Research Article

Development and transfer of dual technology of bio-geyser and agro-waste composting

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Abstract

Agro-wastes can be converted into compost (slow release organic fertilizer) for the improvement of soil fertility. Heat generated naturally during decomposition of agro-wastes that usually remains unnoticed and untapped was effectively used for a beneficial purpose of warming water. By tapping the heat from composting materials, a bio-geyser was developed. The bio-geyser technology was improved by identifying appropriate combination and volumes of composting materials. During 2016-2017, the dual technology of bio-geyser and agro-waste composting was demonstrated at community level in Khyber Pakhtunkhwa (KP), Pakistan using participatory approach. Training events were organized to train the local fabricators and end-users in the use and maintenance of dual technology. The dual technology received overwhelming response from the end-users on account of its simplicity, novelty, cost effectiveness and utility particularly during winter months. End users suggested to provide solar panels in conjunction with bio-geyser units to improve efficiency of technology as shortage of grasses, fodder, etc. during peak winter months appeared to be a limitation towards fast absorption of technology at community level.

Keywords: Agro-wastes; Bio-geyser; Climate change; Compost; Energy crisis

Introduction

Pakistan is facing severe energy crisis that is hampering its economic growth while simultaneously affecting quality of life of masses particularly in rural communities. Due to non-availability of gas in rural and hilly areas of Khyber Pakhtunkhwa province, people are forced to cut forests for arranging fuel wood for cooking and heating water for domestic usage. Supply of electricity is limited due to prevailing national energy crisis. Current situation emphasizes to find alternative energy and heat resources to ensure that quality of life of rural people is not compromised. Locally used biogas plants use animal manure but their use is constrained by non-availability

of large quantities of manure with small farmers and unpleasant odor of manure. Alternative options especially to wood are required for warming water to reduce deforestation as forests contribute to conservation of environment and combat climate change [1, 2].

The rural areas in KP have higher amount of vegetation due to higher amount of rainfall [3, 4]. In autumn, a large amount of litter remains available in rural areas and management of these agro-wastes should be carried out to ensure clean environment. These agro-wastes can be effectively managed to develop compost and the heat generated naturally during decomposition of residues can be sustainably utilized for

heating water. This process converts the problem (waste disposal) into a valuable asset (compost). Composting of agricultural wastes generates a considerable amount of heat, by which temperatures of composting material and water may reach up to 70 °C and 45 °C, respectively within 3-4 days [5]. This unnoticed heat has never been used for any beneficial purpose in Pakistan. This heat can be used for heating water in winter and a farm geyser can be prepared for poor farmers with minimal initial investment and no running expenditure. Additionally, by using this technology, farmers will simultaneously get slow release, nutrient rich organic fertilizer (compost) for enhancing fertility of their soils. The compost provides slow release, environment friendly and odorless fertilizer with reasonable amounts of nitrogen (2%), phosphorus (0.5%), potassium (3%) and micro-nutrients. Its use will help in sustainable build-up of soil fertility and hence increase in crop yield [6].

Enormous potential exists in collecting and using the compost heat as a renewable source of energy. It is possible to increase temperature of water up to 60 °C by passing it through multiple tunnels in series. The heat generated by compost can be used to meet hot water requirements of small farm houses as was reported by [7] during a study conducted in United Kingdom. The heat generated may also be used to provide hot drinking water to livestock in cold areas as reported by [8] who found that closed vertical composting facility has the ability to adequately supply warm drinking water for cows. The research on efficacy of generation, extraction and utilization of compost heat as a source of clean heat/energy was also carried out by [9, 10]. Situation demands to develop and popularize eco-friendly technologies at community level. This paper covers the developmental history of bio-geyser technology, research on various aspects of dual technology, fabrication and use of bio-

geyser and transfer of technology to the end users.

Materials and Methods

Developmental history of technology

Bio-geyser is a by-product of agro-waste composting project at Soil and Environmental Sciences Division of Nuclear Institute for Food and Agriculture (NIFA), Peshawar, Pakistan. During winter season of 2007, while using locally available agro-wastes, litter, lawn clippings, etc. at composting site to develop organic fertilizer, it was found that temperature of composting materials reached up to 65°C within 72 hours following the placement of residues inside the composting pit. The heat produced was used on experimental basis for warming water at institute's mosque. For this purpose, a 3- bin above the ground composting facility was fabricated from cemented blocks. An iron made drum (200L) was placed in the center of each bin to retain water. Three drums were connected to each other and sanitary fittings were adjusted for both water inlet and outlet.

The composting bins were filled with green material (lawn clippings, berseem and lucerne) and the brown material (maize shells, chopped maize stalks and dry autumn leaves) in alternate layers. Composting materials were chopped with a fodder chopping machine, mixed and moistened up to 40% moisture content prior to their use for filling the bins. The bins were covered with thick plastic sheet to reduce escape of compost heat. After 72 hours, it was found that temperature of composting materials and water was 65°C and 50°C, respectively. Heating was maintained by periodic turning and addition of new material and water throughout the winter months (January –April, 2008).

