Ecological Purification System

Operation and Maintenance Manual

Department of Water and Sewerage
Ministry of Infrastructure and Transport
FIJI

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Preface

The implementation of community-based Ecological Purification System (EPS) projects was made possible through funding assistance by the Department of Water and Sewerage (DWS), constructions by the Department of Works, both of which are under the Ministry of Infrastructure and Transport and Technical Assistance from the Japan International Cooperation Agency (JICA).

The EPS is designed to make a germ free safe drinking water by wise use of natural ecological process without chemicals. The EPS water is sweet and delicious like a spring water. This new EPS technology was recently invented by Prof. Dr. Nobutada Nakamoto in Japan. The original Fiji Rota tank system for rural people was invented by DWS in 2013. The Rota tank system has been modified as suitable type advised by Dr. N. Nakamoto (JICA Expert, Dr. Sci.) and Mr. Hide (Hidemitsu Eguchi: JICA Senior Volunteer). This manual was written by Dr. N. Nakamoto and Mr. H. Eguchi. And we are greatly acknowledge to JICA support.

The EPS consists basically 3 tanks of a gravel filter, a sand filter and a storage tank. The system uses natural resources such as natural living organisms, stones, gravel and sand for the purification process.

The EPS is a naturally purifying system which aids in the treatment of raw water for the production of clean and safe drinking water for communities. This EPS project is designed to supply the water demand of drinking and cooking waters for villagers. To assist communities in providing proper care for their EPS projects, this manual includes a background on the theory, the EPS system, the proper operations and the maintenance of this system.

It is the responsibility of the water committee and the operator to follow instructions in this manual for safe water. It must be noted that the more the water usage, the better the water quality will be and we expect maximum usage.

All interested parties are invited to consult my office for technical advice if needed.

Susana Pulini
Director
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Table of Contents

Content **Page No.**

1.0 Ecological Purification System in nature (Fig.1-5)

When plants and animals do not flush out in a small stream on fine day, this water is always clear. Small animals live on the surface of rocks and collect turbid matters. However, after a heavy rain, the water becomes muddy. Soil is easily flushed out from a land and flows into a river due to a heavy rain. Gravel, stone and sand in a river bed are **easily rolled** during storm event under **horizontal** current. Small organisms on and among rocks are easily flushed out, and this muddy water has a contamination risk of germ bacteria.

Fig. 1. Clean water

Fig. 2. Muddy water after a heavy rain

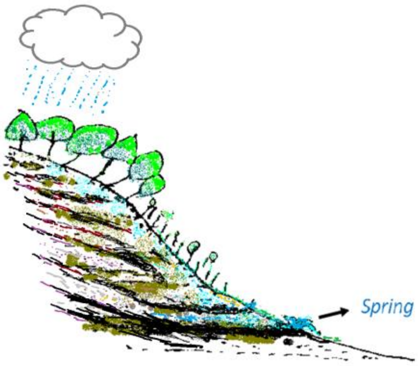


Fig. 3. Water percolates soil layer.

Fig. 4. Spring water is always clean.

Spring water is always clean. This clean water was made by natural ecological purification process. Rain drop penetrates into underground from the surface. This water passes slowly through the soil and rock layers. There is small animals behind fallen leaves on the surface of soil. We can see fungi, bacteria, worm, insect larvae, etc. in this layer. They decompose fallen leaves and mineralize. These organisms live only near the surface, because food for them comes from the surface. This surface layer is biologically active. It is essential for small biological organisms that soil and rock **don't move** in **vertical** structure. This is **gentle** condition for small

Fig. 5. Soil profile

organisms. There is no food for small organisms in deep layer so there is no living organisms. The seepage water from the deep layer through this process becomes germ free. As the result, spring water is clean and safe. This water is usually sweet and delicious.

2.0 Basic Design and Process of EPS project in Fiji (Fig.6)

The EPS (Ecological Purification System) is designed to make a germ free safe drinking water by use of natural ecological process without chemicals. An EPS unit consists basically of 3 Rota mold tanks with a volume of 2,700 liters each. The first tank is filled with gravel and the second tank is filled with sand. The third tank is a storage for purified water. The attach detail design sheets are reffered to practical construction of EPS.

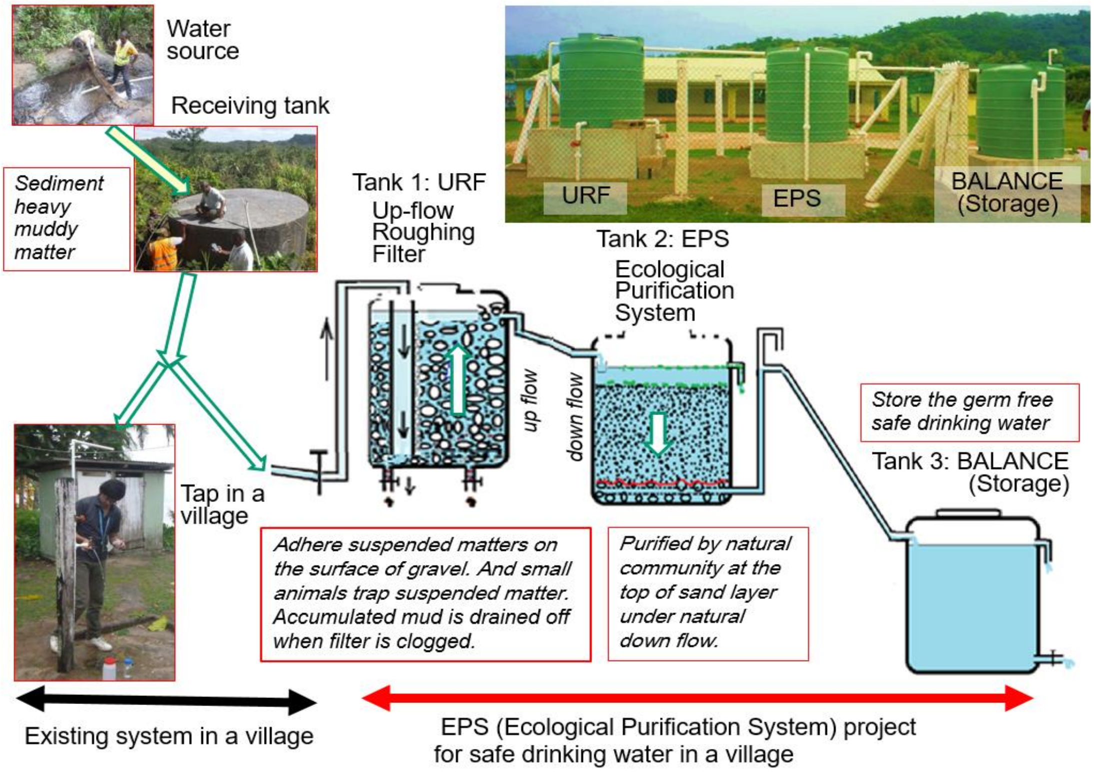


Fig. 6. Basic EPS system is composed with 3 tanks (URF, EPS and storage).

