imbalance of TXA2-PGI2. The USW diathermy group demonstrated significant improvement of blood supply, TG level and blood viscosity, as well as PLT activity and the TXA2-PGI2 ratio.

Effects of USW therapy on collagen Type I

The expression of collagen Type I was significantly lower in the model animals than that in the controls as indicated by the stronger immunohistochemistry staining for rabbits collagen type, while that of the USW diathermy group was significant higher than the control group (P<0.05) (Table 4) USW diathermy can promote the expression of collagen Type I.

Effect of USW therapy on pathological changes of femoral head

The amount of osteoblast in the model group was significantly lower than control group, while in the diathermy group it was significantly increased compared with the model group (P<0.01). The amount of osteoclast in the model and diathermy group was significantly higher than in the control group, and in the diathermy group it was significantly higher than in the model group (P<0.05). The empty cartilage cell lacunae ratios of the model and diathermy groups were significantly higher than in the control group, and the diathermy group showed significant

Table 5. Pathology of femoral head indexes analysis (mean±SD).

Group	Osteoblast (number)	Osteoclast (number)	The empty cartilage cell lacunae ratios (%)	Density of blood vessels under the cartilage (number)
A	21.00±3.63	4.75±1.59	6.51±1.47	11.55±2.16
B	14.75±3.68*	13.06±2.79*	20.29±2.64*	6.69±1.62*
C	36.00±6.02*∆	8.61±2.45*∆	9.18±1.85*∆	14.06±2.15*∆

*P < 0.05 vs. Group A; ∆P < 0.05 vs. Group B.

Table 6. Pathology of femoral head indexes analysis (mean±SD).

Group	Thickness of femoral head cartilage (μm)	Width of bone trabeculae (μm)	Diameters of fat cells (μm)	Adipocyte area rates (%)
A	518.46±62.31	127.55±13.51	43.85±6.24	12.54±3.52
B	229.44±45.91*	73.06±16.61	63.44±7.33*	25.79±4.61*
C	334.50±49.22*∆	102.89±10.17*	52.11±5.80*∆	20.91±2.51*

*P < 0.05 vs. Group A; ∆P < 0.05 vs. Group B.

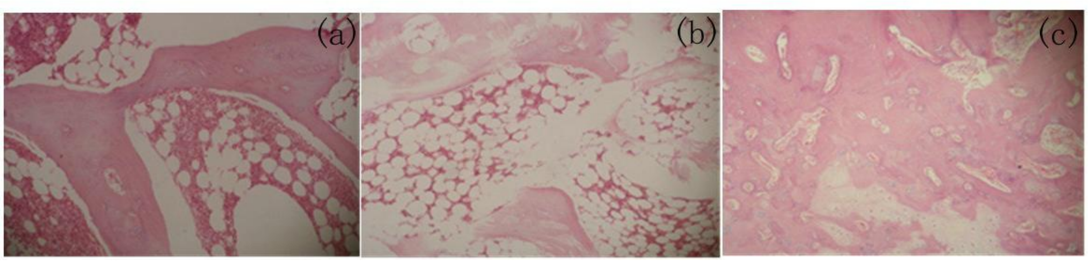

Figure 2. Pathological changes of femoral head were observed. (a):group A: amount of hematopoietic cell was observed in medullary canal, and the ratio of fat cells was normal; (b):group B: bone trabecular was sparse, and the number and size of fat cells was increased;(c):group C: Osteoblasts were observed in bone trabecular, and new vessels were increased.

degradation compared to the model group (P<0.05). The density of blood vessels under the cartilage in the model group was significantly less compared with the control group, while in the diathermy group it was significantly increased compared with the model group (P<0.01) (Table 5).

The thickness of femoral head cartilage in the model and diathermy group was reduced compared with the control group, while it was thicker in the model group than in the diathermy group (P<0.05). The width of bone trabeculae in the model and diathermy group was significantly less compared with the control group, while they were significant wider in the diathermy compared with the model group (P<0.01). The diameters of fat cells in the model and diathermy group were increased compared with the control group, while they were significantly smaller in the diathermy group compared with the model group (P<0.05). The adipocyte area rates in the model and diathermy group were significantly elevated compared with the control group, and rates in the model group were significantly elevated compared with the model group (P<0.05) (Table 6) (Figure 2).

The effects of USW on the expression of VEGF and BMP-2 mRNA

Real-time PCR showed that in femoral head VEGF mRNA and BMP-2 mRNA levels in the model group were higher significantly as compared to those in the control group (P<0.01). Meanwhile, VEGF mRNA and BMP-2 mRNA levels in the diathermy group were significantly higher than those in the model group (P<0.01) (Figure 3).

DISCUSSION

Hormone-induced ANFN will occur when femoral head

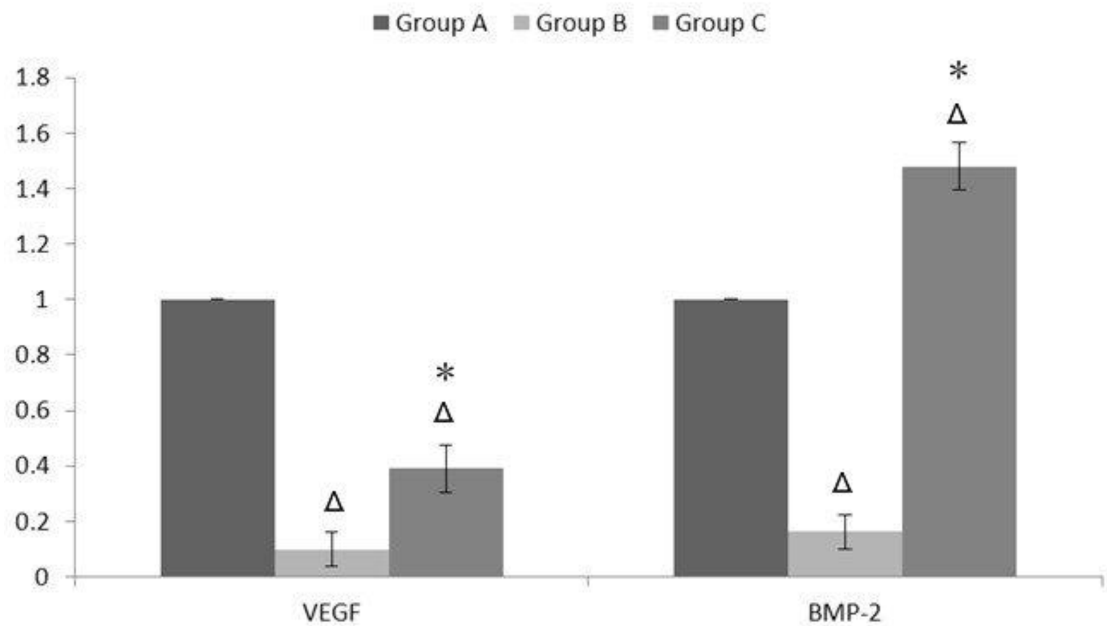

Figure 3. The ultra-short wave induced the expression of VEGF mRNA and BMP-2 mRNA. The weight was measured as described in "Materials and Methods". The mRNA expression was calculated by the $2^{-\Delta\Delta CT}$ method using β-actin as the reference gene (mean±SD). The relative mRNA levels were represented as the ratios by comparing the expression of each group (n=20 for each group). *P < 0.01 vs. Group A, ΔP < 0.01 vs. Group B. Group A: control; Group B: vehicle treated ANFN; Group C: ultra-short wave treated ANFN.

component (osteocyte, bone marrow hematopoietic cells, and fata cells) is dead caused by large dose hormone application. In this study, we have taken the advantage of an ANFN animal model to investigate the effects of USW on hormone-induced femoral head injury. It has been reported that horse serum could induce fat metabolism disorder and mild small arteritis in bone (Wang et al., 2011, Andersen et al., 2013). The hormone could aggravate the potential vasculitis (Zhang et al., 2013). The vasculitis of animal was caused by horse serum, and then a large dose of hormone was used to induce the typical model of osteonecrosis (Song et al., 2010). In the present study, we successfully induced ANFN in rabbits by intravenous injectio of horse serum and methylprednisolone as confirmed by the appearance of osteonecrosis in the femoral head. Loss of weight, poor mental state and declination of exercise capacity were apparent after ANFN. USW improved the weight, mental state and exercise capacity.

In this study, sensitization of rabbits was caused by injection of horse serum, after that, the models were made by the use of hormone. Then we found that the blood-lipoids level was higher after the use of hormone suggesting that hormone could cause hyperlipidemia along with previous studies (Vuksanovic et al., 2006; Grover et al., 2007; Jones, 1992). TXA2 and PGI2 were metabolites of arachidonic acid in plaque lipid membrane. TXA2 could promote platelet aggregation, while PGI2 could inhabit platelet aggregation and diastole blood vessels. The balance of TXA2 and PGI2 was important in regulation of platelet function and vascular tone (Wei et al., 1998). In this study, we found that hormone could increase platelet activity and TXA2 synthesis, decrease the PGI2 synthesis, and increase TXA2/PGI2 ratio. That would prompt thrombosis leading to osteonecrosis of the femoral head. USW effectively inhibited aggregation and activation of platelet in ischemia of tissue, and regulated the balance of TXA2/PGI2; however, but the underlying mechanism still requires further study. Through USW therapy, the hemodynamic parameters were improved, which indicated that ultra-short wave may improve microcirculation, promote the blood flow, and prevent the thrombosis.

The expression of collagen Type I mRNA, a specific molecular marker of early differentiation of osteoblast, was related with osteogenetic activity (Turner and Spelsberg, 1991). Glucocorticoids could inhibit the synthesis of collagen type I in a time- and concentration-dependent way (Delany et al., 1994). In this study, the immunohistochemistry staining of the collagen Type I was significantly lower in the model animals than that in the controls. We speculated that synthesis ability of collagen Type I in controls was decreased, to cause insufficient repair after osteonecrosis. The immunohistochemistry staining of the collagen Type I was significantly higher in the diathermy group than that in the controls. USW could alleviate or reverse the inhibit effect of methylprednisolone against collagen Type I to maintain a good function of osteoblast.

It has been reported that USW could improve the blood flow (Mlynarik et al., 2008), and the improvement of blood flow was the ultimate aim of the treatment of femoral head necrosis in the early stage. In this study, the density of blood vessels under the cartilage in the diathermy group was significantly increased compared with the model group. We considered that the improvement of blood flow increased the cartilage thickness, promoted bone marrow stromal cells differentiate into preosteoblast and osteoblast, increased the source of osteoblast, and then broaden bone trabecular, reduced the osteonecrosis, effectively improved necrotic bone repairing, and prevented the femoral head necrosis. Otherwise, USW could also prevent the bone marrow stromal cells differentiate into fat cell, indirect inhibit intramedullary fat accumulation, reduce the pressure in the femoral head, improve the blood flow of femoral head, and prevent bone ischemia. In this study, we demonstrated that the thickness of femoral head cartilage, the width of bone trabeculae, the diameters of fat cells in the diathermy group than that in the controls.

It has been reported that VEGF and BMP-2 were the two most important factors affecting the repair of femoral head (Vadasz et al., 2004). Glucocorticoids may inhibit the expression of VEGF mRNA, which may participate in the pathological process of bone metabolic abnormalities (Pufe et al., 2003). In this study, VEGF mRNA and BMP-2 mRNA levels in the model group were elevated significantly as compared to those in the control group. That indicated that hormone was strongly inhibit the VEGF synthesis, as it was reported (Li et al., 2005; Gloddek et al., 1999). VEGF mRNA and BMP-2 mRNA levels in the diathermy group were significantly higher than those in the model group. That proved that the USW could induce the expression of VEGF mRNA and BMP-2 mRNA, and enhanced the repair of femoral head after ANFN.