Research on various aspects of dual technology

Following successful use of compost heat for warming water, several planned studies were conducted (2008-2010) with the objective to improve efficiency of bio-

geyser technology. For this purpose, a single bin above ground bio-geyser of 1m³ was fabricated using bricks. Studies on heating potential of composting materials, volume of composting materials around the drum and material for fabrication of drum for retaining water were conducted.

Maximum temperature (65 °C) was recorded when chopped maize stalks were mixed with green Sesbania plants in 3:1 ratio on dry weight basis followed by maize stalks mixed with green Lucerne (60 °C). This temperature lasted for seven days and turning and addition of fresh composting materials again heated it to the same level for next seven days.

A series of studies revealed that the thickness of the composting material should be at least 12-14 inches around the drum of 1 feet diameter. If the width of the composting materials around the drum is less than 12 inches, the water heating efficiency will be gradually decreased. Aluminum made drum was found the best one in terms of fabrication materials for drums to retain water inside the bio-geyser

as it quickly absorbed heat to warm the water as compared to iron, plastic and stainless steel drum. Based on these findings, laboratory scale, domestic and farm scale bio-geysers were fabricated and successfully demonstrated at institute. During 2010-2017, dual technology of bio-geyser and agro-waste composting was successfully demonstrated at several scientific and public forums besides annual farmer days of the institute.

Results and Discussion

Fabrication and use of bio-geyser

Fabrication work involved fixation of stainless steel drum for retention of water, connection of drum to water inlet and outlet, fabrication of wall on all four sides of the drum for retention of agro-wastes, plastering of walls, and provision of perforated plastic pipes and digital temperature gauges. Walls around the drum were constructed at distance of 1-1.5 feet and up to 6 inches above the height of drum. Sketch of small bio-geyser is shown in (Fig. 1).

Figure 1. Sketch of small bio-geyser unit

For large bio-geysers, three drums were used in each unit. All the three drums were interconnected by ½ inch G.I. pipe. The first drum was connected to water supply line with a ball cock fitted at the inlet of the drum to control the water inner flow from tank to the drum. An outlet water tap was fitted to the last drum for discharge of hot water from the bio-geyser unit.

For the purpose of demonstration at community level, drum of bio-geyser was filled with fresh water and water outlet was temporarily sealed to avoid escape of compost heat or warm water during initial phases of composting. The available green and dry agro-wastes/residues were chopped manually or by fodder chopping machine (depending upon availability). Three parts of dry agro-wastes (source of carbon) were thoroughly mixed with one part of green agro-wastes (source of nitrogen). Moisture level of mixture of agro-wastes was maintained at around 40%. Farmers were guided to ensure proper moisture level by making sure that agro-wastes in mixture are neither dry nor free water drains out of hand if mixture is pressed (sponge test). Mixture of agro-wastes was filled around the drum up to the head of drum. Top of unit was covered with a plastic sheet to protect the composting materials from rain as well as to avoid loss of compost heat. Perforated plastic pipes (3 feet long) were fitted around all four sides of drum to ensure adequate aeration to composting materials. End-users were informed about taking all necessary measures to avoid loss of compost heat from the unit during initial phases of decomposition and monitoring temperature of composting materials by using the thermometer provided with the unit. Once the temperature of composting material reaches 65°C, farmers may collect hot water for use. In order to ensure continuous supply of hot water over the next 10-15 days, it is important to regularly add fresh mixture of agro-wastes around the drum till the top of structure at an interval of four days as usually up to one (1) feet space is created due to loss of moisture

from the mixture of agro-wastes during decomposition process. Upon the termination of heat generation, once the temperature of composting materials is around 35°C, farmers were asked to remove all agro-wastes from the unit and leave it on ground or bury into soil for further decomposition over a period of 3-4 months for preparation of compost.

Transfer of technology to the end users

Suitable farmers for the fabrication of bio-geyser units were selected through the cooperation of agriculture/livestock extension department in the districts of Haripur, Abbottabad, Mansehra, Battagram and Swat. Progressive farmers suggested by extension department were briefly interviewed to assess their interest level and capability to use and maintain the technology. A brochure in Urdu language was provided to each end user for complete guideline on the use and maintenance of dual technology of bio-geyser and agro-waste composting. Contents of brochure included benefits of compost, materials and conditions required for preparation of compost, procedure for making compost, troubleshooting during composting and procedure for fabrication and use of bio-geyser.

Twenty-five (25) bio-geyser units were fabricated and demonstrated at selected community sites using participatory approach. Following the successful demonstration of technology, feedback of end-users was recorded on a specific questionnaire. Information on satisfaction with technology, satisfaction with literature (brochure) and guideline provided by developer, training requirements of end-users, difficulties in use of technology and suggestions for further improvement of technology was gathered through the feedback.