The raw water is supplied from an existing pipe line in a village. The natural gravity flow is adopted to this EPS system. The flow rate is easily regulated only by a flow control valve.

There is up-flow current in the gravel tank so called URF (Up-flow Roughing Filter). There is vertical flow. The URF reduces major suspended matter in raw water by the physical and biological function on the surface of gravels. The supernatant of the gravel tank flows into a sand tank. There is natural down flow passing through the sand layer. Complete elimination of any impurities is done at the top of biologically active sand layer. There is vertical flow current in both URF and EPS tanks. The gravel and sand do not move. This vertical condition is gentle for biological community. And final storage tank is called Balance tank or Storage tank. Public tap system in a village is proposed by this project due to a limited amount of filtered safe water.

2.1 Up-flow Roughing Filter (URF: gravel tank) (Fig.7)

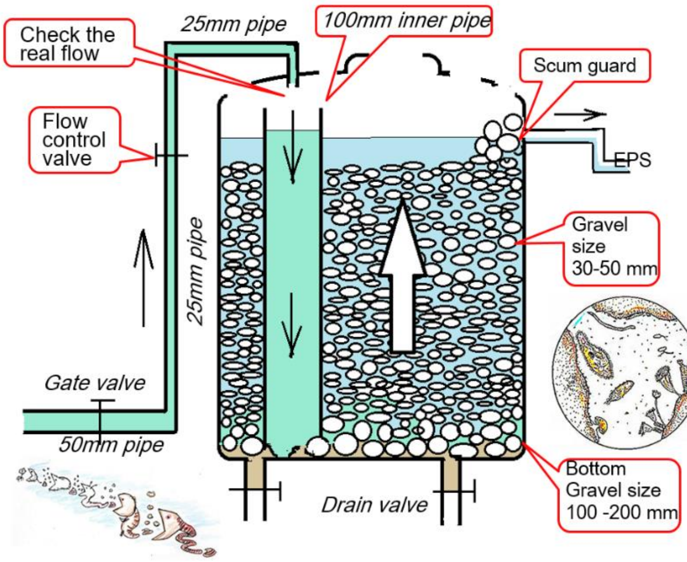


Fig. 7. Outline of URF

The URF is filled with gravel. Suspended matters adhere on the surface of gravel. Heavy particulate matters sink on the bottom. Small animals trap any suspended matters at the surface of the gravel. There is a food chain. Trapped suspended matters are packed in fecal pellets. However, it takes time for animal community to develop on the surface of gravel. When URF is clogged, accumulated mud (mainly fecal pellets) should be drained off from the drain valve. As gravel is just habitat for small organisms, gravel size and uniformity is not important.

2.2 Startup guide for New URF (Fig.8)

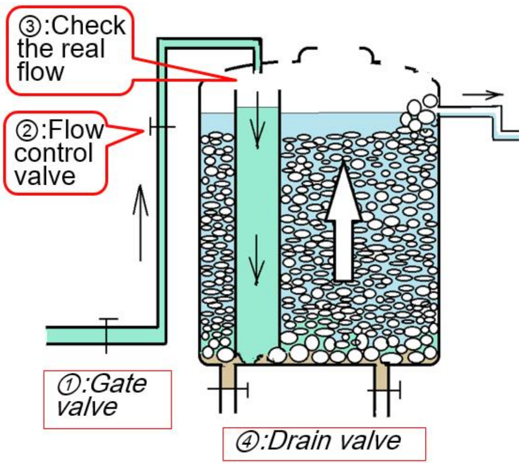


Fig. 8. Essential valves of URF

New gravels adhere a lot of silty fine particles on the surface even the washed gravel. At the startup of new gravel tank, a mechanical cleanup is necessary to wash by the following simple ways.

1) Close Drain valves ④.

2) Fully open Gate valve ①.

3) Inflow rate is controlled by the Flow control valve ② checking the flow③.

4) Muddy water is welling out among gravel filling up near the over-flow level.

5) Close Gate valve ①.

6) Open Drain valves ④ to wash out muddy water almost completely.

7) Close Drain valves ④.

8) Open Gate valve ①.

Repeat at least 3 times from step 4 to step 8 in order to wash out dirty particulate matter on the surface of gravel (mechanical cleaning).

9) Then normal operation (see following section).

After the development the biological community on the surface of gravel, a seepage water becomes sufficiently clean water. However, it takes time (at least several days) to turn up.

2.3 Operation and Maintenance guide for Matured URF (Fig.9)

Normal Operation is very simple after the biological community develops well in URF.

1) Close Drain valves ④ in Figure 8.

2) Fully open Gate valve ①.

3) Inflow rate is controlled by the Flow control valve ② checking the flow ③.

Clear seepage water flows to EPS. This is important to keep aerobic condition for living organisms in the top of sand layer. Usually, nothing to do during a normal operation for maintenance for long period.

If the over-flow from the inner pipe is observed, the URF resistance increases due to accumulation of excess amount of muddy matter at the bottom (Figure 9). We can easily recover this resistance by this drain operation.

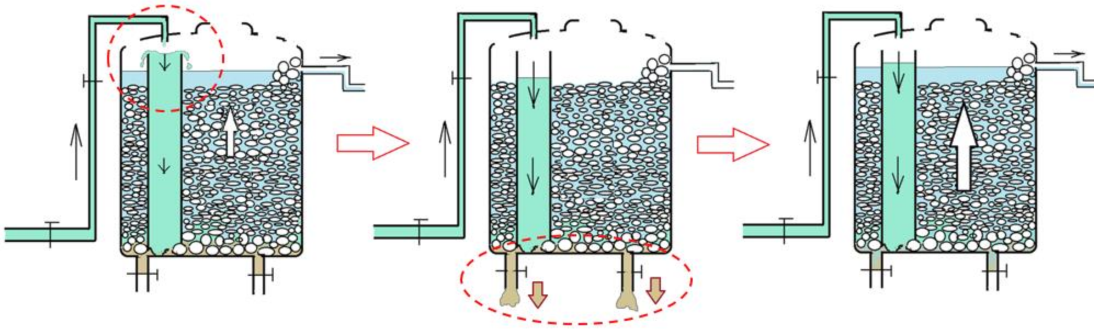


Fig. 9. How to recover the URF resistance using the drain valve.