Conclusion

In our study, these results showed that USW had a positive curative effect on ANFH by promoting biochemical metabolism of bone cells, promoting osteoblastic proliferation and differentiation, improving the blood flow, enhancing the repair of femoral head and so on. USW may be a useful remedy for the treatment of ANFH in the early stage. However, in this study, we used microcalorimetry ultra-short wave therapy, and the function of different dosage USW was unclear, so further studies should be performed to provide more experimental data to support its clinical application.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Scientific Research and Essays

Full Length Research Paper

Analyzing vulnerability and resilience of Turkey to climate change

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The purpose of this study was to analyze the vulnerability and resilience of Turkey to climate change impacts. The Vulnerability Resilience Index was developed to measure Turkey's vulnerability. Adaptive/coping capacity and exposure/sensitivity sectors were generated and used to determine the vulnerability value. First, these sectors were divided into related indicators. Economy, human resources, environment, and governance indicators were used to determine adaptive/coping capacity sector value. Exposure, settlement, food, ecosystems, health, and water indicators were used to determine exposure/sensitivity sector value. Later, proxies for each indicator were established. Proxy indexes were interpreted to indicators and these indicators were connected to sectors. The overall climate change vulnerability of Turkey was constructed based on sectors' values. Results showed that economic capacity was the most vulnerable adaptive/coping capacity indicator and ecosystem sensitivity is the most vulnerable sensitivity indicator for Turkey. It has been found that Turkey's vulnerability to climate change index value was 0.363 indicating low vulnerability.

Key words: Climate change, vulnerability, resilience, adaptive capacity, exposure, sensitivity, Turkey

INTRODUCTION

Climate change is considered one of the greatest challenges facing the world today (Copenhagen, 2009). It is evident that even if all greenhouse gas emissions were immediately halted, climate change would continue for the foreseeable future. Greenhouse gases that have already accumulated in the atmosphere would continue to alter climatic systems, ecological systems, and social systems (Ligetti et al., 2007; CCC, 2010). It is almost universally accepted that the consequences of climate change are likely to be severe and have cumulative or systematic effects on natural and managed systems in various sectors and regions (IPCC, 1997). In order to cope with the consequences and new challenges, regions or countries must develop adaptation policies or actual adjustments that might eventually enhance resilience and reduce vulnerability to expected climate change impacts.

Vulnerability is defined as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including variability and extremes. Vulnerability research started in natural hazard studies focuses on the vulnerability of people to the effects of

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environment and became an important aspect in climate change and policy research (Brooks et al., 2005; Füssel, 2007; Hinkel, 2011, Janssen et al., 2006, Smit and Wandel, 2006). The increasing focus on adaptation has positioned vulnerability as an integral concept in climate change research today (Malone and Engle, 2011). The three components of vulnerability are exposure, sensitivity and adaptive capacity (IPCC, 2001). It is established that high vulnerabilities to climate change depend considerably on geographic location, sectoral and social contexts (Lynn et al., 2011).

Vulnerability assessment is an important tool for understanding the different vulnerability of regions and peoples. The methodological frameworks to investigate vulnerability to climate change embrace sensitivity and adaptive/coping capacity. These assessments are performed for several purposes but their primary objective is to identify the people or places that are most susceptible to harm and to permit vulnerability-reducing actions and improve adaptation planning, unveiling social injustices (Luers, 2005; Malone and Engle, 2011). Each of these purposes entails specific information and targeted approaches. The indexes developed for modeling vulnerability are intended to measure national, regional and local propensities and susceptibilities to the impacts of climate change that are beyond human control (Brooks et al., 2005; Brenkert and Malone, 2005; O'Brein et al., 2004; Parvin and Shaw, 2011). Therefore, vulnerability assessments enhance the capacity to cope with the events, climatic alteration and, hence, protect human well being.

Resilience is often considered to be opposite of vulnerability (Adger 2001; Davoudi et al., 2012). Resilience is the ability of social or ecological system absorb while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change (Ibarran et al., 2008). Resilience assessment is a specific methodology and framework for analyzing and managing the dynamics of resilience in social-ecological systems. It provides a set of participatory tools to help identify thresholds, drivers, dynamics, and actions that either contribute to or erode resilience in social-ecological systems (Resilience Alliance, 2010). It is also important to develop political and social solutions within the system.

Vulnerability assessment rooted in social-ecological systems and resilience research integrates the natural, physical, and societal capacities to cope in the shorter term and adapt in the longer term. In resilience research, this has led to a shift from thinking about always returning to an original state to thinking about preserving and the opportunity to move between multiple stable states (Malone and Engle, 2011). Both the vulnerability and resilience assessments are concerned with how systems respond to climate change. Both concepts together might, therefore, help to clarify the complexities of past environment–society relationships and could contribute to our understanding of how societies have coped with and adapted to past climate variability and weather or weather-related events (Endfield, 2012).

Turkey is a developing country in Western Asia with 76.4 million populations. It became a member of the United Nations Framework Convention on Climate Change in 2004 and the Kyoto Protocol in 2009. These attempts increased the attention given to climate change and its research. It has been stated that Turkey is especially vulnerable to the adverse impacts of climate change because it is located in Mediterranean Basin (IPCC, 2007). Turkish Ministry of Environment and Urbanization developed a national climate change strategy and combating climate change became a national vision in recent years (MEU, 2010a).

Fujihara et al. (2008) and Yano et al. (2007) have found that climate change could place an additional stress on Turkey's ecological and socio-economic systems. Besides, these systems already face tremendous pressures because of rapid urbanization, industrialization, and economic development (Fay et al., 2010). Therefore, it is important to identify Turkey's vulnerability and resilience to climate change impacts. The aim of this study is to assess the current sensitivity, adaptive/coping capacity, vulnerability and resilience of Turkey to climate change.

METHODS

The Vulnerability-Resilience Indicator Model (VRIM) was developed by Moss et al. (2001) to assess vulnerability. The modeling framework allows analysts to evaluate systematically an entity and/or set of indicators, and to indicate the likely vulnerabilities of an area (Brenkert and Malone, 2005). VRIM takes a hierarchical approach in constructing a vulnerability index as the geometric mean of various measures of sensitivity (how systems could be negatively affected by environmental stresses) and adaptive capacity (the capability of a society to maintain, minimize loss of, or maximize gains in welfare).This approach have the advantage of dividing their indicator into two major components - one that reflects sensitivity and a second that reflects adaptive capacity (Yohe et al., 2006). VRIM uses five indicators - settlement, food, ecosystems, health, and water, to assess the sensitivity sector and uses three indicators - economy, human resources, and environment, to assess the adaptive/coping capacity sector. Each indicator has two or three proxies in the model which evaluate their positive and negative relations. The VRIM measures vulnerability with the assessments of sensitivities to climate, and societal coping/adaptive capacities.

There are more data available for the climate change studies and these data is very beneficial to use in VRIM model. There had been some adaptations made on the VRIM in this study. Exposure indicator is included under exposure/sensitivity sector and it was calculated using proxies representing different climate change stress such as sea level rise, temperature change and precipitation change. There has been an affirmation that institutions, governance, and management play an integral role in determining a system's ability to adapt to climate change (Brooks et al., 2005; Brown et al., 2010; Eakin and Lemos, 2006; Engle and Lemos, 2010; Held and Hervey, 2009). Governance had been added as a fourth indicator to the adaptive/coping capacity sector.

Studies on climate change has shown that damage of particulate matter (PM) will be worsened with the increased temperature (Jacob and Winner, 2009; Bell et al., 2007; Patz et al., 2005). It has been suggested that PM is a good proxy to assess air quality (Martuzzi et al., 2002). Deforestation is also important to proxy to assess environmental capacity (Spitalhouse and Steward, 2003). Current study assessed the PM_{10} proxy for one of the environmental capacity indicator proxies. Recent studies recommended that "endangered species" data could be used in ecosystem sensitivity assessment because it is a significant indicator of biodiversity loss (Thuiller, 2007). For the health sensitivity indicator, "ages 65+" and "under five mortality rate" were taken as additional proxies. These two proxies are also significant measures in assessing health sensitivity (Haines et al., 2006; Keim, 2008). The final versions of the vulnerability resilience index (VRI) and data sources are given in Table 1. Once the vulnerability-resilience index was structured, proxy index from 124 countries had been translated into dimensional indexes using dimension index formula (1). All countries which had no missing data were selected for this step. The World Bank, UNESCO and UNEP were the main data sources. Dimension index values were also compared with the world's mean values for each proxy.

$$\text{Dimension Index}_i = \frac{X_i\text{-Min Value}}{\text{Max Value-Min Value}} \quad (1)$$

The proxy index which was in different units and scales were normalized and scaled as maximum and minimum values to make them accountable. After the normalization process, the scores were settled between 0 and 1 (Table 2). By relating proxy index and vulnerability, positive and negative relationships between the proxy and indicator and between the indicator and sector were possible. Each dimensional index is a proxy for the capabilities of the corresponding dimension. The transformation function of income (GDP) to capabilities is likely to be concave. Therefore, using the natural logarithm of the actual minimum and maximum values is recommended for GDP (HD Report, 2011).

Arithmetic means were used to create indicator index. Subsequently, the dimensional index for each proxy was transformed into indicator values. Nine proxies for four indicators were utilized to calculate the adaptation/coping capacity; twenty proxies for six indicators were employed to determine sensitivity (Table 1). The difference between climate change sensitivity and adaptive/coping capacity create the overall vulnerability of a country.

RESULTS

Each country has different and possibly unique geographic, economic and social features that affect its vulnerability to climate change. Also, one country's vulnerability level would be differentiated due to its developmental pathway. Here, Turkey's adaptive/coping capacity, exposure/sensitivity and overall vulnerability to climate change is explained.

Adaptive/coping capacity of Turkey

Adaptive/coping capacity is the ability of a system to respond to and recover from the effects of stress or perturbations that have the potential to alter the structure or function of the system. Turkey's adaptive/coping capacity sector index value was found 0.592 indicating moderate adaptive/coping capacity to climate change impacts (Figure 1). Economic capacity, human resources, environmental capacity, and governance capacity were taken as the indicators of the adaptive/coping capacity sector in this study.

Results were analyzed to delve strengths or weaknesses of Turkey and its barriers or limits of adaptive/coping capacity against climate change impacts. Table 3 presents the proxy values of adaptive/coping capacity sector.

Economic capacity

One of the main variables affect the vulnerability of individuals and communities is economic capacity (Cutter et al., 2003). Economic growth and distribution of income among populations are economic aspects of resilience (Adger, 2000). Turkey's economic capacity indicator index value was found 0.528 pointing moderate adaptive/coping capacity. Turkey's low economic capacity seems an obstacle for adaptation to climate change. The GDP per capita (in US $) and income equity were used as proxies for assessing economic capacity in Turkey.

Apparent indicator that makes large contributions to reduce adaptive capacity of Turkey was low GDP per capita. Turkey's GDP proxy index value was found 0.420 indicating moderate adaptive/coping capacity. Gini coefficient is commonly used as a measure of inequality of income or wealth. Turkey's Gini coefficient proxy index value was found 0.636 indicating high adaptive/coping capacity. This indicates that the distribution of income is close to equal in Turkey.

Human resources capacity

A further aspect of social resilience is human capital which allows examination of links to changes in production, employment, and labor mobility (Adger, 2000). Human resources capacity helps to determine how citizens respond to job shifting caused by climatic variability. Turkey's human resources capacity indicator index value was found 0.759 pointing high adaptive/coping capacity. This result implies that Turkey has advantage against climate change in terms of human resources. Age dependency and literacy were used as proxies for assessing human resources capacity in Turkey.

Age dependency proxy index value was found 0.648 indicating high adaptive/coping capacity. It explains that economically active individuals can use resources to adapt the impact of climate change. The adult literacy ratio is the percentage of those that can understand, read

Table 1. Sectors, indicators, and proxies of the model.