55% beneficiaries rated the dual technology of bio-geyser and agro-waste composting as satisfactory, 28% rated the technology as good and 17% rated the dual technology as very good. Responding to the question on satisfaction with literature provided, 39%

respondents were of the view point that literature was satisfactory, another 39% rated the literature provided as good and 22% rated it as very good. When end-users were asked about their satisfaction level regarding verbal and practical guidelines provided by the representatives of developer of technology, 22% people answered as satisfactory, 28% were of the opinion that guideline was good and 50% respondents regarded it as very good.

When beneficiaries of technology were inquired about further training needs related to use and maintenance of dual technology, 67% end-users desired to receive further training for proper use of bio-geyser and composting technology at their own while 33% were of the view point that additional training is not desired. A summary of findings from the feedback is presented in (Table 1).

Table 1. Summary of findings from feedback on dual technology

Question	Unsatisfactory	Satisfactory	Good	Very good
Satisfaction with technology	0%	28%	55%	17%
Satisfaction with literature	0%	39%	39%	22%
Guideline from developer	0%	22%	28%	50%
Training requirements	67% required training		33% did not need further training	

During the peak winter months, green material is usually short in rural areas of KP as due to harsh weather conditions, vegetation cannot grow. Some end-users were hesitant to use dried agro-wastes with this new technology as in routine, they prefer to use it as feed for livestock or burn it for cooking. It was suggested by end-users to test composting and water heating potential of evergreen plants available in the area as these are available even during peak winter months and farmers can easily use the evergreen plants with this new technology.

It was suggested to couple bio-geyser unit with solar panel for additional heating of water. Few people suggested to alter design of bio-geyser by putting a door on the front wall of unit so that they can add or remove agro-wastes easily besides putting a small roof on top of unit to save the agro-wastes from rain and snow. Two training workshops including practical demonstrations were organized at community level to educate the masses about fabrication and use of dual technology.

We aimed at transfer of newly developed technology of bio-geyser and agro-waste

composting at community level so that people might be able to recognize how science is serving the society. Most of the farmers showed keen interest to learn and use the new technology. Some farmers were initially reluctant to believe that only mixing the agro-wastes in appropriate ratio can provide them hot water during harsh weather in winter. It was generally observed that farmers were reluctant to adopt those technologies that involved labor as most of them were usually pre-occupied with other high priority activities in the field.

In general, most of the beneficiaries cooperated with us in successful fabrication and demonstration of technology. They assisted in arranging agro-wastes and worked together with demonstrator to make the bio-geyser units functional. In some areas, particularly at Battagram district, there was seasonal shortage of fodder/agro-wastes because of prolonged dry spell in 2016, due to which some of the beneficiaries were unable to initially use the technology effectively.

It was found that small bio-geysers were easier to maintain than large bio-geysers at community level. It was mainly because of

the fact that large bio-geyser unit had three bins due to which, larger amounts of residues were initially required to fill it. Collection, chopping and mixing of composting materials for filling the large unit takes a full day of labor activity. But, once filled and adequately maintained, it can provide three times more hot water than small bio-geyser. The overall response from end-users towards use of new technology was positive. End-users showed keen interest to use it at mosque through effective participation of community as it would save cost of fuel and wood for warming water for ablution. Those who used this technology at animal farm regarded it as blessing owing to the fact that in winter, animals usually do not drink cold water due to which their appetite, food intake and productivity is reduced [11]. By using warm water gained through bio-geyser, they were happy that now health and productivity of their animals would improve.

On the overall basis, technology is performing better under field conditions with most of the end-users. Few beneficiaries initially paid less attention to maintain the bio-geysers at their own due to lack of training and seasonal shortage of agro-wastes. It is pertinent to mention that technology adoption and absorption rate is traditionally slow in rural set up in our country due to lack of education [12, 13]. On the overall basis, feedback from end-users was found positive and encouraging towards the new technology.

Conclusion

The dual technology of bio-geyser and agro-waste composting was developed and successfully transferred to end-users in Hazara division and Swat district of Khyber Pakhtunkhwa, Pakistan. Twenty-one (21) small and four (4) large bio-geyser units were fabricated and demonstrated to the end-users using farmer participatory approach. Two training workshops (one in each of the districts of Mansehra and Swat) were organized to train the local fabricators and create awareness among masses for use

and maintenance of dual technology. The technology will gain ground over coming years on account of its simplicity, novelty and cost effectiveness. Feedback of end users will help us to further improve this technology both in terms of modification in design of bio-geyser unit and screening of locally available residues for their water heating potential.

Authors' contributions

Conceived and designed the experiments: A Raza & Z Ali, Performed the experiments: A Raza & Z Ali, Analyzed the data: A Raza, Contributed materials/analysis/ tools: A Raza & Z Ali, Wrote the paper: A Raza & SA Ali.

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