At the first step, the drain valve is fully opened. The opening time is usually short minutes. When the dirty water from the drain turns to clearer water, drain valve is closed. It is not necessary to drain off all the water in URF. This is gentle for working small living organisms in water in URF. Usually one time openning of drain valve is sufficent to recover the filter resistance. The frequency of drain operation depends on the turbidity of raw water. When the raw water is derived from an existing pipe line which has a receiving tank, the frequency of drain operation of URF is a few during a year.

2.4 EPS: Ecological Purification System (Sand Tank) (Fig.10-11)

EPS tank is filled with sand. Relatively large size of sand between 1 to 3 mm is recommended. At the bottom, there is a porous pipe and one layer of stones. Mosquito mesh places over the stone layer. Mesh is used to prevent sand leak into the pipe. Sand too large or fine not recommended.

Suspended free seepage water from URF flows into this EPS. There is a shallow water above the sand layer. Algae grow well and then grazing animals on algae grow in this water and at the top of sand layer. Microbe and small microscopic animals grow on the surface of sand grain. Major living organisms are distributed only near the surface sand layer, as food for them comes from the top. Small microscopic organisms and small animals usually attach on the surface of sand grain. Small animals collect anything and excrete packed fecal pellet. This layer is looks like a dirty sand layer, but this layer is really biologically active. There is a food chain from microbe to small animals in this layer. Animals cannot survive without dissolved oxygen in water. Dry up of supernatant water on the sand layer is dangerous for aquatic organisms. We have to keep water level by use of siphon pipe system for filtrate water (Figure 10). It is important not to scare any animals in this system. So, we have to keep gentle current of water for small animals. As the result, the filtrate of EPS becomes germ free drinkable water after the development of biological community at the top of sand layer which is like a natural soil profile.

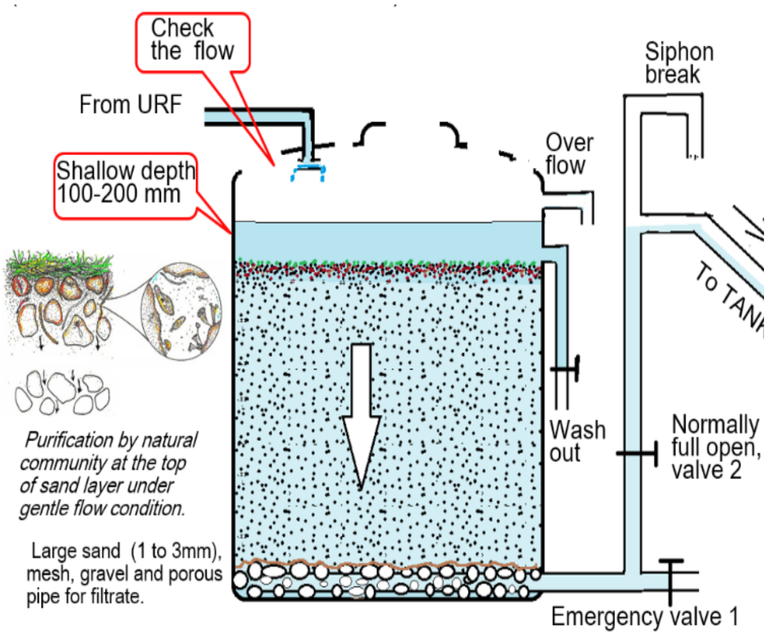


Fig. 10. Basic design of EPS

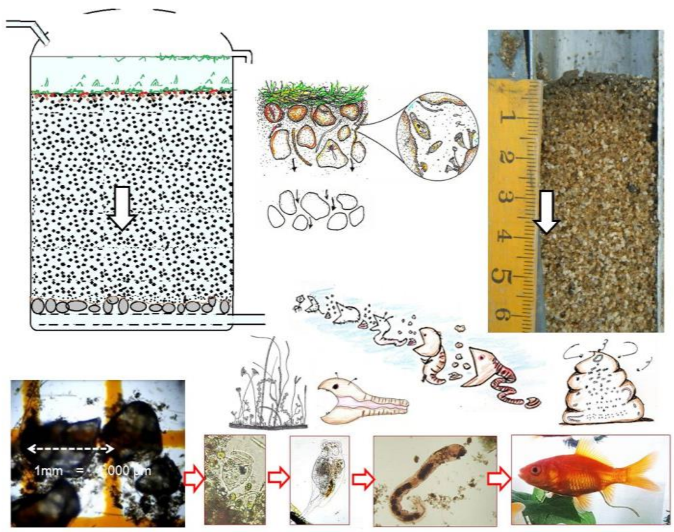


Fig. 11. Outline of EPS function

2.5 Balance tank (storage tank) (Fig.12)

Germ free safe water from EPS tank is stored in Balance (storage) tank. Water demand for drinking and cooking is not constant during a diel activity of a family. The treated water reservoir should always be covered and kept clean. A public tap system is adopted for villager's use by present EPS project. Gentle flow is essential for small organisms under the presence of oxygen in the sand layer of EPS. Always plenty over-flow from the balance tank is not necessary. Little over-flow is enough to keep gentle flow when the tank is full. The suitable flow rate can be regulated by a flow control valve of the raw water into URF (see Figure 8- ②).

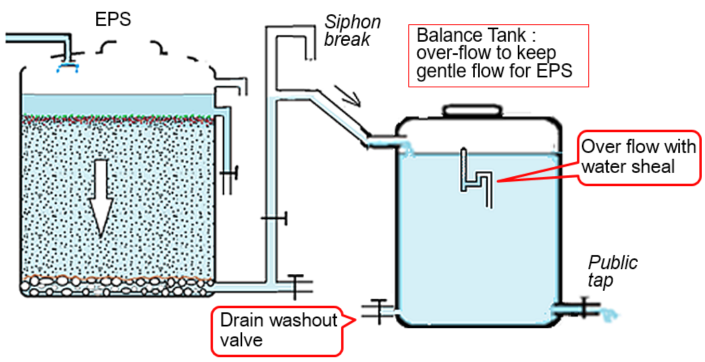


Fig. 12. Outline of EPS function

2.6 Startup guide for EPS (Fig.13-14)

Initial filtrate from the new (fresh) EPS is muddy even the dirty new sand was washed by clean water. It takes days to get clean filtrate.