Sector	Indicator	Proxy	Functional relationships	Source
Adaptive and coping capacity	Economic capacity	GDP per capita	Coping/adaptive capacity ↑ as GDP per capita ↑	WB, 2010
		Income equity (Gini)	Coping/adaptive capacity ↑ as Gini coefficient ↓	WB*
	Human resources	Dependency ratio (% of working-age population)	Coping/adaptive capacity ↑ as dependency ↓	WB, 2010
		Literacy (15+)	Coping/adaptive capacity ↑ as literacy ↑	UNESCO, CIA*
	Environmental capacity	Population density	Coping/adaptive capacity ↓ as population density ↑	UNEP, WB, 2010
		Air quality	Coping/adaptive capacity ↓ as PM_{10} emissions ↑	World Development Indicators,
		Deforestation	Coping/adaptive capacity ↓ as deforestation ↑	WB, 2013
	Governance	Voice/accountability	Coping/adaptive capacity ↑ as voice and accountability ↑	WB, World. Governance Indicators
		Government effectiveness	Coping/adaptive capacity ↑ as government effectiveness ↑	WB, World. Governance Indicators
Exposure/sensitivity	Exposure	Land area below 5 m elevation (%)	Exposure ↑ as land area below 5 m elevation ↑	WB, 2013
		Population living below 5 m elevation (%)	Exposure ↑ as population living below 5 m elevation ↑	WB (2000 population data)
		Population affected by droughts, floods, and extreme temperatures	Exposure ↑ as affected population ↑	WB, 2013
		Temperature change (%)	Exposure ↑ as temperature change ↑	WB, 2013
		Precipitation change (%)	Exposure ↑ as precipitation change ↑	WB, 2013
	Settlement/ Infrastructure sensitivity	Urban population growth (%)	Sensitivity ↑ as urban population growth ↑	WB, 2012
		Improved sanitation facilities (% of population with access)	Sensitivity ↓ as population with access ↑	WHO, WB, 2010
		Improved water sources, rural (% of rural pop. with access)	Sensitivity ↓ as population with access ↑	WHO, WB, 2010
	Food security	Cereal yield	Sensitivity ↓ as production ↑	WB, 2010
		Protein consumption per capita	Sensitivity ↓ as consumption ↑	WB, 2010
	Ecosystem sensitivity	Fertilizer use	Sensitivity is ↓ if use <60 kg/ha or >100 kg/ha; ↑ when use ≥60 and <100 kg/ha	WB, 2010
		Endangered species	Sensitivity ↓ as endangered species ↓	IUCN, 2010
		Terrestrial protected areas (%)	Sensitivity ↓ as terrestrial protected areas ↑	WB, 2013
	Health sensitivity	Fertility rate	Sensitivity ↓ as fertility rate ↓	WB, 2010
		Life Expectancy	Sensitivity ↑ as life expectancy ↓	WB, 2010
		Under-five mortality rate (per 1,000)	Sensitivity ↓ as under-five mortality rate ↓	WB, 2012
		Ages 65+ (%)	Sensitivity ↑ as % of ages 65+ ↑	UNICEF, WB, 2010
	Water resource sensitivity	Renewable internal freshwater resources per capita (m^3)	Sensitivity ↑ as freshwater resources per capita ↓	WB, 2010
		Annual freshwater withdrawals, total	Sensitivity ↑ as freshwater withdrawal ↑	AQUASTAT, WB, 2010
		Average annual precipitation	Sensitivity ↓ as average annual precipitation ↑	WB, 2013

Table 2. Index value categorization.

Index value	Category
0.000-0.200	Very low
0.201-0.400	Low
0.401-0.600	Moderate
0.601-0.800	High
0.801-1.000	Very high

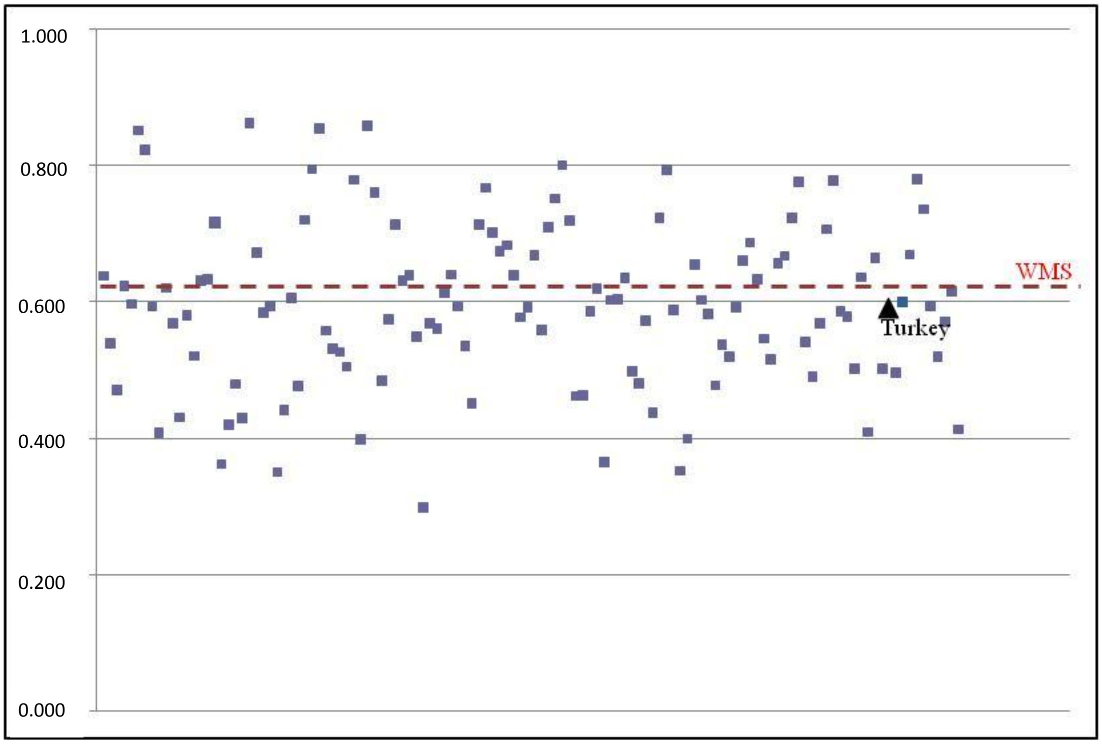

Figure 1. Adaptive/coping capacity of Turkey.

and write a short simple statement on their everyday lives. Turkey's adult literacy proxy index value was found 0.871 indicating very high adaptive/coping capacity.

Environmental capacity

Environmental capacity is an important factor in adaptation process also. Environmental capacity shows the current human pressure on natural resources and health of the environment where the people live. Results showed that Turkey have moderate environmental capacity with an index value of 0.663. Population density, particulate matter (PM_{10}) and average annual deforestation were used as proxies for gauging Turkey's environmental capacity.

It has been found that population density has the major negative effect. Population density proxy index value was found 0.392 indicating low adaptive/coping capacity. This result states that, Turkey's population density has a high pressure on natural sources. Air quality directly affects the quality of human's life. PM_{10} was used as a proxy for air quality. Turkey's PM_{10} proxy index value (0.766) was found high. PM_{10} proxy index value explains that Turkey has low level of air pollution. Deforestation is the process of destroying a forest and replacing it with something else, especially by an agricultural system. Turkey's annual deforestation proxy index was found very high (0.831). It means that deforestation in Turkey is low and this situation creates an advantage against climate change.

Governance capacity

Adaptation to climate change impacts must also be included in the debate on policy issues because of the integrated nature of the climate change (Adger, 2001).

Table 3. Adaptive/coping capacity indicator and proxies of Turkey.

Indicator / proxy	Turkey's score	Rank	Category	WMS
Economic capacity	**0.528**	**45**	**Moderate**	**0.636**
GDP (per capita)	0.420	31	Moderate	0.645
Income equity	0.636	58	High	0.626
Human resources	**0.759**	**69**	**High**	**0.654**
Age dependency	0.648	91	High	0.519
Literacy	0.871	54	Very High	0.789
Environmental capacity	**0.663**	**77**	**High**	**0.595**
Population density	0.392	48	Low	0.356
Air quality	0.766	44	High	0.761
Deforestation	0.831	113	Very High	0.668
Governance	**0.543**	**77**	**Moderate**	**0.499**
Voice and accountability	0.431	56	Moderate	0.500
Government effectiveness	0.655	88	High	0.498

Turkey's governance capacity indicator index value was found 0.543 pointing moderate adaptive/coping capacity. Voice and accountability, and government effectiveness were used as proxies for assessing governance capacity in Turkey. Voice and accountability proxy index value was found 0.431 indicating moderate adaptive/coping capacity. Government effectiveness proxy index was high (0.655). Turkey's government effectiveness rate reveals that Turkey has good public services and policy formulation which are important for implementing climate change adaptation policies. Turkey also has been involved in international negotiations on climate change since 1992 and policies have been regulated in accordance with other UNFCCC members (MoF, 2013).

Exposure/Sensitivity of Turkey

Exposure is degree of climate stress upon a particular unit analysis; due to changes or variability in climate conditions. Sensitivity is basically the biophysical effect of climate change; but sensitivity can be altered by socio-economic changes. Exposure/sensitivity of a country to climate variability and change is based on the degree of changes and its biophysical effects. Turkey's exposure/sensitivity sector index value was found 0.283 pointing low exposure/sensitivity to climate change impacts (Figure 2). Exposure, settlement-infrastructure, food, ecosystems, health, and water sensitivities were taken as the indicators of the sensitivity sector.

Results were analyzed to explore strengths or weaknesses of Turkey and its barriers or limits of exposure/sensitivity sector against climate change impacts. Table 4 presents the proxy values of exposure/sensitivity sector.

Exposure

Exposure indicator measures climate change impacts to a country or region. Turkey's exposure indicator index value was found 0.087 indicating very low exposure/sensitivity. Land area below 5 m elevation, population living in areas below 5 m elevation, temperature change, precipitation change and population affected by droughts, floods, and extreme temperatures proxies were used for assessing exposure of Turkey.

The most significant proxies of exposure indicator were precipitation change and temperature change for Turkey. Precipitation change measures the projected change in annual precipitation in the years 2045 to 2065, relative to the control period 1961 to 2000 (World Bank, 2013). The range reflects the results from nine general circulation models (GCMs), employing the A2 storyline and scenario family. Turkey's precipitation change proxy index was found 0.345 indicating low exposure/sensitivity. Temperature change proxy is the projected change in annual temperature in the years of 2045 to 2065, relative to the control period 1961 to 2000 (World Bank, 2013). The range reflects the results from nine general circulation models (GCMs) at a standardized 2-degree grid, employing the A2 storyline and scenario family. Turkey's temperature change proxy index value was found 0.043 indicating very low exposure/sensitivity. Even though Turkey's temperature change is very low, Turkey is getting warmer than the WMS (0.024). IPCC indicated that Turkey is one of the countries which will be moderately affected from temperature change (IPCC, 2007). Land area below 5 m elevation measures the percentage of a countries land area to its total land area. Turkey's land area below 5 m elevation proxy index value was found very low (0.010). Land area below 5 m

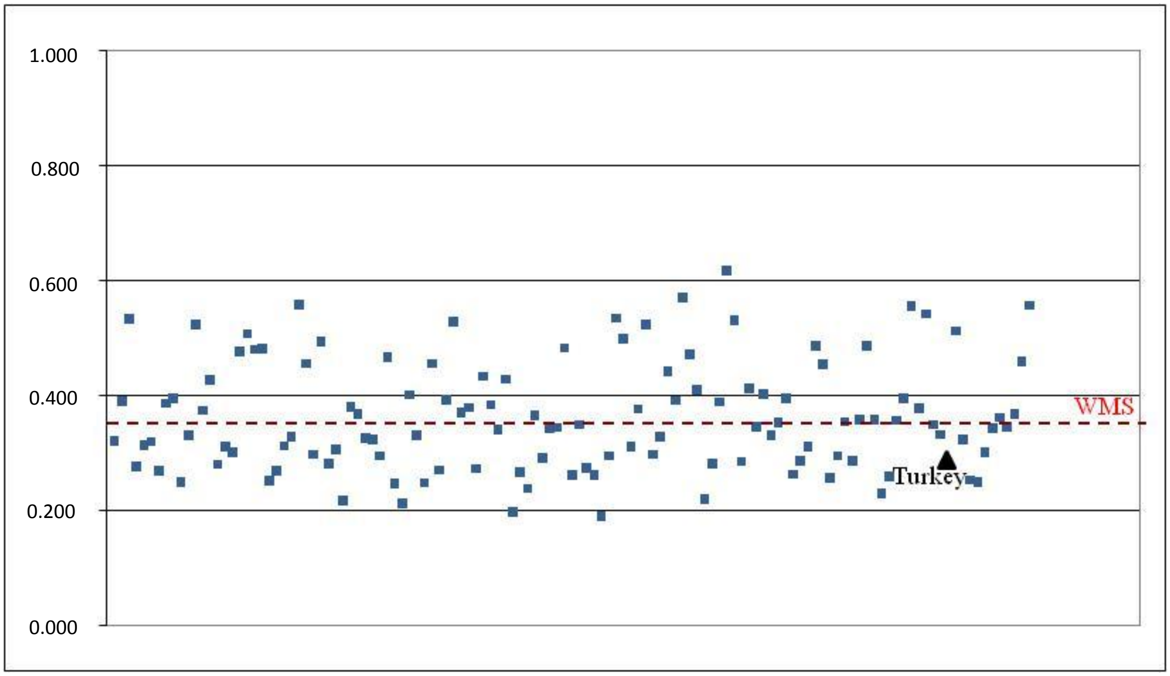

Figure 2. Exposure/sensitivity of Turkey.