At first, EPS tank is filled up with water, then this water drains directly from Emergency valve 1 at the bottom. This water is dirty water. This drain procedure repeats 3 times as same as 2.2 Startup guide for New URF. Then close Emergency valve 1 and this filtrate pours into Balance (Storage) tank. The initial slightly muddy filtrate must be drained from the drain valve of Balance (Storage) tank until filtrate becomes clean and safe water. It takes time to develop mature ecosystem like natural soil structure. It takes usually one month run to develop biological community under normal operation. After the confirmation of the bacteria test, we can use the filtrate as a reliable safe drinkable water.

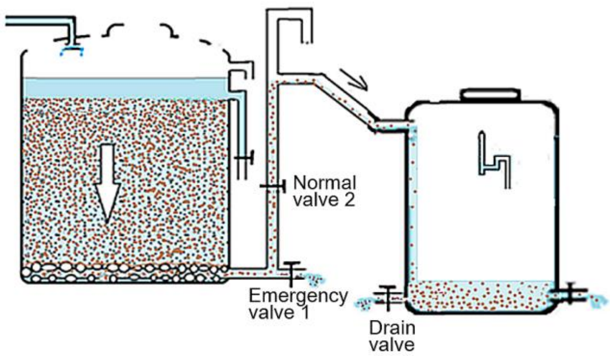


Fig. 13. Initial filtrate must be drained off.

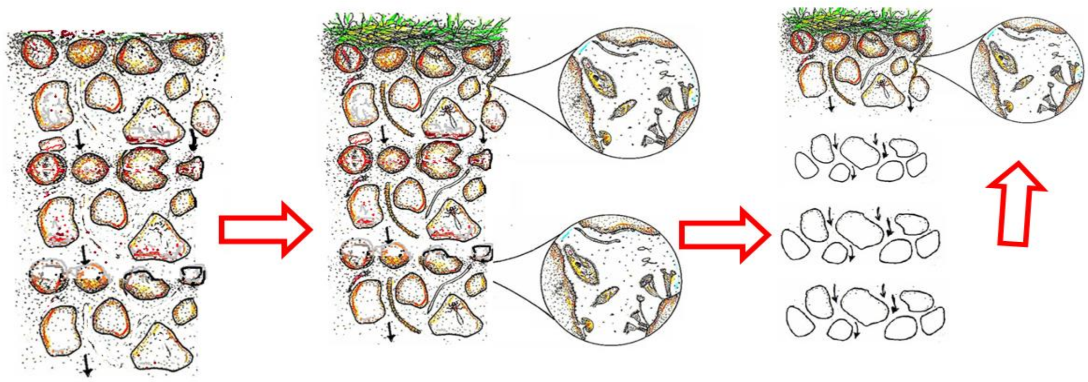


Fig. 14. The surface of the fresh dirty sand is completely cleaned up by small animals.

This mechanism is that dirty fine particles attached to new fresh sand are drained and are scraped out by small organisms under gentle downward flow. Small microscopic size of animals collect and scrape impurities as their food. All the fine particles attached to the surface of the fresh sand grain are cleaned up. It takes days (several weeks) to scrape all the impurity on the surface of the all sand in EPS. Small microscopic animals become hungry and move to near the surface (top) where food comes. Hungry small organisms are always waiting for food near the surface like the natural soil surface (see Figure 5). Then the filtrate becomes a reliable safe drinkable water. We can confirm the reliability by a bacteria test.

2.7 Startup guide for Balance (storage) tank (Fig.15-16)

Inside wall of the balance (storage) tank is also contaminated with bacteria even the new tank. Following step is recommended as a simple way to clean up a new tank. After the confirmation of water quality (bacteria test), we can use the water as a reliable water.

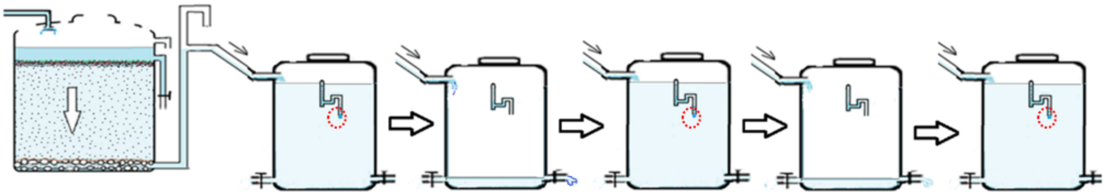


Fig. 15. How to wash the new balance (storage) tank

1) Fill clean filtrate from EPS in a Balance tank until the circle mark of over-flow.

2) Drain up whole stored filtrate in a Balance tank at the bottom valve.

3) Fill again clean filtrate from EPS in a Balance tank until the circle mark of over-flow.

Fig. 16. Over-flow

4) Drain up again whole stored filtrate from the bottom valve.

Repeat this Fill and Drain at least 3 times. After the reliability of germ free water is confirmed by bacteria test of stored filtrate, we can open the tap water for public use.

2.8 Operation and maintenance guide for EPS tank (Fig.17-18)

The flow rate of EPS can be controlled by the inflow control valve to URF (Figure 8). Setting the suitable height level of each pipe is important to maintain the normal operation (Figure 17). The EPS operation is normally there is nothing to do. There should be no over-flow. However, if we can see that something blocking the surface of the sand layer, the filter resistance increases gradually due to accumulate block matter on or beneath the surface. Then over-flow of

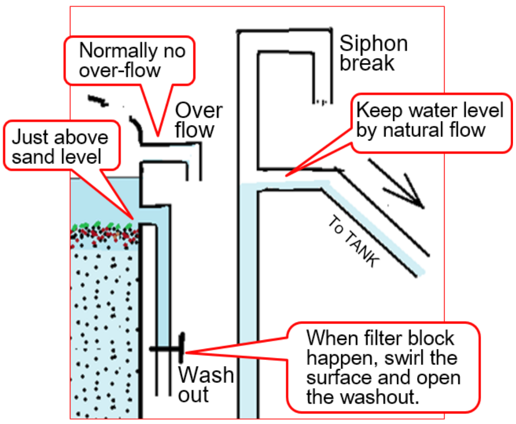


Fig. 17. Height differences of pipes of EPS

water is possible. In this case, block matter in EPS is drained off through the over-flow pipe by the following manner.

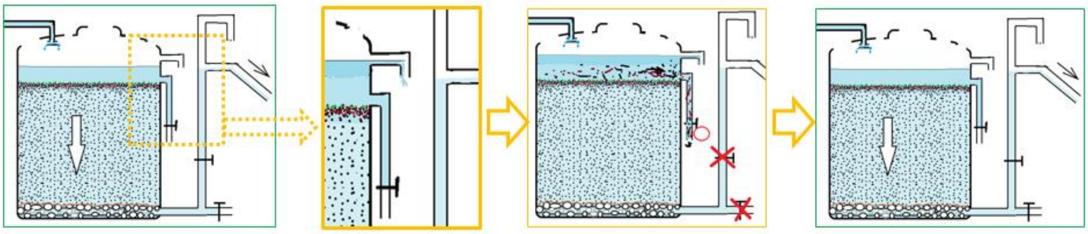


Fig. 18. How to drain and remove surface block matter using drain valve.

1) Close filtrate valve ② (refer to Fig. 8) in order to stop the natural down-flow.

2) Then, swirl gently the sand surface by hand.

3) Open the wash out valve. Dirty blocked matter drains off. One time Drainage is enough.

4) Then, close the washout and open the filtrate valve ② to a balance tank. Filter block will be recovered. Then EPS starts to run normally.

2.9 Operation for Balance (storage) tank

Germ free safe water from EPS tank is stored in Balance (storage) tank. This tank is always kept out the dust. However, un-expected contamination happens into a tank over a long term. Periodical cleanup is necessary as in Figure 15. The frequency of cleanup is at least once a year.

3.0 Question and answer, trouble shooting and recommendation

Biological Phenomena Relation;

B1. Algal growth and disappearance in URF and EPS (Fig.19)

Fig. 19. Algal bloom and disappearance in URF.

We can observe a remarkable algal bloom in URF and EPS. However a disappearance of algae is also observed. This phenomena are related with algae and grazing animal. Photosynthetic activity is depended on radiation and the grazing activity of animal is related to temperature. There are different kinds of algal species and animal species. Growth and disappearance of algae are usually observed as a normal natural phenomenon. Filamentous form of algae dominates usually under slow current condition.

Algae produce oxygen under the sunshine and consume dissolved oxygen during the night. In case of EPS system, the depth is shallow (100 – 200 mm). Retention time of water is very short in the supernatant water. There is no risk of oxygen deficiency during the night. Aerobic condition in water is always kept in this system. This is gentle for algae and other organisms in this system.

B2. Disappearance of algae in URF and EPS (Fig.20)

Algae is an oxygen producer and becomes food for animal. Disappearance of algae is caused by grazing organisms. This means they are hungry organisms and waiting for food. This condition is good to eliminate any particulate matters by organisms. This means maturation of ecosystem takes place in this tank. Hungry organisms is normal condition in natural environment.

Fig. 20. Matured sand surface of EPS

B3. Accumulation of fecal pellet (Fig.21)

Does excrete feces give some trouble to filtrate or not? Is accumulate fecal pellets is acceptable or not? Organisms living in the top of sand layer trap and graze any particulate substances (see Figure 11: EPS function). They produce feces of packed fecal pellet. They always repeat this behavior of trapping and excrete packed feces. Real decomposition from a large molecule to small molecule occurs inside of fecal pellet where fermentation occurs in absence of oxygen. We call this process is mineralization. Organisms can assimilate small molecule. This behavior is same as a behavior of an earthworm in the soil. As better food for animal comes from the surface (top of sand layer), any grazing animals gather near the surface. Complete decomposition is performed within this thin layer. This thickness of biological active layer is almost same thickness during a year. This thickness depends on temperature, because of heterotrophic activity from bacteria to small animal. This thickness of biological active layer is thin in tropical region. Thick biological layer is seen in cold region.

Fig. 21. Thin active layer

B4. Midge larvae (Fig.22-23)

Midge larva in EPS under slow water current condition is observed. This is Chironomid larva which is known as non-bite Mosquito. People confuse similar insect larva of Mosquito and

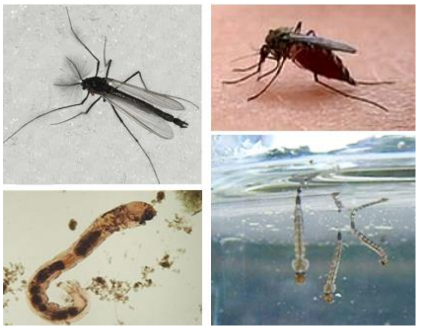


Fig. 22. Chironomid and Mosquito

Chironomid. Mosquito larvae live just beneath the surface and breathe atmospheric air. This larvae is normally found in small water body like a bowl. However Chironomid larva live at a river bed, at the bottom of a pond and a lake where there is presence of dissolved oxygen in water. This larvae breathe dissolved oxygen in water by gills. We can also find carnivorous insect larvae of a dragonfly and a mayfly. Then number of midge larvae decreases during a long run. In case of normal EPS, slow water current is essential for a healthy environment. In extraordinary case, the water current becomes too slow (almost stop), it happed that dissolved oxygen in water decreases until serious concentration. Then Mosquito larvae appears under bad condition of EPS. This condition is not good for every organisms for healthy EPS. Keeping gentle flow is essential.

Fig. 23. Dragonfly larva

EPS System Relation;

E1. Fallen leaves and plastic bag (Fig.24)

Fallen leaves and plastic bags easily drop in water from an open window when strong wind blows. Surface of sand and gravel layer is easily shielded by them. Chicken net is good to cover an open window. And the wire net fence for this treatment system is also recommend to avoid any mischief by children and wild animals.

Fig. 24. Open windows are covered by net.