Table 4. Exposure/sensitivity sector indicators and proxies of Turkey.

Indicator/proxy	Turkey's score	Rank	Category	WMS
Exposure	**0.087**	**58**	Very low	**0.075**
Land area below 5 m elevation	0.010	76	Very low	0.018
Population living in areas below 5m elevation	0.024	72	Very low	0.066
Population affected by droughts, floods, and extreme temperatures	0.015	76	Very low	0.127
Temperature change	0.043	36	Very low	0.024
Precipitation change	0.345	23	Low	0.139
Settlement/infrastructure sensitivity	**0.210**	**75**	**Low**	**0.319**
Urban population growth	0.505	47	Moderate	0.452
Access to sanitation facilities	0.110	71	Very low	0.297
Access to drinking water	0.014	100	Very low	0.207
Food sensitivity	**0.510**	**88**	**Moderate**	**0.598**
Cereal yield	0.713	61	High	0.660
Animal protein	0.307	100	Low	0.536
Ecosystem sensitivity	**0.329**	**74**	**Low**	**0.304**
Fertilizer use	0.390	74	Low	0.341
Endangered species	0.565	19	Moderate	0.314
Terrestrial protected areas	0.031	118	Very low	0.257
Human health sensitivity	**0.192**	**105**	**Very low**	**0.294**
Fertility rate	0.167	74	Very low	0.283
Life Expectancy	0.257	79	Low	0.373
Age 65+(%)	0.261	73	Low	0.304
Under-five mortality rate (per 1,000)	0.084	72	Very low	0.217
Water sensitivity	**0.369**	**102**	**Low**	**0.622**
Annual freshwater withdrawals per person	0.257	46	Low	0.267
Renewable internal freshwater resources per capita	0.484	58	Moderate	0.859
Average annual precipitation	0.365	97	Low	0.739

elevation proxy index value indicates that Turkey's land area below 5 m will be slightly affected from sea level rise because of its topography and location. Population living in areas below 5 m elevation proxy measures the percentage of the country's population to its total population. Turkey's population living in areas below 5 m elevation proxy index value was found very low (0.024). This proxy index indicates that sea level rise will slightly affect the people living in areas below 5 m in Turkey. It is also stated by other researchers that vulnerability related to sea level rise will be very low in Turkey (Simav and Seker, 2013; Karaca and Nicholls, 2008). Droughts, floods and extreme temperatures are the annual percentage of the population that is effected by natural disasters classified as either droughts, floods, or extreme temperature events. Population affected by droughts, floods and extreme temperatures proxy index value was found 0.015 indicating very low exposure/sensitivity. Turkish population will be slightly affected from droughts, floods and extreme temperatures.

Settlement-infrastructure sensitivity

Settlement-infrastructure sensitivity indicator measures climate change impacts on human settlements and infrastructure. Results showed that Turkey have low settlement-infrastructure sensitivity (0.210). Urban population growth, access to sanitation facilities, and access to drinking water in rural areas were used for assessing settlement sensitivity in Turkey.

Turkey's urban population growth proxy index value was found 0.505 indicating moderate exposure/sensitivity.

Access to improved sanitation facilities refers to the percentage of the population with at least adequate access to disposal facilities that can effectively prevent human, animal, insect contact and excreta. Turkey's access to improved sanitation facilities proxy index value was found 0.110 indicating very low exposure/sensitivity. The improved sanitation facilities proxy index value indicates that Turkey has almost sufficient infrastructure. Access to an improved water source in rural area refers to the percentage of the rural population with reasonable access to an adequate amount of water from an improved source, such as a household connection, a public standpipe, a borehole, a protected well or spring, or rainwater collection. Turkey's access to improved water source in rural area proxy index value was found 0,014 indicating very low exposure/sensitivity.

Food sensitivity

Food sensitivity indicator explains future food disruptions or shortages. Turkey's food sensitivity indicator value was found 0.510 pointing moderate exposure/sensitivity. Cereal yields and protein consumption per capita proxies were used to measure food sensitivity in Turkey. It has been stated that corn and wheat are the most vulnerable crops to the climate change (Kanber et al., 2007; Atik et al., 2007). Cereal yields measured as kilograms per hectare of harvested land include wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains. Turkey's cereal yield proxy index value was found 0.713. This result indicates that Turkey's cereal yield production is highly sensitive in the adaptation to the climate change. Protein consumption per capita refers to the supply side. Turkey's animal protein proxy index value was found 0.307 indicating low exposure/sensitivity.

Ecosystem sensitivity

Ecosystem sensitivity indicator explains alterations in pollution, land cover changes and biodiversity. Ecosystem sensitivity indicator index value was found 0.329 pointing low exposure/sensitivity. This result indicates that Turkey's ecosystem will be fairly affected from climate change. Fertilizer use, endangered species and terrestrial protected areas proxies were used to measure ecosystem sensitivity in Turkey.

Industrial agricultural activity has a direct and profound impact on the environment. Turkey's fertilizer use proxy index value was found 0.389 indicating low exposure/sensitivity. The endangered species proxy includes the percentage of critically endangered, endangered or vulnerable animal species classified by the International Union for Conservation of Nature (IUCN). Parmesan (2006) stated that climate change effects the survival of animal species. Endangered species proxy index value was found 0.565 indicating moderate exposure/sensitivity. This result points that Turkey's biologic diversity is under threat. Terrestrial protected areas proxy is the percentage of protected areas to country's total land area. Terrestrial protected areas are totally or partially protected areas of at least 1,000 hectares that are designated according to IUCN's classification and serves as scientific reserves with limited public access. Terrestrial protected areas proxy index value was found 0.031 indicating very low exposure/sensitivity. It has been suggested that climate change will slightly affect terrestrial biodiversity.

Health sensitivity

Health sensitivity includes the direct or indirect effects of climate change. Direct effects refer to deaths caused by excessive heat. Climate change also has the potential to alter the patterns of vector-borne diseases. Health sensitivity indicator index value was found 0.192 pointing very low exposure/sensitivity. This result shows that health sensitivity will be slightly affected from climate change impacts. The fertility rate, life expectancy, age

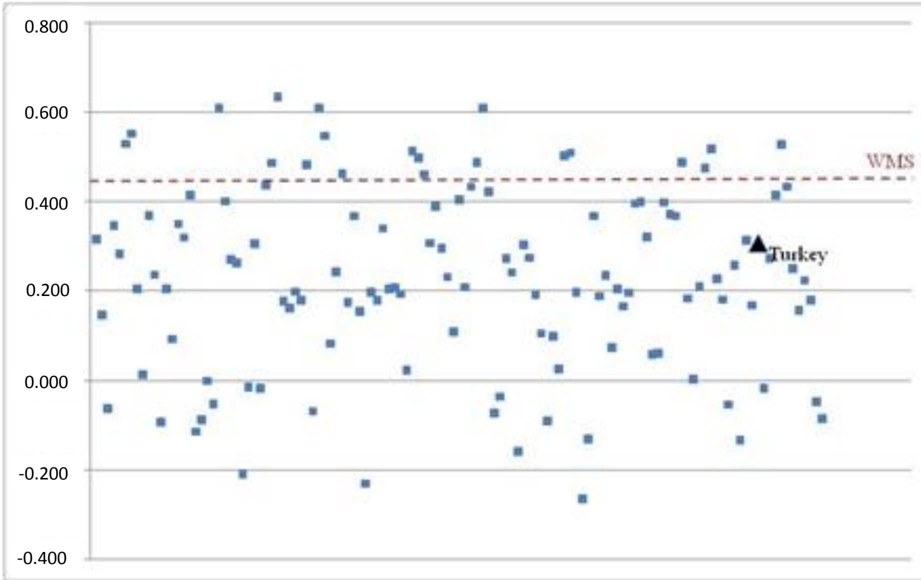

Figure 3. Vulnerability-resilience of Turkey.

65+, and under age five mortality were used as proxies for assessing health sensitivity in Turkey.

Turkey's fertility proxy index value was found 0.167 indicating very low exposure/sensitivity. Life expectancy at birth explains the number of years of a new-born infant would live. Life expectancy proxy index was low (0.257). Life expectancy proxy index value shows that life expectancy in Turkey will be slightly affected from climate change. Senior citizens and new-born infants are the fragile link in the chain of proper care needed group (Martens, 1998; Shea, 2007). Age 65+ proxy index value was found 0.261 indicating low exposure/sensitivity. Under age five mortality rate proxy index was very low (0.084). These results indicates that while senior citizens of Turkey will be moderately affected from climate change, new born infants will be slightly affected.

Water sensitivity

Water sensitivity is an important issue because it is estimated that approximately five billion people of the world will be experiencing water stress (Arnell, 1999). Water sensitivity indicator index value was found 0.369 pointing low exposure/sensitivity. The annual fresh water withdrawals, renewable internal fresh water resources, and average annual precipitation were used as proxies for assessing water sensitivity.

Annual fresh water withdrawals proxy index value was found 0.257 indicating low exposure/sensitivity. The annual fresh water rate indicates that Turkey will experience fresh water shortage. The renewable internal freshwater resources refer to national internal river flows and groundwater from rainfall per capita. Renewable internal fresh water resources proxy index value was found moderate (0.484). Internal fresh water rate indicates that Turkey's internal fresh water will be moderately affected from climate change impacts. Average annual precipitation is the sum of the rainfall and the assumed water equivalent of the snowfall for the year in the country, averaged over the years 1961 to 1990. Average annual precipitation proxy index value was found 0.365 indicating low exposure/sensitivity. National Climate Change Adaptation Action Plan also states that water shortages in Turkey will reach a critical point especially in agriculture and energy production (MEU, 2010b; Maden, 2008; Ozlu, 2007).

Vulnerability of Turkey

The Vulnerability-Resilience Index (VRI) is constructed through the calculation and aggregation of 29 proxies reflecting country-level vulnerability. These proxies are combined into ten indicator categories reflecting adaptive capacity or exposure/sensitivity sectors. Data from 124 countries were used for the vulnerability-resilience assessment. Results are presented in Figure 3.

It has been found that Turkey's vulnerability to climate change index value was 0.363 indicating low vulnerability. Data suggests that Turkey will be fairly affected from the impact of climate change. Turkey's vulnerability value is slightly above the WMS (0.431). Turkey ranks the 80th place of 124 countries for vulnerability (Figure 4). Even though Turkey's vulnerability value is far above those of the most vulnerable countries such as Niger (0.999), and Guinea (0.961); it is noticeably below those of the most resilience countries such as Denmark (0.000), and Finland (0.027).