E2. Size of gravel and sand (Fig.25-26)

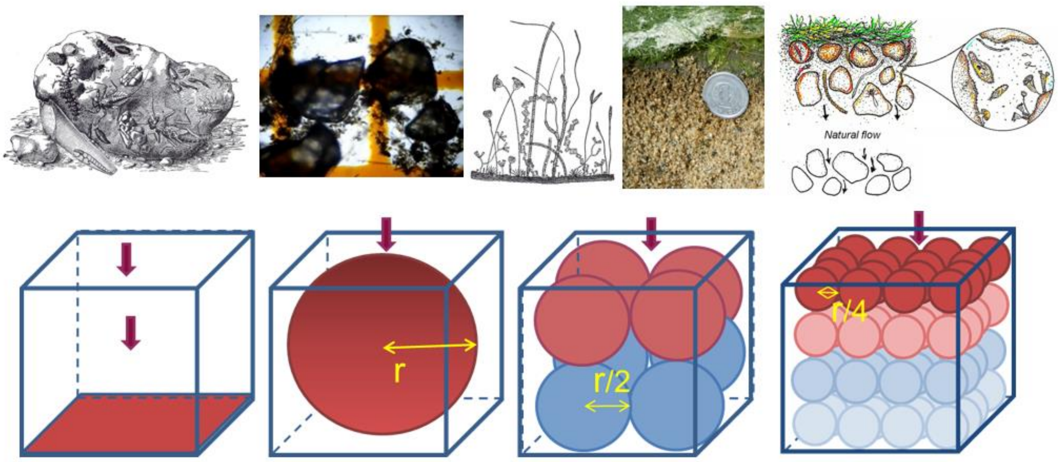


Fig. 25. Small organisms live on the surface and area of gravel surface

URF is filled with gravel and EPS is filled with sand. Both gravel and sand are just habitat for small organisms. Most of small organisms live on the surface of substrata (sand particle) under slow current condition. They are easily washed away in water by the current among gravel and sand. They live only at the top of sand layer where food comes. Hungry small animals are always waiting for food near the surface. Wider space of a surface area is better to give a wider area for small organisms. However, water has viscosity. Current resistance relates to the space size among gravels and sands. Extreme fine sand gives a strong current resistance. But a total space area of the gravels in a box is smaller than a total space area of sands in a same volume size of a box (Figure 25). In case of URF, it is essential to drain easily accumulated mud at the bottom. Then 30 mm to 50 mm size of gravel is recommended for URF. In case of EPS, a complete purification by sand layer by small organisms is our goal. There is natural downward current. If too small size of fine sand is filled into the tank, filter resistance increases and hard to get a large volume of filtrate.

Fig. 26. Uniform size of sand is not important.

After a long run of EPS, fine particulate matter like silt accumulate on the surface of sand layer. This is accumulation of fecal pellets by the activity of small animals. This is really active layer of microscopic small organisms. This biological active layer is soft and filter clog does not happen. Beneath the biological active layer, there is a large size of sand and whole depth of sand layer is also large. This is a definite layer to hold particulate and dissolved matter which was failed to trap at the top of sand layer. EPS has a complete fail safe system to reduce any impurities.

E3. Germ bacteria (Fig.27)

There is so many kinds of bacteria in nature. Risky bacteria is germ pathogenic bacteria which causes serious sickness. Size of bacteria is about 1/1000 of 1 mm which we cannot see by naked eyes. We can confirm the presence of germ bacteria by an incubation test in a

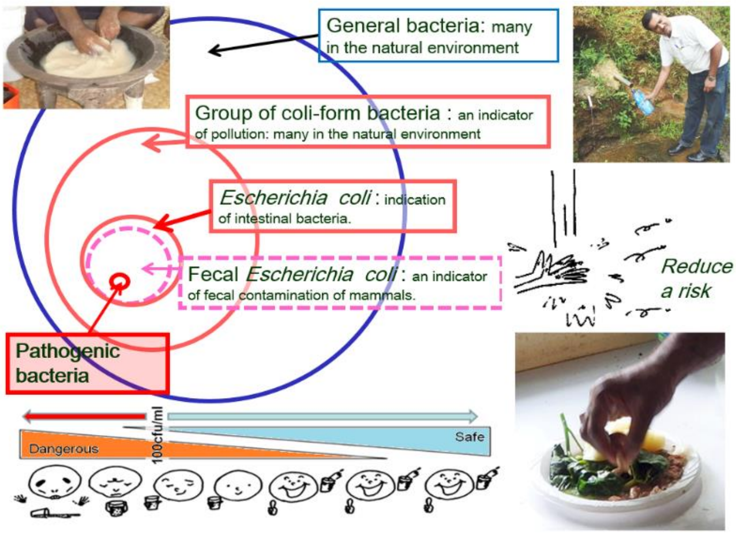


Fig. 27. General bacteria and pathogenic bacteria

laboratory. This test is done by a professional organization. However, people believes that a clean spring water is safe water without bacteria test. They know the safety is confirmed by their sense of experience during a long life. This EPS water is an artificial spring water which is germ free.

E4. Water shortage and recover the function (Fig.28)

Performance to make safe water progresses under gentle flow to EPS. This gentle flow is the key for easy operation. However, raw water supply breaks sometime into URF due to less water or no water. The seepage water disappears from the gravels in URF and the surface sand of EPS is also dried up. This is risky for active organisms in the EPS system. We have to avoid this condition to keep normal operation. However, this water shortage happens unexpectedly.

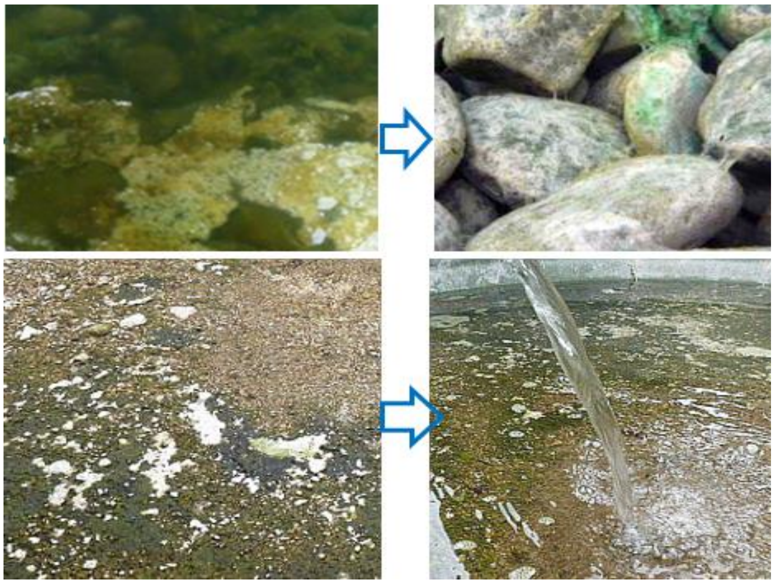


Fig. 28. Drying and re-wetting

Usually natural organisms have an ability to survive during bad condition and period. They escape to better site. They turn to resting form (cyst or egg) for dry condition. They tolerate during bad condition. When water comes back again, organisms reactivate again. Organisms come back to fresh water site where food is available for them. This phenomena is known as drying-wetting phenomena in nature. However, there is a risk to leakage some bacteria from EPS. DWS cannot provide risky water for villagers. Keep gentle flow to provide germ free water for villagers.

Recommendation Relation;

R1. Work record of care taker

Daily work records of water source, URF, EPS and storage tank are important for operator and maintainer to achieve better result of EPS.

R2. Frequent drain off from URF (Fig.29)

Frequent drain off from URF is necessary to reduce the filter resistance of URF. It is caused by excess inflow of suspended matter from water source (raw water). Usually the raw water is derived from an existing supply pipe which is connected to a receiving tank. This tank has a sediment removal function of suspended matter. Check the sedimentation tank. If raw water is derived directly from surface water of a river, setting of a new sedimentation tank or additional URF are considered to reduce a load of suspended matter.

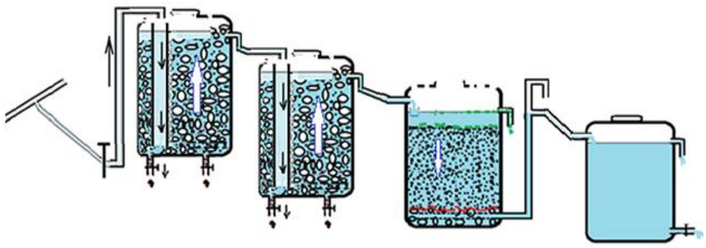


Fig. 29. Addition of URF

R3. Frequent water shortage (Fig.30)

Frequent water shortage occurs due to less water or no water from water source. It is necessary to have sufficient source. So a new water source can be identified. If water is supplied during the night, one of the solutions is an additional receiving tank.

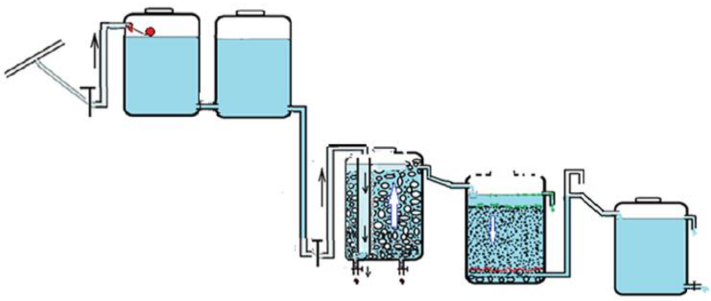


Fig. 30. Addition of receiving tanks

R4. Capacity of EPS system

Rota tank system of 2,700 liters can supply a fairly large amount of clean water. Surface area of Rota tank is 1.54 m2. EPS system is similar to English slow sand filter. Slow sand filter (SSF) treatment started in UK in cold region. EPS treatment capacity is related with filter area and biological activity and temperature. The original filter rate of English filter in 1829 is 2 m/d and traditional English standard is 5 m/d. And the present filter rate of Thames Water Company in London is 10 m/d. As an ability of purification is depended on biological activity, this activity depended on temperature. We can adopt higher flow rate in warm climate region. The potential ability of purification was confirmed in Samoa

Table 1. Summary of EPS capacity

EPS Capacity of Tank (2,700 liter tank)									
Radius of tank (r):0.7m = Filter area (pxrxr), 1.54 m2									
Flow rate			Filtrate rate			Suppy capacity for person			remarks
m/d	cm/h	m3/d	liter/d	liter/h	liter/m	2 liter/d	6 liter/d	100 liter/d	
2	8	3.1	3,080	128	2.1	1,540	513	31	Original filter rate in UK, in 1829
5	20	7.4	7,392	308	5.1	3,696	1,232	74	Traditional English standard
10	42	15.4	15,400	642	10.7	7,700	2,567	154	Present Thames rate
15	63	23.1	23,100	963	16.0	11,550	3,850	231	Acceptable rate in warm region
20	83	30.8	30,800	1,283	21.4	15,400	5,133	308	Acceptable rate in warm region

by JICA project recently. Calculated capacity on different flow rate is summarized in following table. Water demand of drinking water is 2 liters/person/day. In case of this project, 6 liters/person/day is proposed. And we may supply 100 liters/person/day in case of small village.

R5. Keep tap close to save water (Fig.31)

EPS capacity of this Rota tank system is relatively large. However, if one tap is opened during a day, a huge amount of treated water is lost during a day. All the villagers have to remind the tap close and the rubber washer of every tap to avoid the water loss.

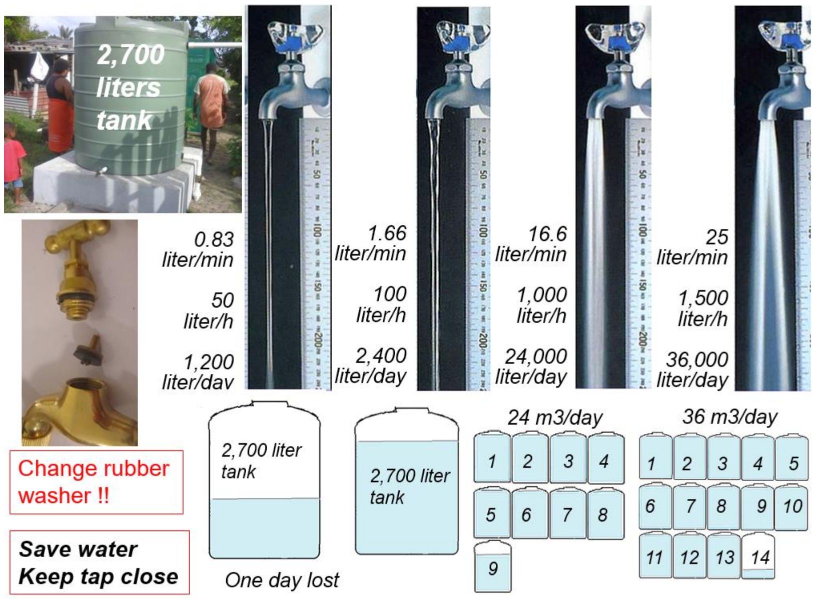


Fig. 31. Keep tap close to save water

R6. Additional public tap and storage tank (Fig.32)

Rota mold tank with a volume of 2,700 liters has a large capacity to produce safe water. Additional public taps and additional storage tanks are useful to supply safe water in a village that is scattered.