Turkey's low vulnerability to climate change impacts

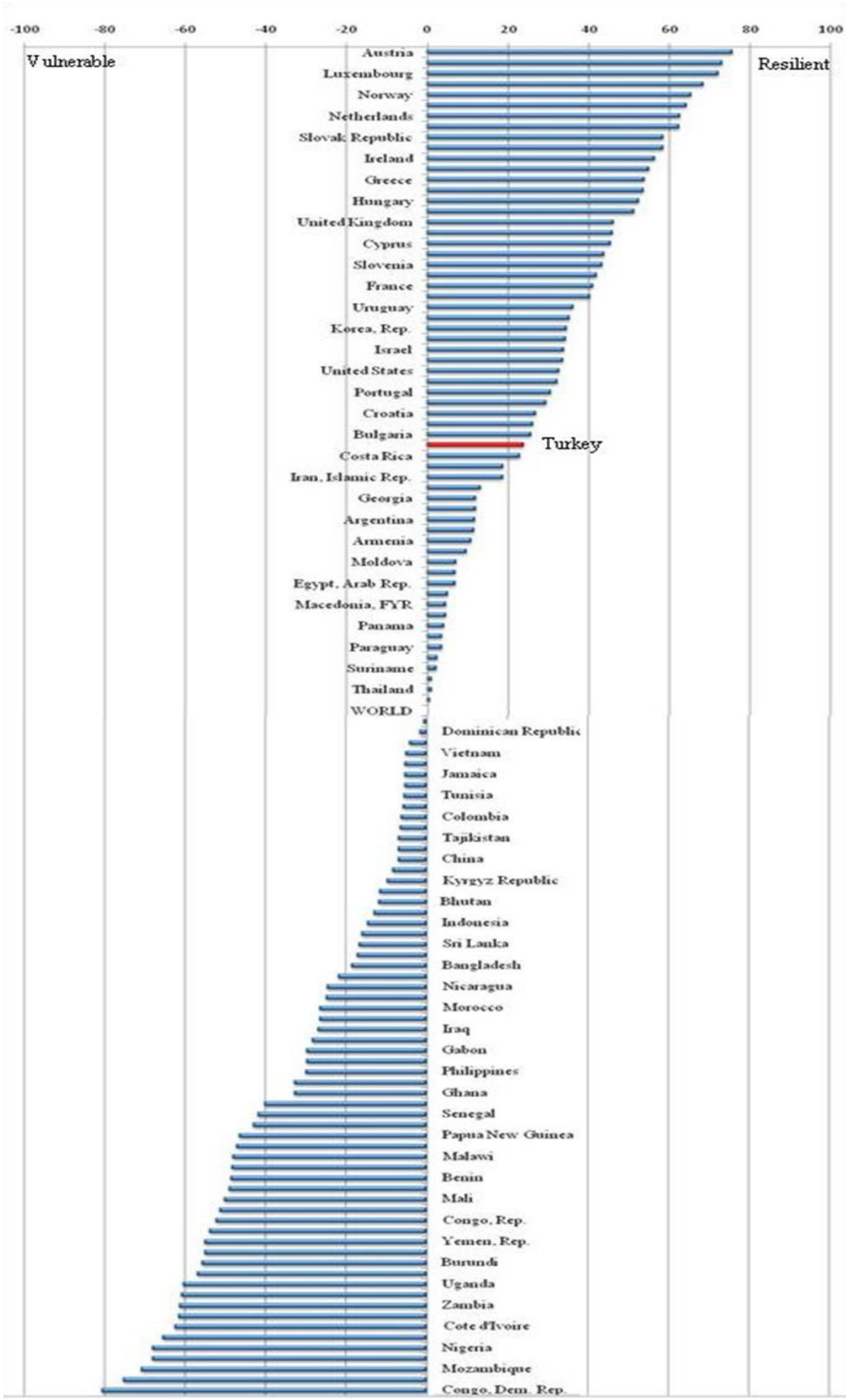

Figure 4. The climate change vulnerability of Turkey scaled for global values (0-axis represents world mean).

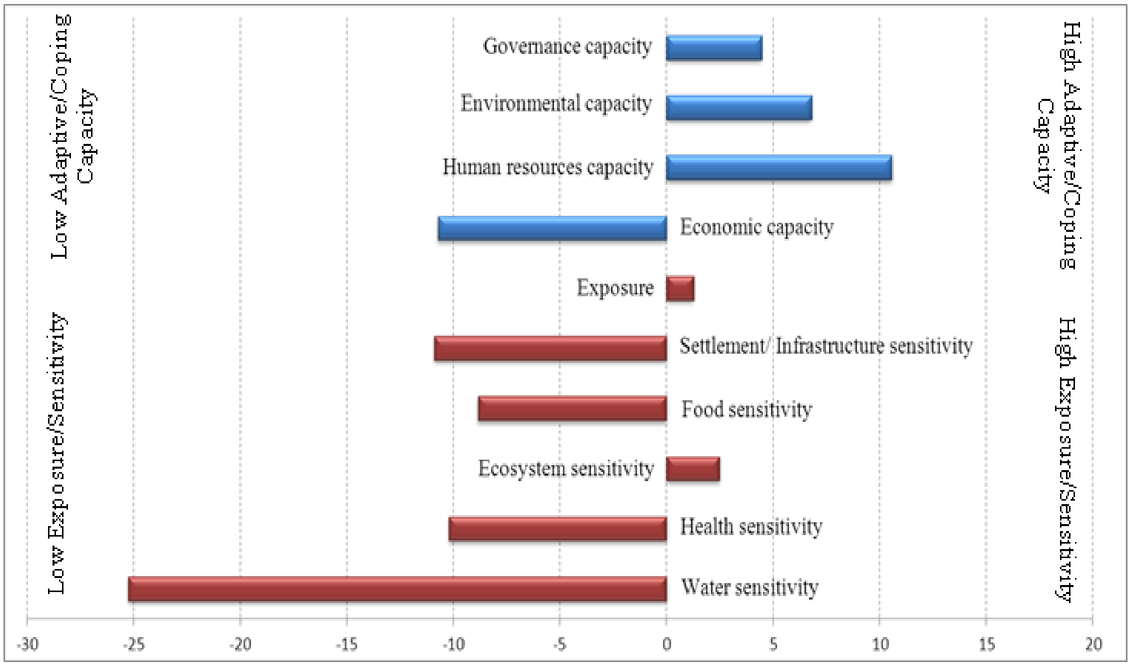

Figure 5. The adaptive/coping capacity indicators and exposure/sensitivity indicators for Turkey (0-axis represents world mean).

was also confirmed by other indexes. Environmental Performance Index (EPI) indicators are for environmental purposes, Vulnerability Resilience Indicator Model (VRIM) and Climate Vulnerability Monitor (CVM) indicators are for climate change vulnerability. It has been observed that the current study (VRI) is very consistent with these indexes in terms of Turkey's vulnerability.

Adaptive/coping capacity and exposure/sensitivity sectors were analyzed and related to WMS to understand Turkey's strengths and weaknesses in vulnerability. Results are presented in Figure 5.

Adaptive/coping capacity sector index value for Turkey was found 0.592 indicating moderate vulnerability. It shows that Turkey's adaptive/coping capacity is moderate against combating climate change impacts.

It is seen that Turkey's human resources capacity is relatively high. This indicates that Turkish individuals could respond to job shifting caused by climatic variability because of their education level and readiness for the labor force. Apparent indicator that makes large negative contributions to coping/adaptive capacity is economic capacity. 1005 U.S.D GDP per capita is low and this creates a disadvantage for the Turkish society causing limited access to resources that can be used to adapt to climatic variability and change.

Exposure/sensitivity indicator value for Turkey was found 0.087 indicating very low sensitivity. It means that Turkey's exposure/sensitivity is durable against climate change impacts. It was found that one of the indicators, the ecosystem sensitivity index value is 0.329 indicating low sensitivity. This indicates that there is a low pressure on ecosystems or natural resources of today. However, other countries' index values showed that Turkey's ecosystem sensitivity is relatively high comparing to them. It can be said that ecosystem sensitivity in Turkey's, is the weakest indicator compare to other countries (Figure 5). Apparent indicator that makes large positive contributions to exposure/sensitivity sector is water sensitivity. Water sensitivity indicator has been found 0.369 indicating low sensitivity. This result explains that Turkey will fairly be experienced water stress due to climate change.

CONCLUSION AND RECOMMENDATIONS

One nation's future vulnerability depends not only on climate change but also on development pathways (IPCC, 2001). In this context, assessing vulnerability in developing and least developed countries is an important component in formulating national and international adaptation strategies. It is also significant in increasing the sustainability of development. IPCC (2001) emphasizes that the adaptive capacity dealing with climate change risks is closely related to sustainable development and equity. Because enhanced adaptive capacity has a constructive effect on sustainable development. Turkey's adaptive capacity needs to be improved in order to ensure a sustainable development. Previous studies assessed Turkey's vulnerability with an impact assessment approach (UNFCCC, 2009; MEU, 2010b). It was underlined that the vulnerability of a nation to climate change impacts in next ten to twenty years will be dominated by socio-economic factors and legacy issues (Fay et al., 2010). While current research took climate change impacts in consideration, it has also assessed the quantitative measures of Turkey's coping/adaptive capacity, sensitivity, and vulnerability. It is clearly pictured that Turkey will be facing socio-economic, governance, and environmental challenges. Besides, the negative effects of climate change will include increased summer temperatures, decreased winter precipitation, loss of surface water, and increased frequency of droughts, land degradation, coastal erosion, and floods. Governance institutions should put internal and external sanctions into practice to lessen negative impacts of climate change in all sectors. Because each sector has an effect on the others, the overall vulnerability of development will be greater than expected.

There is still a need for a more comprehensive understanding of the role of institutions and culture in shaping adaptive capacity. While this research was based on quantitative data, the study of climate change could also include qualitative data to explain its impacts in all sectors.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Notes

Country List: Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bangladesh, Belarus, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Chile, China, Colombia, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Denmark, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Estonia, Ethiopia, Finland, France, Gambia, The Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guyana, Honduras, Hungary, India, Indonesia, Iran, Islamic Rep., Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea, Rep., Kyrgyz Republic, Latvia, Lithuania, Luxembourg, Macedonia, FYR, Madagascar, Malawi, Malaysia, Maldives, Mali, Mexico, Moldova, Mongolia, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Portugal, Romania, Russian Federation, Rwanda, Senegal, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Sudan, Suriname, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, United Kingdom, United States, Uruguay, Uzbekistan, Venezuela RB, Vietnam, Yemen Rep., Zambia.

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Paradigm shift to strengthen public health programming: A case for a unified public health leadership approach

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The continued challenges in public health programs and in particular the dearth of tested approaches that hinges on systems thinking approach, holistic planning and implementation with all relevant stakeholder calls for newer approaches in public health leadership. This work advances a unified leadership theory drawn from skills approach, high coaching and high directive behavior and system thinking approach. The unified leadership approach underscored key leadership themes: system thinking, vision, power sharing, process based and collateral leaderships. It is expected that such a multi-prong approach will strengthen holistic planning with input from all concerned partners, facilitate clarity of roles and balancing of power so that it will improve coordination, collaboration, commitment, program sustainability and oversight function that will result in effective public health interventions.

Key words: Leadership theories, leadership styles, program outcomes

INTRODUCTION

Public health challenges are complex with rapidly evolving topical issues at local, national and international levels driven by globalization, policy changes, economic crises, natural and man-made disasters such wars, terrorism including use of biological agents of diseases, deforestation, global warming and large scale destruction of flora and fauna through constructions (Nahavandi, 2012). The collaboration of all stakeholders at various levels will go a long way in addressing the root causes of disease and health related events and the provision of effective promotive, preventive, curative and rehabilitative health services which goes beyond the realms and capacity of any single organization (Koh and Jacobson, 2009).

This collaboration requires effective partnership and depending on the problem to be addressed; partners could be multilateral organizations such as United Nations agencies (WHO, UNICEF, UNFPA, UNDP, World Bank, etc.), to international donors, national and local community based support groups and organizations that could be public, private for profit and private not for profit. However, it is important to note that irrespective of the composition and competencies of partners, they collaborate with the understanding and belief that they have something to gain in the partnership which will support attaining their respective organizational objectives.

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This work is aimed at reviewing the current trend in collaborative leadership researches and applications in public health practices to underscore areas of weaknesses and how best to address the identified gaps in existing literature. The specific objectives are:

1) For players in public health programs to gain better understanding of how leadership styles affect the operations and outcomes of organization and programs.
2) Review and document how leaders maneuver and overcome the negative effect of their leadership styles on ownership, commitment and team spirit among various stakeholders in an organization and public health program in order to provide ways how to address program delivery issues.
3) Contribute to the design of potential policies and strategies to facilitate collaboration, commitment and proactive involvement and participation of community structures, private organizations and authorities vested with the responsibility of leading the public health programs at all levels.

METHODOLOGY

Literature search was conducted from several databases (MEDLINE, CINAHL Plus, ISI web of Science, Nursing and Allied Health source, Social Science Direct, SAGE), and the web sites of multi-lateral organizations of the United Nations Systems (WHO, UNICEF, UNFPA) using Google scholar, PUBMED and EBSCO search engines. MeSH words and phrases used included leadership styles, leadership behaviour, trait theory, skills approach, contingency theory, theories of behaviour, public health leadership, decision making in organizations, program ownership, and community engagement. Articles were screened to ensure it reflected or encompasses the key words of this article and 32 articles/reports have met the inclusion criteria based on concordance among the authors. Priority was given to articles and reports published from 2006 to 2013 and they constituted about two thirds of articles cited.

The contextual basis of various leadership theories

One of the unavoidable questions in public health services is how to ensure efficient and effective delivery of services which is usually influenced by the leadership behavior and style along the service delivery continuum. Leadership style was reported to be a determinant for the level of trust, staff and followers accord their leaders, their level of motivation, team dynamics, commitment and zeal to identify with the leaders vision and the mission required to achieve health program goals (Burke et al., 2006). The performance of leaders is often influenced by the policy environment, economic factors, organizational ethics and individual attitudes and competencies which are also individually linked to leadership style and thus making leadership approach the over bearing factor that defines the success of organizations and public health programs (Avolio et al., 2009).