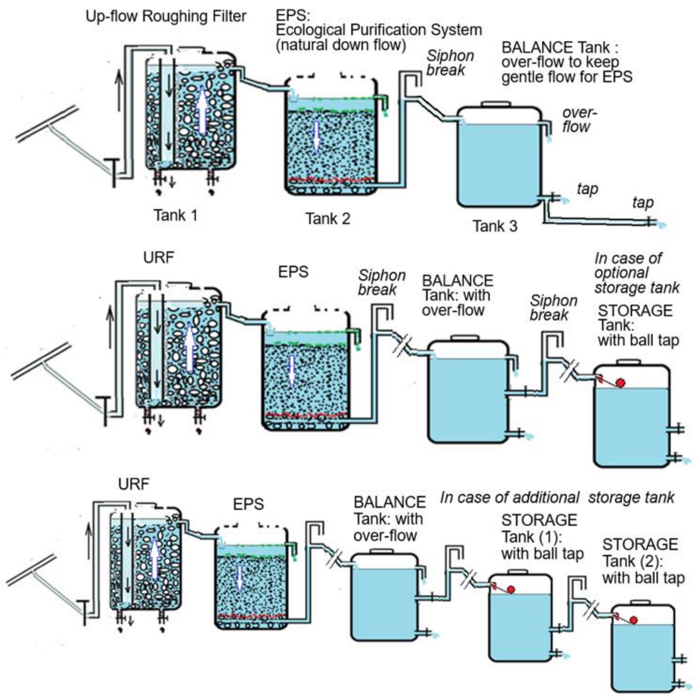


Fig. 32. Addition of public tap and storage tank

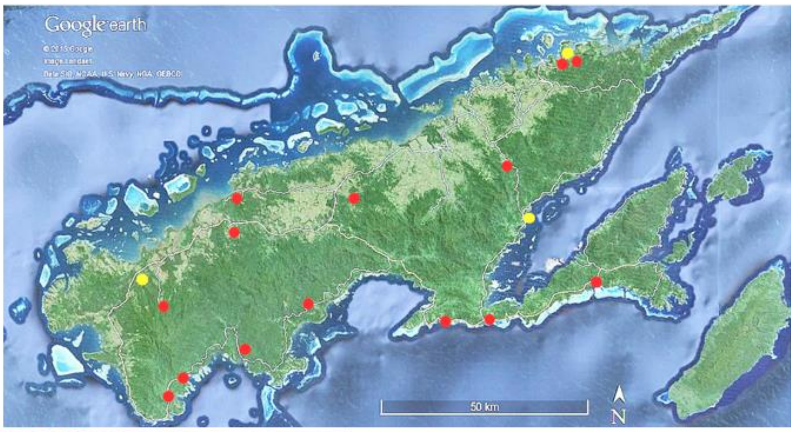
R7. Community meeting and discussion

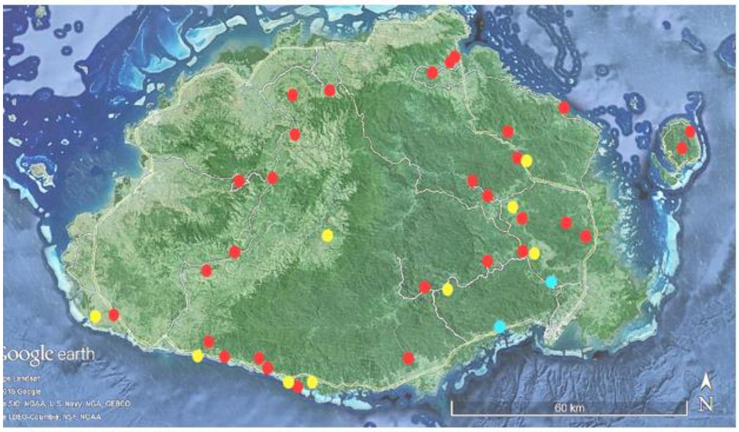
Exchange of information in a community is important for the better function of EPS. Fiji is the first trial country in the world to provide safe water for a number of villagers.

Daily use improves water quality

Northern division
14villages (+3villages)
Naua, Ravuka, Naividamu, Nabavatu, Banikea, Nasawana, Batinivurewai, Keka, Nagigi, Vivili, Bagasau, Nayarabale, Nasuva, Nasolo
(Nawailevu, Korotasere, Visoqo)

Western division
16villages (+3villages)
Naiserelagi, Nabalabala, Nalidi, Komave, Nalebaleba, Natawa, Bukuya, Koroboya, Nadelei, Toga, Nailawa, Navala, Semo, Tagaqe, Biausevu, Balenabelo
(Draubuta, Nalele, Vatukarasa)





Central & Eastern divisions
16villages (+6villages)
Naqali, Navolau, Namosi, Nadakuni, Namaqumaqua, Nasautoka, Savu(Tailevu), Sote, Nataleira, Nairukuruku, Nakorosule, Nakavu, Lovoni, Nasaumatua, Vuniivisavu, Toki
(Savu(Naitasiri), Navutulevu, Vunaniu, Waivaka, Nabaitavo, Naveicovatu)

EPS project completed 2015 fiscal year :
46 villages (red mark)
Another villages (yellow mark) were secured only budget. (These are not yet started construction.) : 12 villages (until Dec. 2015)
These 12 villages were already completed until May 2016.

Total village sites are completed 60 (58 + 2 pilot sites) until June 2016.

2 pilot sites (blue): Kalokolevu and Navatuvule of 2013 project.
46 village sites (red) and 12 village sites (yellow) of 2015 project.

Fig. 33. Fiji EPS project sites from 2013 to June 2016.

Any information to the Government of Fiji will be useful to improve EPS. If there is any problem which cannot be rectified then please contact:

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