The significance of leadership of Public health programs cannot be over stressed since it is an embodiment of the principles of primary health care and human rights in general such as equity, a just and egalitarian society in order for all to achieve a state of health that promotes attainment of individual and collective potentials (Koh and Jacobson, 2009; Koh, 2009). Thus leaders that are able to aggregate individual/community and program goals and provide regular and accurate performance feedback have invariably recorded improved team performance by over a third of what was previously known (Roebuck, 2011). This therefore calls for a deliberate systematic engagement of followers/community gate keepers by public leaders at all levels through multi-pronged styles that will foster support, and team spirit among all stakeholders in order to achieve the common program goals. The need for effective leadership among social, political and management scientists has remained a topical issue for several decades with primary focus being on what factors, attributes and behaviors that define leadership performance. The outcome of this drive has given birth to several leadership theories and approaches such as the trait theory, the skills approach, the contingency theory, the leadership behavioral and contemporary theories (Nahavandi, 2012).

It should be noted that, these theories and approaches are not sacrosanct; therefore more than one theory is usually displayed by leaders for effective management. This means leaders approach issues differently depending on the challenges they faced and other factors that influence the selection of their leadership style. Moreover, the attitude and behavior of leaders is determined by their value system and to some extent influenced by the values of their followers/staff (Bruno and Eduardo, 2006) and leadership performance is most effective if there is commonality in the value system of the leaders and follower (Khrishnan, 2005). The influence of self-awareness on the actions of leaders enables the leader to control his/her emotions in order to think and take actions based on facts rather than one driven by emotions, although sometimes the appropriate use of emotions could further make his followers to trust, believe in his mission and go all the way to achieve the leaders' vision (Ioannidou and Konstantikati, 2008). Above all, leadership approaches that are in tandem with systems thinking (Mumford et al., 2000), and engages all formal and informal stakeholders including staff and communities have been reported to create joint ownership and increase accountability (Alexander et al., 2001, 2003).

Problem statement and gaps in existing literature

The underlying root causes of topical public health challenges such as HIV/AIDs, Maternal and child mortality, drug abuse, violence and man-made disasters such as terrorism and global warming are closely related to individual/community attitude, behaviors and value system (Gamm, 1998; Mumford et al., 2000). The successive inability to address these root causes was rightly summed up by the World Health Organization (WHO) that it is due to "(the) toxic combination of bad policies, economics, and politics…that a majority of people in the world do not enjoy the good health and that primary health care, which integrates health in all of government's policies, is the best framework for doing so" (WHO, 2008, p. 3).

One of the principles of Primary Health Care is community participation which facilitates partnership, cooperation, and group approach for common holistic development of Public health interventions (WHO, 2009). Without mincing words, the "bad policies" referred to by the World Health Organization were developed based on findings of several researches that largely accorded minimal focus on collaborative leadership (Alexander et al., 2001). The performances of Public health programs are determined by factors within and outside the health sector and health system (WHO, 2009). This underscores the need for assessing the strengths, weaknesses, opportunities and threats for both the internal and external environment in order to identify all the relevant stakeholders particularly in the implementing communities, and brain storm to come up with a plan that is holistically in tandem with systems thinking approach (WHO, 2009). However, reports from several studies indicated that the abysmal performance of public health interventions is as a result of the lack of involvement of community gate keepers, and other relevant community based structures and organizations indicating lack of systems thinking approach (Gamm, 1998; Mumford et al., 2000). The lack of common plan could easily result in duplication of efforts and waste of scarce resources by various stakeholders.

When assigning responsibilities, it should be in line with the competences and capabilities of all stakeholders and agreed upon during pre-planning meetings and the development of plan of action. Failure for balancing and fair apportioning of authority among the stakeholder could easily result in demotivation among stakeholders which may lead to inter-agency/organizational conflicts, low commitment and ineffective program outcome (Alexander et al., 2001; Gamm, 1998).

All planning and implementation efforts need to be preceded by community diagnoses where members of community members are not just engaged in identifying their felt needs, but also be asked to prioritize them, and suggest how best to address them. This allows for a dialogue on technical options from public health experts and the community views in terms of the cultural beliefs, so that adequate understanding is reached with clear roles and responsibility for both sides. Failure to build partnership in this approach could lead to mistrust between the community and the technical coalition of stakeholders, labeling of the intervention as their program and not our program. Even where the intervention is successful, there will be challenges with sustainability after the funding agencies withdraw their funds for any reason (Alexander et al., 2003; Health Reform Foundation of Nigeria, 2007; Horowitz et al., 2009).

Furthermore, if the implementing communities have cultural values of consensus approach to decision making process on issues that relates to common good of the community, failure to take into consideration their views will be taken as a direct affront to their heritage and will further make them alienate the technical and donor groups which will invariably impact negatively on the participation of the members of the community (Israel et al., 1998; Murray, 2011). It is therefore important for the leaders of public health program to take adequate time to orientate all stakeholders on the aims and objectives of the program and what the expected role of each stakeholder is. Programs that failed to conduct systematic orientation of all concerned partners were reported to have suffered in house frictions, poor commitment to oversight functions and low accountability (Folta et al., 2012; Roussos and Fawcett, 2000; Mitchell and Shortell, 2000). This orientation effort must be backed by continued review and feedback to keep the tempo and dispel misconceptions and assumptions (Alexander et al., 2003).

Finally the core and central contributory factor to failure of some public health programs is the lack of collaborative and participatory leadership approach of public health authorities and implementing agencies as they failed to provide avenues for staff and followers (members of the community) to provide additional insights and make them feel that their suggestions and contributions will be factored into the plan of action (Alexander et al., 2001; Mumford et al., 2000). Ignoring of staff and community views will result in failure to identify and own the plan of action and non-participation.

Paradigm shift towards a unified public health leadership approach

Our unified public health leadership approach is developed based on the identified gaps in literature review which includes lack of system thinking for holistic approach to planning (Gamm, 1998; Mumford et al., 2000); lack of consideration for the views of followers and workers (Alexander et al., 2001; Mumford et al., 2000); poor sharing of power among stakeholders of a given population based intervention program (Alexander et al., 2001; Gamm, 1998); lack of proactive engagement of communities (Alexander et al., 2003); lack of orientation for all stakeholders for accountability (Folta et al., 2012; Roussos and Fawcett, 2000; Mitchell and Shortell, 2000); decisions not guided by background context (Israel et al., 1998) and leadership style not in consonance with customs of the community (Murray, 2011).

Our unified leadership approach is a cocktail of various leadership theories cashing on their strengths in order to reduce the weakness in various leadership approaches. Moreover, our unified leadership approach uses health system thinking as the foundation for all the approaches. The approach is based on our belief and understanding that attaining health and wellbeing is beyond the statutory function of the Ministry of Health and aligns with systems thinking method. This is because the determinants of health and wellbeing are influenced by the physical, social, chemical, cultural and economic factors in addition to the genotypic make of up of each person (WHO, 2008). It is therefore a biosocio-economic, political and cultural context of where an individual is born, develop, live, work, his/her health related behaviors (intimate sexual acts, diet, exercise, tobacco, alcohol and drugs) in conjunction with socio-economic standing and access to health capitals (WHO, 2008). These context requires leaders to understand that health programs are affected by both factors within and outside of the health system and are responsible for the continued reported health inequalities and disparities within and between a given place and time (Bezruchka, 2010; WHO, 2008). Therefore decision making process in the unified leadership approach calls for leaders to scan both the internal and external environment to outline the strengths, weakness, threats and opportunities in order to ensure a holistic assessment of operationalization of public health programming and the inclusion of all stakeholders (Mumford et al., 2000; WHO, 2009; Zaleznik, 2004). This allows one to understand the background context including the current attitude and behaviors so that a multi-prong leadership approach will ultimately provide a level playing field, understanding, collaboration and commitment of all stakeholders towards common program objectives and goals (Leischow and Milstein, 2006).

In order to ensure better trust, respect and collaboration with implementing communities unified leadership approach will promote the engagement and participation of community leaders and other gate keepers. In addition, the aim is also to canvass for understanding, diagnosis of the problem, jointly participate in the planning in order to see the problem as theirs and to ensure that the local cultural beliefs are taken into consideration (Alexander et al., 2001, 2003). Moreover, it also provides opportunity to canvass for local resources (volunteers, funds, office space) from the community.

Finally, the unified leadership approach utilizes the skills and competencies of each stakeholder in order to match competencies/skills with task that will be assigned to each of the stakeholders which is in tune with the skills approach in organizational leadership. The skill approach is underscored by the fact that leadership competency can be improved through training and retraining particularly in both technical and managerial areas (Nahavandi, 2012). The skills approach in the unified leadership approach is necessary because public health has its foundation in epidemiology and biostatistics, driven by data and its effectiveness is based on agreed process and monitoring indicators that are designed in line with the plan of action (Koh, 2009). The skills approach is therefore a necessary competence of public health experts in order to have a systematic approach to identifying problems (problem solving skills), analyze available strategies to address the problem (social judgmental skills), and how to lead and coordinate the human resources (social skills) mainly guided by high coaching and high directive leadership behavior which will improve skills and motivate staff and followers into leadership positions (Nahavandi, 2012).

How the unified leadership approach addressed the gaps in the literature review

The participation of all relevant stakeholders is necessary for the success of any community based interventions that is directed at reducing morbidity, mortality and disability (Nahavandi, 2012). In order to canvass for acceptance and participation of members for any given population level public health intervention, there is the need for a systematic and proactive engagement of all stakeholders at all levels.

Depending on the public health issues and the cultural beliefs regarding a particular health issue, there is the need to identify community gate keepers such as religious, traditional, opinion and political leaders including the leadership of community based organizations and other funding agencies that have interest on the issue being considered for intervention. These groups of community gate keepers are revered by people in their communities who look up to them for guidance. They also tend to have a good understanding of the local customs, norms and traditions and will provide better insights on the inner thinking of their community members to guide the selection of appropriate strategies for planned intervention.

Furthermore, sensitization and reorientation of community gate keepers like religious leaders will make them include topical public health issues in their weekly sermons to canvass for support and behavioral change of their followers. Overall, the inclusion of all stakeholders and partners in the decision making process and program planning, implementation and monitoring has potential for strengthening ownership, commitment, resource mobilization and oversight function towards the desired program goals (Center for Health Promotion, 2007).

The approach also provides opportunity to have frank discussions with members of the community and the technical team so that concerns are addressed, adequate information regarding the planned intervention is shared before the development of plan of action which will ultimately facilitate the success of the program as was reported in Canada (Macaulay et al., 1997) and India (National Informatics Centre, 2005).

The success of any public health program is greatly determined by both factors within and outside the Public Health Department and the Ministries of Health (WHO, 2009) and therefore indicating significant interconnectivity with not only the units in the Health Ministry but also with other sectors outside the realm of the Ministry of Health with several actors whose organizational objectives might not be exactly the same with that of the Public Health authority, thereby underscoring the need for collaboration, integration and holistic approach to planning and implementation of public health population based interventions (WHO, 2009).

Visual representation of the proposed unified public health leadership approach

The unified leadership approach not only promotes proactive engagement of all stakeholders but also takes into consideration both internal and external factors that could influence the operationalization of any public health intervention with a view to strengthening intersectoral collaboration, and stronger network of groups with common characteristics and interest in line with the Leadership Member Exchange and the Social network theory (Nahavandi, 2012; Sparrowe and Liden, 2005) (Figure 1). It also provides avenue for development of common plans with all stakeholders including community gate keepers, community based structures, NGOs, Public and private interest groups. It provides avenue for blending of technical information with cultural, political and economic context as well as the input from staff and subordinates of the leader with regular feedback and review meetings to bring all on the same page during the life time of the program.

EMPIRICAL EVALUATION OF THE UNIFIED PUBLIC HEALTH LEADERSHIP APPROACH

Qualitative and quantitative research methods will be used to evaluate the performance of leadership approach (Avolio, et al., 2009). Public health programs will be selected based on location and diversity of the staff and community members. Within each selected program and respective location, the followers and staff will be stratified and selected using multistage and proportionate to size sampling techniques. Where the number of the target population that have met the eligibility/inclusion criteria has exceeded the desired sample size based on the weighted population of a selected site in relation to the overall total target population of all selected sites, then participants will be selected using random sampling technique using list of all staff and line list of households and the table of random numbers (Frankfort-Nachmias and Nachmias, 2008). The data collection should explore for insights of the participants on the various aspects of the unified leadership approach and should focus on the key leadership themes: system thinking, vision, power sharing, process based and collateral leaderships as was similarly done to assess the performance of collaborative leadership in community based public health interventions (Alexander et al., 2001, 2003). The results should be reported in narrative form and simple descriptive statistics depending on the aim of each question (Frankfort-Nachmias and Nachmias, 2008).

The quantitative method in the form of quasi-experimental/interventional design is appropriate to assess the performance of interventions relating to leadership theories (Avolio et al., 2009). The choice of the design depends on local scenario, type of intervention, duration of intervention and objectives of the evaluation and may take the form of no control group design, post intervention only design, or nonequivalent control group design. In particular the pre-test post-test using non-equivalent control design has been used to build the skills of technical staff to improve the service delivery such as immunization staff performance in Turkey (Uskun et al., 2008), several African countries (Mutabaruka et al., 2010), and in Kansas State, USA (Paschal et al., 2008) and risk reduction among automobile workers in the United Arab Emirates (Ruslan et al., 2010) which further support the appropriateness of

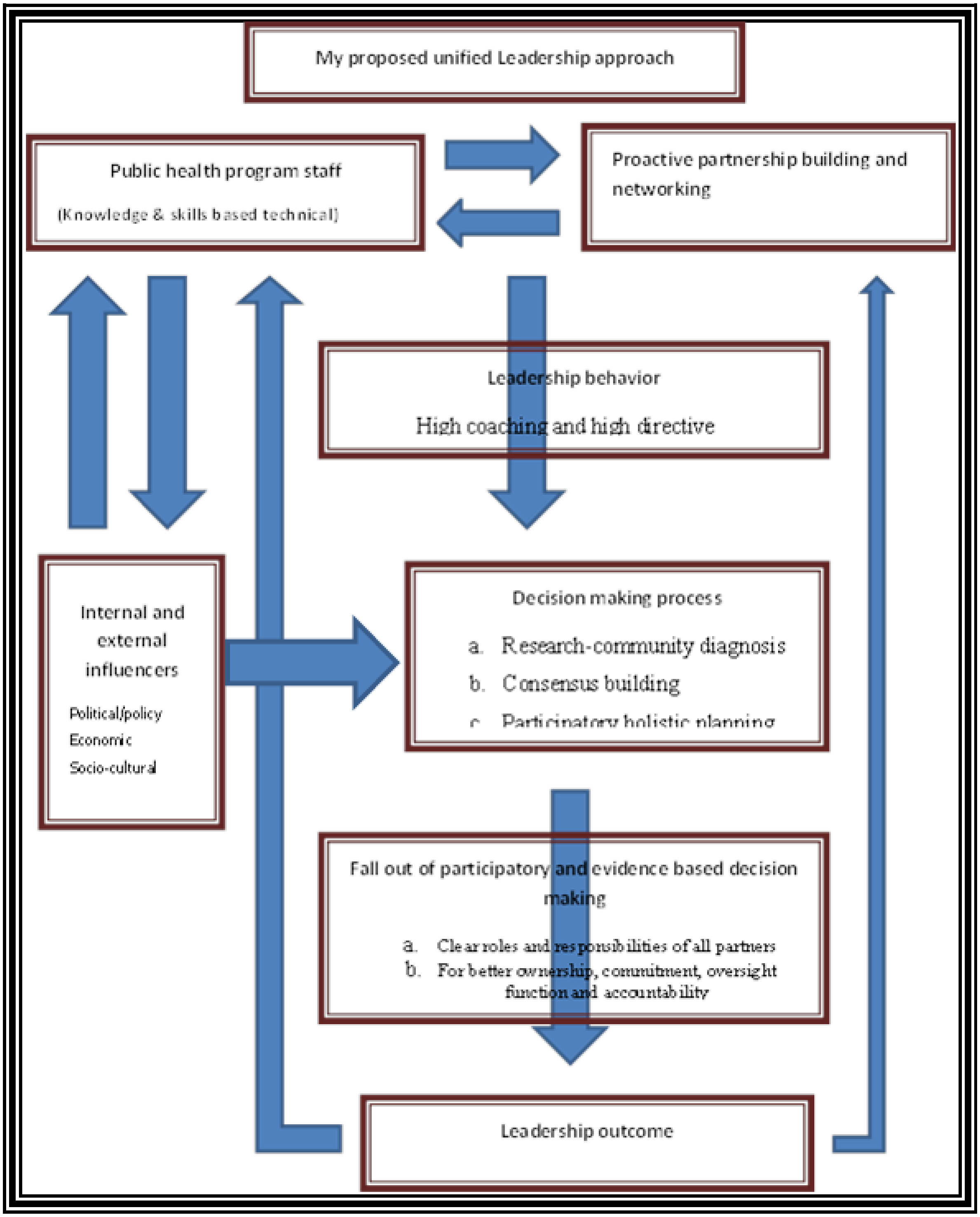

Figure 1. Visual representation of the proposed unified public health leadership approach.

our planned sampling method of evaluation. The intervention group will be exposed to the unified leadership approach while the control will only be exposed to the leadership theory after the evaluation of the theory in order to fulfill ethical requirements (Frankfort-Nachmias and Nachmias, 2008). The target

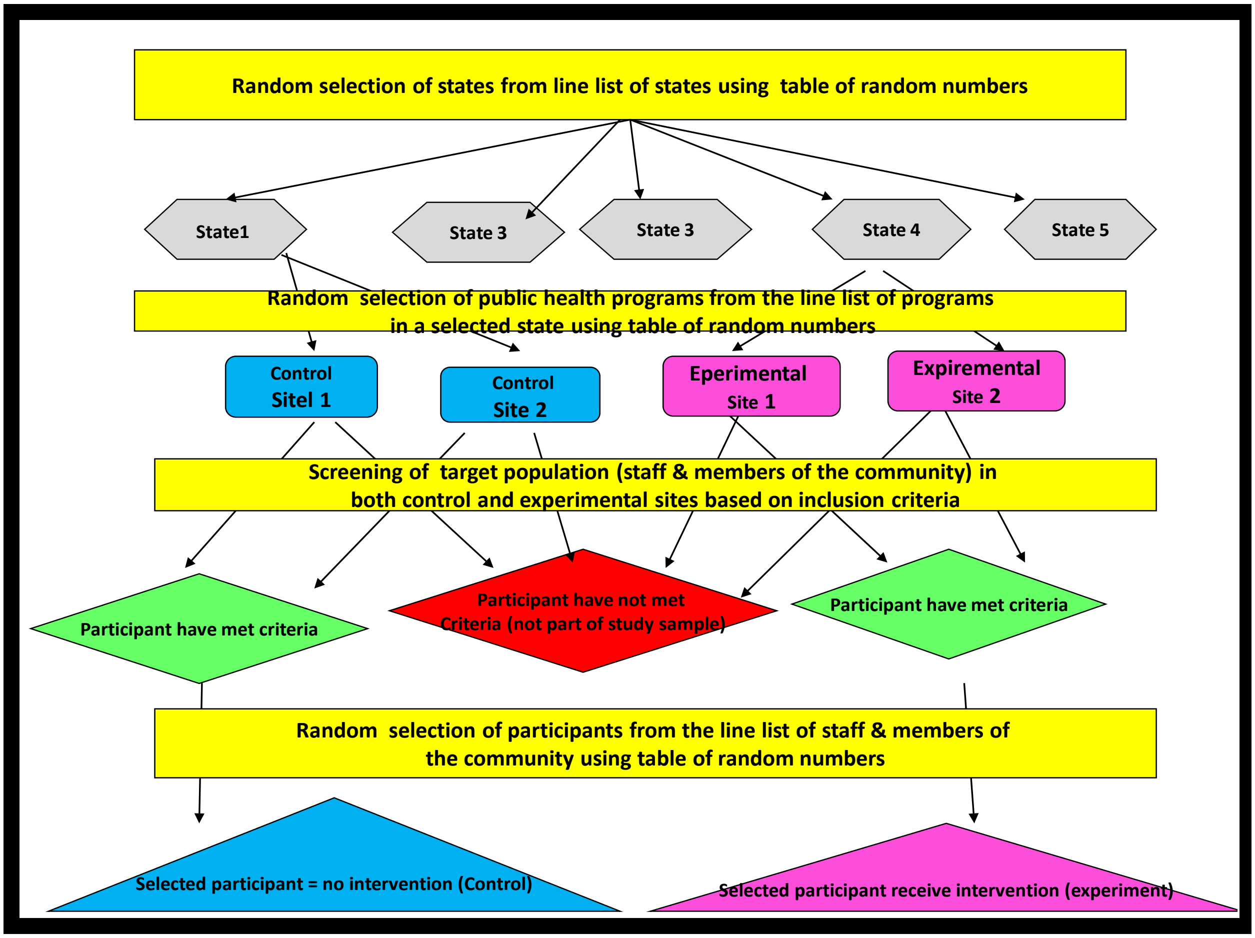

Figure 2. Sampling strategy.

population will include program staff and members of the community who will be selected using a multistage sampling technique.

Sampling strategy

Stage 1: Random selection of states from line list of states (provinces) using table of random numbers.

Stage 2: Random selection of public health programs from the line list of programs in a selected state using table of random numbers.

Stage 3: Screening of target population (staff and members of the community) in both control and experimental sites based on inclusion criteria.

Stage 4: Random selection of participants from the line list of staff and members of the community using table of random numbers (Figure 2).

The analysis will include bivariate (Avolio et al., 2009), Pearson product momentum correlation, and hierarchical multivariate logistic regression analysis (Hana et al., 2012).

Conclusion

Public health problems are complex and the performance of public health programs and leadership is usually influenced by both internal and external environment and hence requires the collaboration of several partners and in particular the implementing communities. Previous research efforts on collaborative leaders though have covered partnership but there is a dearth of literature on the best leadership approach that makes partnership effective (Koh and Jacobson, 2009). Furthermore, literature review done in this work indicated similar gaps which accounted for poor outcome of some partnership to enhance community health. Based on the identified gaps, a unified leadership approach that is based on systems thinking approach, skills approach, collaborative and participative decision making process driven by high coaching and high directive behavior is proposed. The evaluation of our unified public health leadership requires both qualitative and quantitative method. The data from the quantitative designs could be analyzed using correlational and multiple regression statistic methods. A qualitative study design is necessary to shed more light, on the views of program staff and community members with thematic areas for analysis to include system thinking, vision, power sharing, process based and collateral leaderships and will be reported using narrative method and descriptive statistics.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Scientific Research and Essays

Full Length Research Paper

Exploring anti-acetylcholinesterase, antioxidant and metal chelating activities of extracts of *Moringa oleifera* L. for possible prevention and cure of Alzheimer's disease

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The aim of this research is to explore the natural flora of Kashmir for novel plant products for their possible applications in the prevention and treatment of Alzheimer's disease (AD). In the current study, *Moringa oleifera* L. was selected for its possible memory-enhancing potential. Extracts of various parts of the plant were screened for anti-acetylcholinesterase, antioxidant and metal chelating activities. The data obtained clearly establish that impure fraction (MSC) obtained from methanolic shoot extract by silica-gel chromatography showed significant anti-AChE (IC_{50}; 77.58 µg/ml), antioxidant (IC_{50}; 1.26 µg/ml) and metal chelating potential (80%). Factions MSC1 (pure compound) and MSC2 obtained from MSC by thin layer chromatography (TLC) separation showed significant action against AChE activity with IC_{50} values of 64.53 and 120.38 µg/ml, respectively. Methanolic leave extract has also shown significant anti-AChE activity (IC_{50}; 77.32 µg/ml) with weaker antioxidant potential (IC_{50}; 127.27 µg/ml). We conclude that methanolic shoot extracts of the plant with high anti-acetylcholiesterase and antioxidant activities may have AD therapeutic potential.

Key words: *Moringa oleifera* L., Alzheimer's disease, anti-acetylcholinesterase, antioxidant activity.

INTRODUCTION

Alzheimer's disease (AD), the most common type of dementia, is a neurodegenerative disorder that affects memory, understanding, behavior and the ability to work. An estimated 35.6 million people are living with dementia worldwide and the number is expected to increase up to 66 million by 2030. Only in Asia, 14 million people had Alzheimer's or other forms of dementia in 2005 and this is expected to grow to 24 million by 2020 (Anders and Martin, 2010). Currently, there is no cure for AD except the use of acetylcholinesterase inhibitors, the only most effective therapy that has shown consistent positive results (Wolf-Klein et al., 2007). However, pathophysiology of AD is quit complex which involves several different biochemical pathways (Bolognesi et al.,

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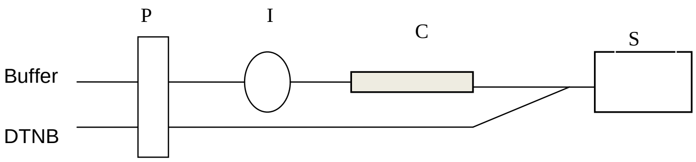

Figure 1. Flow Injection manifold used in this study. P = peristaltic pump, I = injection valve, C = enzyme column, S = spectrophotometer.

2009; Murali, 2002). There is increasing evidence that free radical-induced oxidative damage plays a vital role in the pathogenesis of AD (Foy et al., 1999).The multifactorial nature of AD suggests that a multi-targeted therapeutic approach might be more advantageous than single target drugs (Bolognesi et al., 2009). Natural products with antioxidant properties in addition to actylcholinesterase inhibitory activity could be regarded as highly desirable (Mathew and Subramanian, 2014). Effective AD therapeutic potential of currently approved drug galanthamine, a plant derived alkaloid, may also be attributed to its added antioxidant potential (Nordberg and Svensson, 1998). Until recently, natural plant products have gained much attention as AChE inhibitors and there is still a need for exploring nature for newer potent and long lasting AChE inhibitors with minimal side effects. A large number of plant species from different parts of the world have been screened for cholinesterase inhibitory activity (Mangialasche et al., 2010; Murray et al., 2013; Mehta et al., 2012).

In this study, we have selected *Moringa oleifera* L., a small medium-sized evergreen or deciduous tree, native to Northern India, Pakistan and Nepal (Gupta et al., 1989). Various parts of the plant are used for the treatment of nervous system disorders (Fahey; 2005). In this study, we have screened the crude extracts of various parts of the plant (leaves, shoot and stem-bark) for anti-AChE, antioxidant, and metal chelating activities for their possible role in memory-enhancing therapy.

EXPERIMENTAL

Chemicals

Acetylcholinesterase (E.C. 1.1.3.7) from electric eel, controlled porosity glass (CPG-24, 80-120 mesh, mean pore diameter of 22.6 nm), 2,2dithiobis (2-nitrobenzoic acid) (DTNB) and acetylthiocholine iodide were purchased from sigma-Aldrich. Potassium persulphate, 2,2-Azinobis (3-ethylbenzothiazoline-6-sulfonic acid) and ferrozine (sodium3-(pyridin-2-yl)-1,2,4-triazine-5,6-diyl]bis(benzene-4,4'-sulphonate) were purchased from Merk, ferrous sulphate; and other reagents were of analytical grade. Distilled deionised water was used throughout the study.

Extraction and purification

Fresh shoots, leave and bark of *M. oleifera* L. were collected and dried in gloom for several weeks. The dried material was crushed separately into powder form. 200 g dried powdered material of each part was soaked separately and progressively in organic solvents with increasing order of polarity (n-Haxan, ethylacetate, chloroform, acetone, ethanol and methanol) for 8 to 10 days along with successive extraction. Each extract was evaporated in a rotary evaporator and concentrates were collected and stored for further processing. In order to fractionate the crude extract and to purify different components, various chromatographic techniques were employed. Column chromatography was carried out using silica-gel G-F254 type 60 of E. Merck (Art. 7734, 70-230 mesh) as stationary phase and organic solvents were used as mobile phase. Preparative thin-layer chromatography was performed on silica-gel preparative plates (20" multiply 20", 0.5 mm thickness, Merck PF154, type 60).

Determination of anti-acetylcholinesterase activity

A simple flow injection technique with immobilized enzyme column was adopted for the study. The peristaltic pump for carrier stream propulsion was an Ismatech-Reglo, and Rheodyne RH 5020 (Anachem) injection valve was used for injection of standard and sample (extract). The manifold tubing was 0.5 mm i.d. PTFE. The volume of the sample and substrate mixture injection loop was 100 µl. Flow injection manifold used for the study is shown in Figure 1. Immobilized enzyme was packed in a mini column and its activity was measured by injecting standard substrate solutions into a carrier stream of the phosphate buffer (0.1 M, pH 8.5) after passing through the column. The reaction product was mixed with the chromogen (DTNB) in a second stream and absorbance (As) was measured at 405 nm in a flow cell (30 µl volume, 10 mm path length) using Shimdzu 1700 spectrophotometer. For inhibition study, each extract was mixed with standard solution of substrate and the mixture (sample+standard) was injected into a stream of the phosphate buffer (0.1 M, pH 8.5) passed through the immobilized enzyme column; then decrease in absorbance (Ai) was recorded. The activity of immobilized enzyme was studied both in the presence and absence of the inhibitor. Percent inhibition by the extracts was calculated by the formula; % inhibition= As–Ai/As*100. IC_{50} values were determined by log probit analysis.

Antioxidant activity

ABTS radical cation decolorization assay

ABTS radical cation decolorization assay was explored for the study. 2,2-Azinobis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) in water (3 mM final concentration) was oxidized using potassium persulfate (2.5 mM) for at least 12 h in the dark. The $ABTS^{\cdot+}$ solution was diluted with deionized water to an absorbance of 1.89 ± 0.3. Absorbance of $ABTS^{\cdot+}$(Ao) as a standard with 2 ml of deionized water was measured at 405 nm. For percent scavenging activity, extracts at final concentration of 10 to 200 µg/ml were mixed with 1 ml $ABTS^{\cdot+}$ and incubated at room temperature for 10 min. The reaction mixture was diluted to 3 ml by adding distilled deionized water. Absorbance (Ai) of the reaction mixture was recorded. Percent scavenging potential (PS) of the extracts was calculated by the equation; PS = (Ao – Ai)/Ao*100 and IC_{50} values were calculated as described above.

Metal chelation activity

Ferrizine assay was adopted for metal chelation activity study. 50 µg/ml of sample was added to a solution of ferrous sulphate (2 mM, 500 µl). The reaction was initiated by the addition of ferrozine (0.25 mM, 500 µl). The mixture was vigorously shaken and left standing for 10 min at room temperature. In controls, 200 µl of deionized water was used to quantify the reaction mixture. Ferrozine reacts

Table 1. Anti-AChE activity of various extracts of stem-bark, shoot and leaf of *M. oleifera* L.

S/No.	Fractions	Conc. tested (µg/ml)	M.I ± S.E.M[a]	(IC_{50} µg/ml)[b]
1	EAB	140 280 500	23.7±1.53 42.40±1.65 61.43±2.10	349.96.(290.34-452.32)
2	MB	140 280 500	20.10±1.32 32.53±1.48 55.90±2.16	441.11(357.53-629.19)
3	EB	27 266 366	14.20±1.90 38.50±1.1 52.80±2.40	401.39(267.69-765.34)
4	ML	17 86.66 150	17.23±1.30 50.36±0.81 68.06.±0.77	77.34(60.91-100.32)
5	EL	38 96 166	12.43±1.24 31.8±1.17 58.8±0.52	140.82(117.99-180.79)
6	EAS	43 172 354	16.0±0.70 40.3±1.17 57.2±1.57	254.04(192.85-376.98)
7	MS	16 33 167	14.4±1.41 20.46±1.95 58.20±2.56	120.59(88.10-190.22)
8	ES	28 140 180	12.40±2.00 50.50±1.6 65.70±1.55	121.70(100.42-150.55)
9	MSC	33 66 166	32.60±1.63 40.56±0.80 70.46±0.90	77.58(61.02-101.19)
10	MSC1	33 66 100	40.53±0.856 45.76±1.50 60.23±2.05	64.53(41.91-117.10)
11	MSC2	33 66 132	15.63±1.59 26.50±2.00 55.23±1.55	120.38(97.76-168.13)

M.I., mean %inhibition, [a]Each value represents the mean ±S.E.M. (n=3), [b]IC_{50} values determine by log probit analysis. 95% confidence intervals given in parentheses.

with the divalent iron to form stable magenta coloured complex which absorbs at 517 nm. Absorbance of the reaction mixture in the presence (Ai) and absence of the extracts (Ao) was recorded. Absorbance of all extracts was also recorded and omitted from the Ai where needed. The percentage chelating activity of the extracts was calculated by the formula,

(%) Chelation=(Ao – Ai)/Ao*100.

RESULTS AND DISCUSSION

Our results demonstrate that ethyl acetate (EAB), methanolic (MB) and ethanolic (EB) extracts of bark and ethyl acetate extract of shoot (EAS) have weaker action against AChE activity with IC_{50} values of 349.96. 441.11 and 401.39 µg/ml, respectively. Furthermore, methanolic (MS), ethanolic shoot (ES), and ethanolic leave (EL) extracts showed moderate action (IC_{50}120.59, 121.70 and 140.82 µg/ml) while methanolic (ML) extract showed stronger action (IC_{50} 77.34 µg/ml) (Tables 1 and 2).

Appearance of fine needle like crystals in MS and significant anti-AChE activity led to the isolation and further study of these crystals. The extract was subjected to silica-gel chromatography and three main fractions, MSA (1% n-haxane/Acetone), MSB (2%Methanol/Chloroform) and MSC (5% Methanol/Chloroforms) were collected. All impure fractions were studied for their anti-AChE activity and only MSC (IC_{50} 77.58 µg/ml) was found active.

Table 2. Antioxidant and metal chelating activity of various extracts of stem-bark, shoot and leave of *M. oleifera* L.

S/No.	Fractions	Conc. tested (µg/ml)	M.I ± S.E.M[a]	(IC_{50} µg/ml)[b]	% inhibition 50 µg/ml
1	EAB	33 66 166	27.84±0.65 40.34±0.55 51.03±1.6	146.13(95.98-446.48)	54.4
2	MB	3 33 66	23.30±.0.56 50.56±1.2 68.32±3.4	23.43(15.54-36.32)	38.6
3	EB	3 33 66	15.34±0.66 50.24±1.3 65.41±3.4	27.61(19.96-39.28)	68.6
4	ML	33 66 166	13.19±0.43 25.21±0.8 60.56±2.5	127.27(104.97-166.36)	NA
5	EL	33 66 166	15.56±0.45 29.85±0.98 65.17±2.6	110.50(92.26-139.85)	NA
6	EAS	33 166 200	13.9±0.15 40.23±0.45 50.32±0.99	201.33(175.72-242.63)	32.4
7	MS	3 33 66	28.12.±1.2 53.54±2.3 65.64±3.5	20.64(12.47-34.65)	NA
8	ES	3 33 66	29.35±0.89 60.56±1.6 75.12±2.6	13.22((8.33-19.60)	NA
9	MSC	3 33 66	61.99±1.6 85.21±2.6 92.34±1.8	1.26(0.29-2.69)	80.0

M.I., mean %inhibition, [a]Each value represents the mean ±S.E.M. (n=3), [b]IC_{50}values determine by log probit analysis. 95% confidence interval given in parentheses.

Active fraction, MSC, was further subjected to thin layer chromatography (TLC) based separation for purification. Two fractions, MSC1 and MSC2 (8:2 n-Hexane/Acetones) were collected. Fraction MSC1 was identified as a pure compound. Fraction MSC2 showed moderate while MSC1 showed stronger action against AChE activity with IC_{50} values of 120.38 and 64.53 µg/ml, respectively (Table 1).

Results of the study further revealed that both shoot and bark extracts possess stronger $ABTS^{\cdot+}$ scavenging potential with IC_{50} values of 23.43, 27.61, 20.64, 13.22 and 1.26 µg/ml for MB, EB, MS, ES and MSC, respectively. ML and EL extracts showed reasonable activity, whereas EAS and EAB showed comparatively weaker action. Results are presented in Table 2. The percentage metal chelating potential for 50 µg/ ml of extract in a reaction mixture was determined for all of the above mentioned extracts. In the study, leaf and shoot extracts (ML, EL, MS and ES) were found inactive. Only ethanolic and ethyl acetate extracts of bark exhibited good activity (68 and 54%, respectively). MB and EAS showed weaker potential (38 and 32%). However, MSC showed excellent metal chelating potential (80%) (Table 2).

Conclusion

We conclude that methanolic shoot extracts of the plant with high anti-acetylcholiesterase and antioxidant activities may have an AD therapeutic potential. Further evaluation is required to identify the active ingredients, access their bio-safety in *in vivo* animal models.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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